



# Standard Test Method for Weight [Mass] of Coating on Iron and Steel Articles with Zinc or Zinc-Alloy Coatings<sup>1</sup>

This standard is issued under the fixed designation A 90/A 90M; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon ( $\epsilon$ ) indicates an editorial change since the last revision or reapproval.

*This standard has been approved for use by agencies of the Department of Defense.*

## 1. Scope

1.1 This test method covers procedures for determining the weight [mass] of coating on iron or steel sheet, wire, and other articles in which the coating is zinc or a zinc alloy, such as zinc-5 % aluminum (including zinc-5 % aluminum-mischmetal and zinc-5 % aluminum-0.1 % magnesium) or 55 % aluminum-zinc. In the body of this test method, reference to zinc coating shall be interpreted to also include zinc alloy coating except where specifically stated otherwise.

1.2 The final results determined by this test method shall be expressed in inch-pound units or SI units, depending on the units used in the material specification to which the results are to be compared. Certain portions of the procedure involving determination of specimen weight [mass] have traditionally been performed in SI units, and corresponding inch-pound units are not included.

1.3 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.* For specific hazards statements see 5.1.

## 2. Referenced Documents

### 2.1 ASTM Standards:

A 653/A 653M Specification for Steel Sheet, Zinc-Coated (Galvanized) or Zinc-Iron Alloy-Coated (Galvannealed) by the Hot-Dip Process<sup>2</sup>

A 792/A 792M Specification for Steel Sheet, 55 % Aluminum-Zinc Alloy-Coated by the Hot-Dip Process<sup>2</sup>

A 875/A 875M Specification for Steel Sheet, Zinc-5 % Aluminum Alloy-Coated by the Hot-Dip Process<sup>2</sup>

D 1193 Specification for Reagent Water<sup>3</sup>

E 29 Practice for Using Significant Digits in Test Data to

Determine Conformance with Specifications<sup>4</sup>

E 691 Practice for Conducting an Interlaboratory Study to Determine the Precision of a Test Method<sup>5</sup>

## 3. Significance and Use

3.1 This test method provides a standard method for determining the weight [mass] of coating for comparison with specification requirements. A coating of zinc on iron or steel articles provides protection against corrosion. As the protection is provided by sacrificial loss of zinc, the degree of protection is proportional to the weight [mass] of zinc coating. Specifications for zinc-coated articles frequently provide for different classes of coating so that the purchaser can select the coating weight [mass] most suitable to his needs.

## 4. Reagents

4.1 *Purity of Reagents*—Reagent grade chemicals shall be used in all tests. Unless otherwise indicated, it is intended that all reagents shall conform to the specifications of the Committee on Analytical Reagents of the American Chemical Society, where such specifications are available.<sup>6</sup> Other grades may be used, provided it is first ascertained that the reagent is of sufficiently high purity to permit its use without lessening the accuracy of the determination.

4.2 *Purity of Water*—Water used to prepare chemical solutions shall be reagent water as defined by Type IV of Specification D 1193.

4.3 *Antimony Trichloride Solution*—Dissolve 20 g of Sb<sub>2</sub>O<sub>3</sub> or 32 g of SbCl<sub>3</sub> in 1000 mL of HCl (sp gr 1.19).

4.4 *Hydrochloric Acid* (sp gr 1.19)—Concentrated hydrochloric acid (HCl).

4.5 *Hydrochloric Acid—Antimony Trichloride Solution*—Add 5 mL of antimony trichloride solution to 100 mL of HCl (sp gr 1.19).

4.6 *Hydrochloric Acid* (1 + 1)—Mix 500 mL of HCl (sp gr

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<sup>2</sup> *Annual Book of ASTM Standards*, Vol 01.06.

<sup>3</sup> *Annual Book of ASTM Standards*, Vols 10.01 and 11.01.

<sup>4</sup> *Annual Book of ASTM Standards*, Vols 10.02 and 14.02.

<sup>5</sup> *Annual Book of ASTM Standards*, Vol 14.02.

<sup>6</sup> “Reagent Chemicals, American Chemical Society Specifications,” Am. Chemical Soc., Washington, DC. For suggestions on the testing of reagents not listed by the American Chemical Society, see “Analytical Standards for Laboratory U.K. Chemicals,” BDH Ltd., Poole, Dorset, and the “United States Pharmacopeia.”

1.19) with 500 mL of reagent water and cool to room temperature.

## 5. Hazards

**5.1 Warning**—Small amounts of the poisonous gas stibine ( $\text{SbH}_3$ ) may be evolved during the stripping process using the hydrochloric acid-antimony trichloride method. Hydrochloric acid fumes are present, and hydrogen gas is evolved in the stripping process. Therefore, the test should be performed under conditions of adequate ventilation. A fume hood is recommended for large numbers of samples or where the test is to be carried out frequently over extended periods of time.

## 6. Sampling

**6.1 Zinc-Coated Sheets**—Samples for weight [mass] of coating determination shall be secured in accordance with Specifications A 653/A 653M, A 792/A 792M, or A 875/A 875M depending on the type of coating.

**NOTE 1**—For convenience in calculating test results in inch-pound units, the specimen should have an area of 5.08 in.<sup>2</sup> of sheet (2.25 ± 0.01-in. square or 2.54 ± 0.01 in. in diameter). The weight [mass] of coating in grams on a specimen of that area is numerically equal to the weight [mass] of coating in ounces per square foot of sheet. For results to be reported in metric units, the specimen should have an area of 3330 mm<sup>2</sup> of sheet (57.7 ± 0.1-mm square or 65.1 ± 0.1 mm in diameter).

**6.2 Zinc-Coated Wire**—Samples shall be secured as designated in the appropriate specification. The specimen of wire may be of any length over 12 in. [305 mm], but preferably about 24 in. [609 mm]. Where a continuous length is not available, shorter lengths totaling over 12 in. [300 mm], but preferably about 24 in. [600 mm], shall be used. Since the density of the steel is known 0.283 lb/in.<sup>3</sup> [7830 kg/m<sup>3</sup>], it is not necessary to use a specific length of specimen.

**6.3 Zinc-Coated Articles Other Than Sheet or Wire**—Samples for weight [mass] of coating determination shall be secured as designated in the appropriate specification. Except as otherwise provided, the specimens should have a minimum area of 3 in.<sup>2</sup> (2000 mm<sup>2</sup>) of zinc-coated surface. For very small items, several pieces may have to be stripped to obtain the minimum area.

**6.3.1** In the case of threaded articles, such as bolts and screws, the determination shall be made on a portion of the articles that does not include any thread.

## 7. Procedure

**7.1** Stripping of zinc alloy coatings containing less than 90 % zinc shall be done using the dilute hydrochloric acid method. Stripping of coatings containing 90 % or more zinc may be done using either hydrochloric acid-antimony trichloride solution or dilute hydrochloric acid (1 + 1) (alternative standard method).

**7.2** Clean the specimens by washing with solvent naphtha or other suitable solvent, then rinse with alcohol, and dry thoroughly.

**7.3** Determine the weight [mass] of the specimens individually to the nearest 0.01 g, except that articles other than sheet or wire with a specimen weight [mass] over 125 g may have the weight [mass] determined to the nearest 0.1 g. After determining the weight [mass], immerse each specimen singly

in the stripping solution and allow to remain until the violent evolution of hydrogen has ceased, and only a few bubbles are being evolved. This requires about 15 to 30 s, except in the case of sherardized coatings, which require a somewhat longer time. The same solution may be used repeatedly until the time required for stripping becomes inconveniently long. The temperature of the stripping solution shall at no time exceed 100°F [38°C]. After stripping, wash the specimens by scrubbing them under running water, dip in hot water, and wipe or blow dry. Determine the weight [mass] of the specimens again, to the same precision as in the initial determination.

**7.3.1** When determining the coating weight [mass] on one side of sheet material, use the procedure described in 7.3, except use a “stop-off” to protect one side from the stripping medium. Acid-resistant paints or lacquers, acid-resistant tape, or mechanical devices fastened to the test specimen are examples of commonly used “stop-off” materials. Apply the “stop-off” to the specimen after the initial determination of weight [mass] and removed before the second determination of weight [mass]. Because of the possibility of moisture absorption during the stripping process, the “stop-off” must not be on the specimen during either weight [mass] determinations. The coating weight [mass] on the second side may be determined subsequently without a “stop-off on the first side.

**7.4 Sheet Specimens**—Determine the area of sheet (one surface) to the nearest 0.01 in.<sup>2</sup> [5 mm<sup>2</sup>]. If specimens were prepared to the dimensions as provided in Note 1, they shall be presumed to have an area of 5.08 in.<sup>2</sup> [3330 mm<sup>2</sup>]. When it is not possible to determine the area accurately, as in specimens from corrugated sheets, the thickness of the stripped sheet shall be determined to the nearest 0.001 in. [0.01 mm].

**7.5 Wire Specimens**—Determine the diameter of the stripped wire to the nearest 0.001 in. [0.01 mm] by taking the average of two measurements at right angles to each other.

**7.6 Specimens Other Than Sheet or Wire**—Determine the total coated area of the original specimen to the nearest 0.01 in.<sup>2</sup> [5 mm<sup>2</sup>]. Alternatively, for specimens of uniform thickness of base metal, such as a piece of plate or pipe, determine the average thickness of the stripped specimen to the nearest 0.001 in. [0.01 mm].

## 8. Calculation

### 8.1 Zinc-Coated Sheet:

#### 8.1.1 Results in Inch-Pound Units:

**8.1.1.1** When the area of sheet is determined, calculate the weight [mass] of zinc coating as follows:

$$C = [(W_1 - W_2)/A] \times K \quad (1)$$

where: =

$C$  = weight [mass] of coating, oz/ft<sup>2</sup> of sheet,

$W_1$  = original weight [mass] of specimen, g,

$W_2$  = weight [mass] of stripped specimen, g,

$A$  = area of sheet, in.<sup>2</sup> or mm<sup>2</sup>, and,

$K$  = a constant = 5.08 when  $A$  is in in.<sup>2</sup> =  $3.28 \times 10^3$  when  $A$  is in mm<sup>2</sup>.

**NOTE 2**—If the specimen was prepared to the dimensions as provided in Note 1, having an area of 5.08 in.<sup>2</sup>, the loss of weight [mass] in grams is

numerically equal to the weight [mass] of coating in ounces per square foot of sheet.

8.1.1.2 When it is not possible to secure a specimen of measurable area, the following equation may be used to calculate the weight [mass] of coating:

$$C = [(W_1 - W_2)/W_2] \times T \times K \quad (2)$$

where: =

- $C$  = weight [mass] of coating, oz/ft<sup>2</sup> of sheet,
- $W_1$  = original weight [mass] of specimen, g,
- $W_2$  = weight [mass] of stripped specimen, g,
- $T$  = thickness of stripped sheet, in. or mm, and
- $K$  = a constant = 652 if  $T$  is in in. = 25.7 if  $T$  is in mm.

8.1.2 *Results in Metric Units:*

8.1.2.1 When the area of sheet is determined, calculate the weight [mass] of zinc coating as follows:

$$C = [(W_1 - W_2)/A] \times K \quad (3)$$

where: =

- $C$  = weight [mass] of coating, g/m<sup>2</sup> of sheet,
- $W_1$  = original weight [mass] of specimen, g,
- $W_2$  = weight [mass] of stripped specimen, g,
- $A$  = area of sheet, in.<sup>2</sup> or mm<sup>2</sup>, and
- $K$  = a constant =  $1.55 \times 10^3$  if  $A$  is in in.<sup>2</sup> =  $1 \times 10^6$  if  $A$  is in mm<sup>2</sup>.

NOTE 3—If the specimen was prepared to the dimensions as provided in Note 1, having an area of 3330 mm<sup>2</sup> of sheet, the factor  $K/A$  is approximately 300, which may be used in the calculation.

8.1.2.2 When it is not possible to obtain a specimen of measurable area, the following equation may be used to calculate the weight [mass] of coating:

$$C = [(W_1 - W_2)/W_2] \times T \times K \quad (4)$$

where:

- $C$  = weight [mass] of coating, g/m<sup>2</sup> of sheet
- $W_1$  = original weight [mass] of the specimen, g,
- $W_2$  = weight [mass] of the stripped specimen, g,
- $T$  = thickness of stripped sheet, in. or mm, and
- $K$  = a constant =  $1.99 \times 10^5$  if  $T$  is in in., =  $7.83 \times 10^3$  if  $T$  is in mm.

8.2 *Zinc-Coated Wire:*

8.2.1 *Results in Inch-Pound Units:*

8.2.1.1 Calculate the weight [mass] of zinc coating as follows:

$$C = [(W_1 - W_2)/W_2] \times D \times M \quad (5)$$

where: =

- $C$  = weight [mass] of coating, oz/ft<sup>2</sup> of stripped wire surface,
- $W_1$  = original weight [mass] of specimen, g,
- $W_2$  = weight [mass] of stripped specimen, g,
- $D$  = diameter of stripped wire, in. or mm, and
- $M$  = a constant = 163 if  $D$  is in in., = 6.42 if  $D$  is in mm.

8.2.2 *Results in Metric Units:*

8.2.2.1 Calculate the weight [mass] of zinc coating as follows:

$$C = [(W_1 - W_2)/W_2] \times D \times M \quad (6)$$

where: =

- $C$  = weight [mass] of coating, g/m<sup>2</sup> of stripped wire surface,
- $W_1$  = original weight [mass] of specimen, g,
- $W_2$  = weight [mass] of stripped specimen, g,
- $D$  = diameter of stripped wire, in. or mm, and
- $M$  = a constant =  $4.97 \times 10^4$  if  $D$  is in in., =  $1.96 \times 10^3$  if  $D$  is in mm.

8.3 *Zinc-Coated Articles Other Than Sheet or Wire:*

8.3.1 *Results in Inch-Pound Units:*

8.3.1.1 Calculate the weight [mass] of zinc coating as follows:

$$C = [(W_1 - W_2)/A] \times N \quad (7)$$

where: =

- $C$  = weight [mass] of coating, oz/ft<sup>2</sup> of surface,
- $W_1$  = original weight [mass] of specimen, g,
- $W_2$  = weight [mass] of stripped specimen, g,
- $A$  = coated area of original specimen, in.<sup>2</sup> or mm<sup>2</sup>, and
- $N$  = a constant = 5.08 if  $A$  is in in.<sup>2</sup> =  $3.28 \times 10^3$  if  $A$  is in mm<sup>2</sup>.

8.3.1.2 If the specimen has a uniform thickness of base metal, the weight [mass] of the zinc coating may be calculated as follows:

$$C = [(W_1 - W_2)/W_2] \times G \times Z \quad (8)$$

where: =

- $C$  = weight [mass] of coating, oz/ft<sup>2</sup> of surface,
- $W_1$  = original weight [mass] of specimen, g,
- $W_2$  = weight [mass] of stripped specimen, g,
- $G$  = thickness of stripped specimen, in. or mm, and
- $Z$  = a constant = 326 if  $G$  is in in. or 12.8 if  $G$  is in mm.

8.3.2 *Results in Metric Units:*

8.3.2.1 Calculate the weight [mass] of zinc coating as follows:

$$C = [(W_1 - W_2)/A] \times N \quad (9)$$

where: =

- $C$  = weight [mass] of coating, g/m<sup>2</sup> of surface,
- $W_1$  = original weight [mass] of specimen, g,
- $W_2$  = weight [mass] of stripped specimen, g,
- $A$  = coated area of original specimen, in.<sup>2</sup> or mm<sup>2</sup>, and
- $N$  = a constant =  $1.55 \times 10^3$  if  $A$  is in in.<sup>2</sup> =  $1 \times 10^6$  if  $A$  is in mm<sup>2</sup>.

8.3.2.2 If the specimen has a uniform thickness of base metal, the weight [mass] of the zinc coating may be calculated as follows:

$$C = [(W_1 - W_2)/W_2] \times G \times Z \quad (10)$$

where: =

$C$  = weight [mass] of coating,  $\text{g}/\text{m}^2$  of surface,

$W_1$  = original weight [mass] of specimen, g,

$W_2$  = weight [mass] of stripped specimen, g,

$G$  = thickness of stripped specimen, in. or mm, and

$Z$  = a constant =  $9.95 \times 10^{-4}$  if  $G$  is in in., =  $3.92 \times 10^{-3}$  if  $G$  is in mm.

## 9. Report

9.1 Weight [mass] of coating on zinc-coated sheet is expressed in weight [mass] per unit area of sheet, which is the sum of the weights of coating on both surfaces of the sheet. Weights [masses] of coating on each surface of the sheet are not necessarily equal. Coating weights [masses] on all zinc-coated articles other than sheets are expressed in weight [mass] per unit area of surface.

9.2 Report the weight [mass] of zinc coating to the nearest 0.01  $\text{oz}/\text{ft}^2$  when reporting in inch-pound units.

9.3 Report the weight [mass] of zinc coating to the nearest 1  $\text{g}/\text{m}^2$  when reporting in metric units.

9.4 When the weight [mass] of coating of a number of specimens is to be averaged to determine conformance with a specification limit, the average value shall be reported to the

precision described in 9.2 and 9.3 in accordance with the Rounding Method of Practice E 29.

## 10. Precision and Bias

10.1 *Precision*—The precision of this test method for sheet product with commercial zinc and zinc-alloy coatings has been determined in accordance with Practice E 691.

10.1.1 The repeatability was found to be 0.049  $\text{oz}/\text{ft}^2$ , and the reproducibility was found to be 0.060  $\text{oz}/\text{ft}^2$ .

10.2 The precision of the test method for other products or coating materials has not been determined.

NOTE 4—Repeatability and reproducibility, based on test error alone, are defined as the difference, in absolute value, of two test results obtained in the same laboratory or between laboratories on the same material. The differences will be expected to exceed the repeatability or reproducibility only about 5 % of the time.

10.3 *Bias*—Since there is no accepted reference material suitable for determining the bias for the procedure in this test method, bias has not been determined.

## 11. Keywords

11.1 55 % aluminum-zinc alloy coating; coating weight [mass]; steel sheet; steel wire; zinc alloy coatings; zinc coating; zinc-5 % aluminum alloy coating; zinc-5 % aluminum-0.1 % magnesium alloy coating; zinc-5 % aluminum-mischmetal alloy coating

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# Standard Specification for Zinc-Coated (Galvanized) “Iron” Telephone and Telegraph Line Wire<sup>1</sup>

This standard is issued under the fixed designation A 111; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon ( $\epsilon$ ) indicates an editorial change since the last revision or reapproval.

## 1. Scope

1.1 This specification covers “iron” wire with Class A, Class B, and Class C zinc coatings, suitable for use in telephone, telegraph, and signal transmission.

1.2 The values stated in inch-pound units are to be regarded as the standard. The values given in parentheses are for information only.

## 2. Referenced Documents

### 2.1 ASTM Standards:

A 90/A 90M Test Method for Weight [Mass] of Coating on Iron and Steel Articles with Zinc or Zinc-Alloy Coatings<sup>2</sup>

A 370 Test Methods and Definitions for Mechanical Testing of Steel Products<sup>3</sup>

A 902 Terminology Relating to Metallic Coated Steel Products<sup>2</sup>

B 6 Specification for Zinc<sup>4</sup>

B 193 Test Method for Resistivity of Electrical Conductor Materials<sup>5</sup>

## 3. Terminology

3.1 *Definitions*—For definitions of terms used in this specification, see Terminology A 902.

## 4. Ordering Information

4.1 Orders for wire under this specification shall include the following:

4.1.1 Size (in decimal fractions of an inch (or millimetre)),

4.1.2 Grade,

4.1.3 Class of zinc coating (A, B, or C),

4.1.4 Mandrel test for zinc coating (as desired, mandrels Nos. 1 to 12 for Class A or as desired, mandrels Nos. 3 to 12 for Classes B and C), and

4.1.5 ASTM designation and year of issue.

NOTE 1—*Example*—A typical order including the necessary informa-

tion to guide the manufacturer, is as follows:

5000 lb of 0.109-in. Grade BB wire, Class A coating, mandrel No. 3, ASTM Specification A 111.

## 5. Zinc for Coating

5.1 The zinc used for the coating shall be any grade of zinc conforming to Specification B 6.

## 6. Base Metal

6.1 The base metal shall be steel made by the open-hearth, basic-oxygen or electric-furnace process, or iron of such quality and purity that when processed and zinc coated the finished wire will have the properties prescribed in this specification for its size and grade.

## 7. Joints

7.1 The wire shall be furnished in coils of one continuous length. Welds made prior to the final wire drawing shall be permitted.

## 8. Sampling

8.1 The inspector shall select at random during the visual examination specified in Section 18, 1 sample coil from every 10 coils in the first 100 coils of the lot, and 1 sample coil for every additional 35 coils but not less than 3 coils from the entire lot. From each coil of galvanized wire thus selected, a sample of suitable length shall be taken for the weight of coating, the mechanical and the electrical tests as specified in Sections 9-14, inclusive.

## 9. Weight of Coating

9.1 The weight of zinc coating, in ounces per square foot (or grams per square metre) of uncoated wire surface, shall be not less than that specified in Table 1.

9.2 *Weight of Coating Test*—The zinc coating shall be tested for weight by a stripping test in accordance with Test Method A 90/A 90M.

## 10. Adherence of Coating

10.1 The zinc coating shall remain adherent when the wire is wrapped at a rate of not more than 15 turns per minute in a close helix of at least two turns around a cylindrical mandrel of the diameter specified. The mandrel diameter shall be approximately an even multiple of the diameter of the wire tested. The mandrel shall be specified by the number corresponding to this

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<sup>2</sup> *Annual Book of ASTM Standards*, Vol 01.06.

<sup>3</sup> *Annual Book of ASTM Standards*, Vol 01.03.

<sup>4</sup> *Annual Book of ASTM Standards*, Vol 02.04.

<sup>5</sup> *Annual Book of ASTM Standards*, Vol 02.03.

**TABLE 1 Minimum Weights of Zinc Coating**

Nominal Diameter of Coated Wire, in. (mm)	Minimum Weight of Zinc Coating, oz/ft <sup>2</sup> (g/m <sup>2</sup> ) of Uncoated Wire Surface		
	Class A	Class B	Class C
0.109 (2.77) and over	0.80 (245)	1.60 (490)	2.40 (730)
0.083 (2.11)	0.70 (215)	1.40 (425)	2.10 (640)

diameter ratio. For example, mandrel No. 1 and mandrel No. 12 designate mandrel diameters respectively one and twelve times the wire diameter.

NOTE 2—The coatings on all commercially available wire manufactured to meet this specification will pass a wrap test on mandrel No. 12. Coatings are available for passing wrap tests on mandrels as small as No. 1 for Class A, and No. 3 for Classes B and C. Coatings passing wrap tests on mandrels of intermediate sizes may be specified.

10.2 The zinc coating shall adhere firmly to the wire and shall be considered as meeting this requirement if, due to wrapping about the specified mandrel, it does not flake and none of the coating can be removed from the wire by rubbing with the bare fingers. Loosening or detachment during the adhesion test of superficial, small particles of zinc formed by mechanical polishing of the surface of zinc-coated wire shall not be considered cause for rejection.

**11. Breaking Strength**

11.1 The breaking strength of the galvanized wire shall not be less than that specified in Table 2 when tested in accordance with Test Methods and Definitions A 370.

**12. Elongation**

12.1 The elongation of the galvanized wire shall be not less than 10 % in 10 in. (254 mm) when tested in accordance with Test Methods and Definitions A 370. The elongation shall be determined as the permanent increase in length after failure of a marked section of the wire originally 10 in. (254 mm) in length.

**13. Ductility**

13.1 The base metal of the galvanized wire of each grade shall not fracture when the wire is wrapped at a rate of not more than 15 turns per minute in a close helix of at least two turns around a cylindrical mandrel of a diameter equal to the nominal diameter of the wire tested.

**14. Resistivity**

14.1 The weight resistivity of the wire expressed in ohm pound per square mile (ohm gram per square metre) at 20°C

(68°F) shall conform to the requirements specified in Table 3.

14.2 *Resistivity Test*—The resistivity shall be determined in accordance with Test Method B 193.

**15. Size and Permissible Variations**

15.1 *Size*—The size of the galvanized wire shall be expressed as the diameter of the wire in decimal fractions of an inch (or millimetre).

15.2 *Permissible Variations*—The permissible variations of the galvanized wire from the nominal diameter shall be as follows:

Nominal Diameter of Wire, in. (mm)	Permissible Variations, plus or minus, in. (mm)
0.109 (2.77) and over	0.004 (0.10)
0.083 (2.11)	0.003 (0.08)

15.3 *Gaging*—The wire of each coil selected for purpose of test (Section 8) shall be gaged in three places; one near each end of the coil and one approximately at the middle. A coil shall be rejected if the diameter, at any point, is not within the limits specified in 15.2.

**16. Workmanship, Finish, and Appearance**

16.1 The galvanized wire shall be free of splints, scales, inequalities, flaws, and other imperfections not consistent with good commercial practice. The coating shall be continuous and reasonably uniform.

**17. Inspection**

17.1 The manufacturer shall afford the inspector representing the purchaser all reasonable facilities, without charge, to satisfy him that the material is being furnished in accordance with this specification. All tests and inspection shall be made at the place of manufacture, prior to shipment, and shall be so conducted as not to interfere unnecessarily with the operation of the works.

**18. Rejection**

18.1 The inspector shall visually examine the entire shipment of lot of coils for surface imperfections. If, after visual examination, more than 3 % of the coils in the entire lot are found defective, the entire lot shall be subject to rejection. If more than 3 % of the samples selected in accordance with Section 8 fail to pass any of the tests specified in Sections 9-15, inclusive, the entire lot shall be subject to rejection. If not more than 3 % of the samples fail, a second set of samples, consisting of two specimens from each of the coils from which the original nonconforming samples were taken, shall be cut and tested for the nonconforming properties. If any of these samples fail, the entire lot shall be subject to rejection.

**19. Packaging**

19.1 The finished wire shall be furnished in compact coils

**TABLE 2 Breaking Strength Requirements**

Nominal Diameter of Coated Wire, in. (mm)	Size (Birmingham Wire Gage)	Breaking Strength, min, lbf (N)	
		Grade BB	
0.238 (6.05)	4	2 270 (10 100)	
0.203 (5.16)	6	1 650 (7 340)	
0.165 (4.19)	8	1 090 (4 850)	
0.148 (3.76)	9	880 (3 910)	
0.134 (3.40)	10	720 (3 200)	
0.120 (3.05)	11	575 (2 560)	
0.109 (2.77)	12	475 (2 110)	
0.083 (2.11)	14	275 (1 220)	

**TABLE 3 Resistivity Requirements**

Class of Coating	Weight Resistivity, max, Ω·lb/mile <sup>2</sup> (Ω·g/m <sup>2</sup> )	
	Grade BB	
A	6200 (1.092)	
B	6050 (1.062)	
C	5900 (1.033)	

reasonably symmetrical in shape. The diameter of the eye of each coil shall be not less than 17 in. (432 mm), nor more than 24 in. (610 mm).

19.2 The weight of wire in each coil shall conform, within a variation of plus or minus 10 %, to the nominal values specified in Table 4.

19.3 Each coil shall be securely bound in four separate places, equally spaced, with at least two wrappings of galvanized wire not smaller than 0.080 in. (2.0 mm) in diameter. As an alternative, coils may be securely bound in three separate

places, equally spaced, with a zinc-coated steel strap. The steel crimping seal used to fasten the strap shall be either zinc-coated or painted steel. For bundles with a nominal weight less than 100 lb (45.4 kg) the steel strap shall be not less than ½ in. (12.7 mm) wide by 0.020 in. (0.51 mm) thick. For bundles with a nominal weight of 100 lb (45.4 kg) or more, the steel strap shall be not less than 5/8 in. (15.9 mm) wide by 0.020 in. (0.51 mm) thick, and each binder shall be looped around several strands of wire and then passed around the coil and tightened. The outer end of each coil shall be bent back over the binding wire or strap or else tucked into the coil and shall be identified by an appropriate tag to facilitate locating the end.

**TABLE 4 Nominal Amount of Wire in Each Coil**

Nominal Diameter of Coated Wire, in. (mm)	Size (Birmingham Wire Gage)	Approximate Length, ft (m)	Nominal Weight of Wire in Each Coil, lb (kg)
0.238 (6.05)	4	1 320 (402)	200 (91)
0.203 (5.16)	6	1 760 (536)	193 (88)
0.165 (4.19)	8	2 640 (805)	191 (87)
0.148 (3.76)	9	2 640 (805)	154 (70)
0.134 (3.40)	10	2 640 (805)	126 (57)
0.120 (3.05)	11	2 640 (805)	101 (46)
0.109 (2.77)	12	2 640 (805)	83 (38)
0.083 (2.11)	14	2 640 (805)	48 (22)

## 20. Marking

20.1 To each coil of wire shall be securely attached a durable tag showing the size, grade, class of coating, ASTM designation A 111, and the name or mark of the manufacturer.

## 21. Keywords

21.1 iron products—zinc-coated; steel wire—zinc-coated; telephone/telegraph wire

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# Standard Specification for Metallic-Coated, Steel-Woven Wire Fence Fabric<sup>1</sup>

This standard is issued under the fixed designation A 116; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon ( $\epsilon$ ) indicates an editorial change since the last revision or reapproval.

## 1. Scope

1.1 This specification covers metallic-coated steel fence fabric having a series of horizontal (line) wires, with vertical (stay) wires woven or wrapped around the line wires, forming rectangular openings. The fence fabric is suitable for use in fences for farm field enclosure (to keep domestic animals in or out), for highway or railroad right-of-way fencing (to control access), and other similar uses.

1.2 This specification covers fence fabric in various designs, tensile strength grades, and metallic coating types and grades.

1.3 The values stated in inch-pound units are to be regarded as the standard. The values given in parentheses are for information only.

1.4 The text of this specification references notes and footnotes which provide explanatory material. These notes and footnotes (excluding those in tables and figures) shall not be considered as requirements of the specification.

## 2. Referenced Documents

### 2.1 ASTM Standards:

A 90/A 90M Test Method for Weight [Mass] of Coating on

Iron and Steel Articles with Zinc or Zinc-Alloy Coatings<sup>2</sup>

A 370 Test Methods and Definitions for Mechanical Testing of Steel Products<sup>3</sup>

A 428/A 428M Test Method for Weight of Coating on Aluminum-Coated Iron or Steel Articles<sup>2</sup>

A 641/A 641M Specification for Zinc-Coated (Galvanized) Carbon Steel Wire<sup>2</sup>

A 700 Practices for Packaging, Marking, and Loading Methods for Steel Products for Domestic Shipment<sup>4</sup>

A 809 Specification for Aluminum-Coated (Aluminized) Carbon Steel Wire<sup>2</sup>

A 856/A 856M Specification for Zinc-5 % Aluminum-Mischmetal Alloy-Coated Carbon Steel Wire<sup>2</sup>

A 902 Terminology Relating to Metallic Coated Steel Products<sup>2</sup>

### 2.2 U.S. Federal Standard:

Fed. Std. No. 123 Marking for Shipments (Civil Agencies)<sup>5</sup>

2.3 U.S. Military Standards:

MIL-STD-129 Marking for Shipment and Storage<sup>5</sup>

MIL-STD-163 Steel Mill Products, Preparation for Shipments and Storage<sup>5</sup>

## 3. Terminology

3.1 *Definitions*—For definitions of terms used in this specification, refer to Terminology A 902.

3.2 *Definitions of Terms Specific to This Standard:*

3.2.1 *intermediate wires, n*—line wires other than top and bottom wires.

3.2.2 *top and bottom wires, n*—line wires at the edge of the fence fabric (the top and bottom edges as erected).

## 4. Classification

4.1 The woven wire fabric covered by this specification is classified as described in the following sections.

4.2 *Design Number*—Numbers describing standard sizes and constructions of this fabric, as listed in Table 1.

4.3 *Metallic Coating Type:*

4.3.1 *Coating Type A*—Made from aluminum-coated wire.

4.3.2 *Coating Type Z*—Made from zinc-coated wire.

4.3.3 *Coating Type ZA*—Made from zinc-5 % aluminum-mischmetal alloy (Zn-5Al-MM) coated wire.

4.4 *Metallic Coating Class*—The specified amount of coating (coating weight[mass]) on the strand wire. See Table 2 for the coating classes available.

4.5 *Tensile Strength Grades*—The fabric is available in strength grades of 60, 125, and 175 (see Table 1).

NOTE 1—The design numbers are related to the characteristics of the construction of the fence fabric. The design number indicates the number of line wires, approximate height, stay wire spacing, and size (gage) of the line and stay wires.

## 5. Ordering Information

5.1 Orders for material under this specification shall include the following information, as necessary to describe each product ordered.

5.1.1 Name of material (woven steel fence fabric);

5.1.2 Quantity (number of rolls);

5.1.3 Design Number (see Table 1);

5.1.4 Tensile strength grade (see Table 1);

<sup>1</sup> This specification is under the jurisdiction of ASTM Committee A05 on Metallic-Coated Iron and Steel Products and is the direct responsibility of Subcommittee A05.12 on Wire Specifications.

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<sup>2</sup> *Annual Book of ASTM Standards*, Vol 01.06.

<sup>3</sup> *Annual Book of ASTM Standards*, Vol 01.03.

<sup>4</sup> *Annual Book of ASTM Standards*, Vol 01.05.

<sup>5</sup> Available from Standardization Documents Order Desk, Bldg. 4 Section D, 700 Robbins Ave., Philadelphia, PA 19111-5094, Attn: NPODS.



**TABLE 1 Design Numbers for Woven Wire Fence Fabric**

Design Numbers	Number of Horizontal Wires	Fence Height		Spacing of Stay Wires, in. (cm)	Size, Steel Wire Gage	
		Nominal (Design), in.	Specified (Actual), in. (cm)		Intermediate Line and Stay Wires	Top and Bottom Wires
No. 9 Grade 60						
1155-12-9	11	55	55.5 (141)	12 (30)	9	9
1047-12-9	10	47	46.5 (118)	12 (30)	9	9
939-12-9	9	39	38.5 (98)	12 (30)	9	9
832-12-9	8	32	31.5 (80)	12 (30)	9	9
726-12-9	7	26	25.5 (65)	12 (30)	9	9
949-12-9	9	49	49.0 (124)	12 (30)	9	9
845-12-9	8	45	45.0 (114)	12 (30)	9	9
635-12-9	6	35	35.5 (90)	12 (30)	9	9
1155-6-9	11	55	55.5 (141)	6 (15)	9	9
1047-6-9	10	47	46.5 (118)	6 (15)	9	9
726-6-9	7	26	25.5 (63)	6 (15)	9	9
No. 11 Grade 60						
1047-12-11	10	47	46.5 (118)	12 (30)	11	9
939-12-11	9	39	38.5 (98)	12 (30)	11	9
832-12-11	8	32	31.5 (80)	12 (30)	11	9
726-12-11	7	26	25.5 (65)	12 (30)	11	9
845-12-11	8	45	45.0 (114)	12 (30)	11	9
635-12-11	6	35	35.5 (90)	12 (30)	11	9
1047-6-11	10	47	46.5 (118)	6 (15)	11	9
939-6-11	9	39	38.5 (98)	6 (15)	11	9
832-6-11	8	32	31.5 (80)	6 (15)	11	9
726-6-11	7	26	25.5 (63)	6 (15)	11	9
No. 12½ Grade 60						
1047-12-12½	10	47	46.5 (118)	12 (30)	12½	10
939-12-12½	9	39	38.5 (98)	12 (30)	12½	10
832-12-12½	8	32	31.5 (80)	12 (30)	12½	10
726-12-12½	7	26	25.5 (65)	12 (30)	12½	10
845-12-12½	8	45	45.0 (114)	12 (30)	12½	10
635-12-12½	6	35	35.5 (90)	12 (30)	12½	10
1047-6-12½	10	47	46.5 (118)	6 (15)	12½	10
939-6-12½	9	39	38.5 (98)	6 (15)	12½	10
832-6-12½	8	32	31.5 (80)	6 (15)	12½	10
726-6-12½	7	26	25.5 (63)	6 (15)	12½	10
No. 14½ Grade 60						
939-6-14½	9	39	38.5 (98)	6 (15)	14½	11
832-6-14½	8	32	31.5 (80)	6 (15)	14½	11
726-6-14½	7	26	25.5 (65)	6 (15)	14½	11
No. 12½ Grade 125						
1047-12-12½	10	47	46.5 (118)	12 (30)	12½	10½
939-12-12½	9	39	38.5 (98)	12 (30)	12½	10½
832-12-12½	8	32	31.5 (80)	12 (30)	12½	10½
726-12-12½	7	26	25.5 (65)	12 (30)	12½	10½
1047-6-12½	10	47	46.5 (118)	6 (15)	12½	10½
939-6-12½	9	39	38.5 (98)	6 (15)	12½	10½
832-6-12½	8	32	31.5 (80)	6 (15)	12½	10½
726-6-12½	7	26	25.5 (65)	6 (15)	12½	10½
No. 12½ Grade 125						
1478-6-12½	14	78	78.0 (198)	6 (15)	12½	12½
No. 14 Grade 125						
1047-12-14	10	47	46.5 (118)	12 (30)	14	12½
939-12-14	9	39	38.5 (98)	12 (30)	14	12½
832-12-14	8	32	31.5 (80)	12 (30)	14	12½
726-12-14	7	26	25.5 (65)	12 (30)	14	12½
1047-6-14	10	47	46.5 (118)	6 (15)	14	12½
939-6-14	9	39	38.5 (98)	6 (15)	14	12½
832-6-14	8	32	31.5 (80)	6 (15)	14	12½
726-6-14	7	26	25.5 (65)	6 (15)	14	12½
No. 14½ Grade 125						
1047-12-14½	10	47	46.5 (118)	12 (30)	14½	12½
939-12-14½	9	39	38.5 (98)	12 (30)	14½	12½

**TABLE 1** *Continued*

Design Numbers	Number of Horizontal Wires	Fence Height		Spacing of Stay Wires, in. (cm)	Size, Steel Wire Gage	
		Nominal (Design), in.	Specified (Actual), in. (cm)		Intermediate Line and Stay Wires	Top and Bottom Wires
832-12-14½	8	32	31.5 (80)	12 (30)	14½	12½
726-12-14½	7	26	25.5 (65)	12 (30)	14½	12½
1047-6-14½	10	47	46.5 (118)	6 (15)	14½	12½
939-6-14½	9	39	38.5 (98)	6 (15)	14½	12½
832-6-14½	8	32	31.5 (80)	6 (15)	14½	12½
726-6-14½	7	26	25.5 (65)	6 (15)	14½	12½
No. 12½ Grade 175						
1375-12-12½	13	75	74.5 (189)	12 (30)	12½	12½
1047-12-12½	10	47	46.5 (118)	12 (30)	12½	12½
1047-9-12½	10	47	46.5 (118)	9 (23)	12½	12½
1047-6-12½	10	47	46.5 (118)	6 (15)	12½	12½
1775-6-12½	17	75	74.5 (189)	6 (15)	12½	12½
1561-6-12½	15	61	60.0 (152)	6 (15)	12½	12½
1375-6-12½	13	75	74.5 (189)	6 (15)	12½	12½

**TABLE 2** **Minimum Weight of Metallic Coating**

Size, Steel Wire Gage	Diameter in. (mm)	Minimum Weight of Coating, oz/ft <sup>2</sup> (g/m <sup>2</sup> )					
		Type A Grade 60	Type Z Class 1 Grade 60	Type Z Class 3 Grades 60, 125, and 175	Type ZA Class 20 Grade 60	Type ZA Class 40 Grades 60, 125, and 175	Type ZA Class 80 Grades 60, 125, and 175
No. 9	0.148 (3.76)	0.40 (122)	0.35 (107)	0.90 (275)	0.20 (61)	0.40 (122)	0.80 (244)
No. 10	0.135 (3.43)	0.35 (107)	0.30 (92)	0.85 (259)	0.20 (61)	0.40 (122)	0.80 (244)
No. 10½	0.128 (3.25)			0.85 (259)		0.40 (122)	0.80 (244)
No. 11	0.120 (3.05)	0.35 (107)	0.30 (92)	0.85 (259)	0.20 (61)	0.40 (122)	0.80 (244)
No. 12½	0.099 (2.51)	0.32 (98)	0.28 (85)	0.80 (244)	0.20 (61)	0.40 (122)	0.80 (244)
No. 14	0.080 (2.03)			0.70 (214)		0.40 (122)	0.80 (244)
No. 14½	0.076 (1.93)	0.30 (92)	0.25 (76)	0.70 (214)	0.20 (61)	0.40 (122)	0.80 (244)

5.1.5 Metallic coating type (see 4.3);

5.1.6 Metallic coating class (see Table 2);

5.1.7 ASTM designation and year of issue, and

5.1.8 Certification, or test report, or both, if required (see Section 13).

NOTE 2—A typical ordering description is as follows: Woven-steel fence fabric, 60 rolls, Design Number 1047-6-12 ½, Grade 60, Coating Type Z, Coating Class 3, to ASTM A 116-\_\_\_\_, with certification.

5.2 All rolls of fence fabric accepted by the purchaser shall be billed on the basis of the original length of the rolls before sampling unless changed by contractual agreement.

## 6. Material

6.1 *Wire*—The metallic coated wire used in the fabrication of the fence fabric shall conform to the requirements of Specifications A 809, A 641/A 641M, and A 856/A 856M for Coating Types A, Z, ZA, respectively.

6.2 *Coated Wire*—The steel wire shall be coated before fabrication, to the coating class specified in the order and conforming to the coating weight [mass] specified in Table 2.

## 7. General Requirements

7.1 *Construction*—The sizes and constructions for fence fabric furnished under this specification shall be in accordance with the requirements of Table 1 for the design number specified in the order, within the tolerances stated in Section 8.

7.2 *Splices*—Splicing of the individual line wires by means of a wrap joint, mechanical fasteners, or an electric butt weld is

permitted. The maximum number of line wire splices or joints shall not exceed one-half of the number of line wires in any 330 ft (101m)(20 rod) roll of fabric. Such splices and joints shall be made in a workman-like manner and welded joints shall be coated with the corresponding Type A, Z, or ZA-coating material to provide corrosion protection equivalent to the type coated wire being used.

7.3 *Stay Wires*—The woven wire fence fabric shall have uniformly wrapped joints and all stay wires shall be properly spaced and substantially perpendicular to the line wires.

7.4 *Fence Fabric Length*—The length of fence fabric in a roll shall be 330 ft (101 m)(20 rod).

7.5 *Breaking Strength*—The breaking strength of line wires shall conform to the requirements of Table 3 for the grade specified in the order. There is no strength requirement for the stay wires.

## 8. Permissible Variations in Dimensions

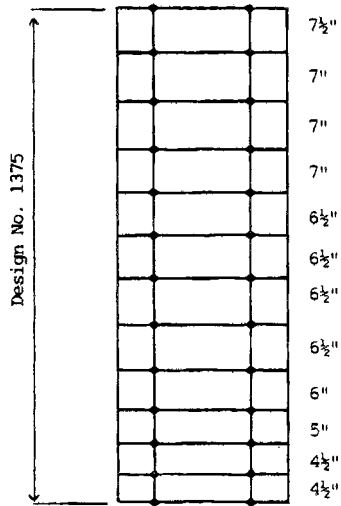
8.1 *Wire Diameter*—The permissible variation of the wire, from the nominal diameter shown in Table 3, shall be  $\pm 0.005$  in. ( $\pm 0.127$  mm). Determine the diameter using a micrometer or other suitable measuring instrument, based on the greatest and least measurement at the same cross-section, with measurement to the nearest 0.001 in. (0.025 mm). The average of the two measurements shall be considered the diameter of the test specimen.

8.1.1 *Out-of-Roundness*—Due to the mechanics of manufacture, a certain amount of out-of-roundness is expected on

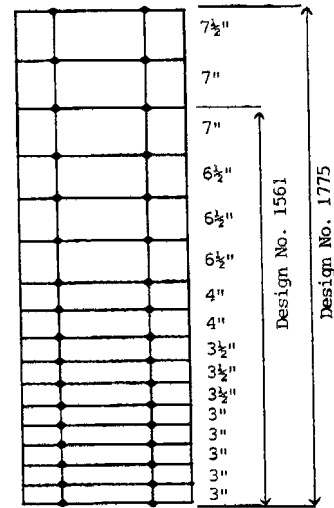
**TABLE 3 Breaking Strength of Line Wires**

NOTE 1—There is no breaking strength requirement for stay wires.

Size, Steel Wire Gage	Tensile Strength Grade, ksi	Nominal Diameter in. (mm)	Minimum Breaking Strength Line Wires Only lbf (N)
9	60 (60)	0.148 (3.77)	1030 (4590)
10	60 (60)	0.135 (3.43)	860 (3820)
10½	125 (125)	0.128 (3.25)	1610 (7160)
11	60 (60)	0.120 (3.05)	685 (3050)
12½	60 (60)	0.099 (2.51)	460 (2050)
12½	125 (125)	0.099 (2.51)	960 (4280)
12½	175 (175)	0.099 (2.51)	1345 (5990)
14	125 (125)	0.080 (2.03)	630 (2800)
14½	60 (60)	0.076 (1.93)	270 (1210)
14½	125 (125)	0.076 (1.93)	565 (2520)



**FIG. 2 Fence Fabric Dimensions for Design Number 1375**



**FIG. 3 Fence Fabric Dimensions for Design Numbers 1561 and 1775**

the stay wires of the finished fence fabric. No limits are placed on out-of-roundness of the stay wires.

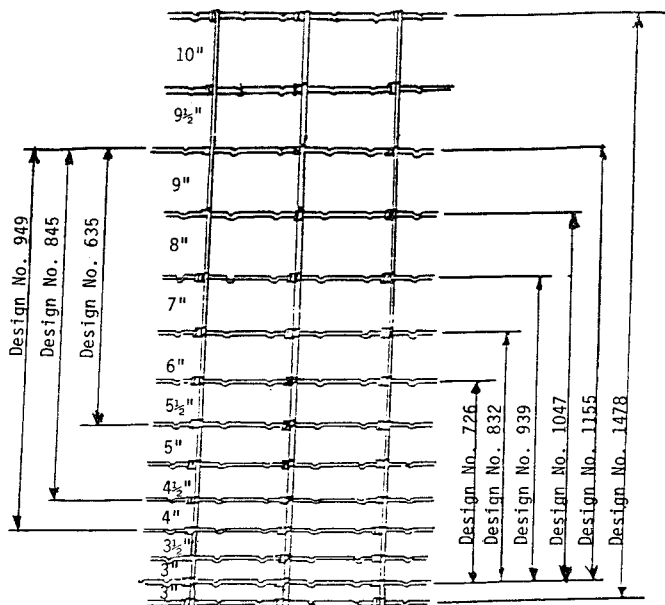
8.2 *Fabric Height*—The height of the woven wire fence fabric (center-to-center distance between top and bottom wires) shall not vary more than 1 in. (25 mm) from the specified height shown in Table 1. The specified height of the fence fabric is based on the sum of the line wire spacings shown in Fig. 1, Fig. 2, or Fig. 3. The nominal (design) height shown in Table 1 corresponds to the value in the design numbers, and is for information only.

8.3 *Line and Stay Wire Spacing*—The spacing between individual pairs of line wires, or individual pairs of stay wires, shall not vary from the nominal dimensions more than 3/8 in. (10 mm). The tolerance on the spacing of pairs of line wires shall not alter the tolerance on the overall height of the fence fabric.

8.4 *Fence Fabric Length*—The length of fence fabric in a roll shall be the specified length within a tolerance of -0 and +3 %.

**9. Sampling and Testing**

9.1 *Sampling*—For the purpose of tests, select one roll at random from every 50 rolls, or fraction thereof in a lot, or a



**FIG. 1 Fence Fabric Dimensions for Design Numbers**

total of seven rolls, whichever is less. A lot shall consist of all rolls of a single design, grade, coating type, and coating class offered for delivery at the same time. A sample for physical tests is a length of fence fabric, at least 3 ft (1 m) long, cut from the end of the sample roll to include at least three of the vertical (stay) wires.

9.2 *Testing for Weight of Coating*—Coating weight for Types Z and ZA shall be determined in accordance with Test Method A 90/A 90M. Coating weight for Type A shall be determined in accordance with Test Method A 428/A 428M.

9.2.1 A test specimen for weight of coating determination shall consist of a number of lengths cut from a single wire, excluding all wire knots, wraps, and welded sections, such that the total length of wire tested is a minimum of 12 in. (305 mm). Test at least six test specimens for weight of coating, selected as follows:

- 9.2.1.1 One specimen from the top or bottom line wires,
- 9.2.1.2 Three specimens from different intermediate line wires, and
- 9.2.1.3 Two specimens from different vertical (stay) wires.

9.3 *Tests for Breaking Strength*—Cut specimens approximately 12 in. (305 mm) in length from the line wires, excluding knots, wraps, and welds. Test for breaking strength in accordance with Test Method A 370. Test at least four specimens, with one specimen from the top or bottom line wires, and three specimens from intermediate line wires.

9.4 *Pretesting of Wire*—Instead of testing wire for breaking strength and weight of coating from the completed fence fabric in accordance with 9.2 and 9.3, the manufacturer, at his election, shall establish compliance with the requirements in Sections 6 and 7 by tests made on wire prior to fabrication. If the manufacturer makes this election, the purchaser still has the right to test wire from the completed fence fabric for compliance.

9.5 *Inspection for General Workmanship*—For the purpose of inspection, a maximum of two rolls from the lot, as described in 9.1, shall be subjected to observations for the line and stay wire spacing, overall length, and workmanship.

9.5.1 Instead of inspecting for length by unrolling full rolls, the purchaser and manufacturer have the option of agreeing on a weight per roll related to the fabric design, or measuring tools employed during manufacturing. The purchaser still reserves the right to confirm the length by actual measurement.

## 10. Retests and Rejection

10.1 If one or more of the test specimens from a sample roll of fence fabric fail the weight-of-coating test, or the breaking strength test, the lot shall be subjected to retests. For retest purposes, four additional rolls for each 50 rolls offered shall be sampled. The lot size then becomes 50. Test specimens shall be cut in accordance with 9.2 or 9.3 as appropriate.

10.2 If more than four of the 24 retest specimens for weight-of-coating fail to meet the requirements of Table 2, or if any of the retest specimens has less than 75 % of the specified coating weight, the entire lot represented by the retest specimens may be rejected.

10.3 If more than 3 of 16 retest specimens for breaking strength fail to meet the requirements of Table 3, or if any of the retest specimens has less than 90 % of the specified breaking strength, the entire lot represented by the retest specimens may be rejected.

10.4 If instead of rejecting the entire lot as provided for in 10.2 or 10.3, the producer may test specimens from every roll as provided for in 9.2 or 9.3 and resubmit those rolls meeting specification requirements.

## 11. Inspection

11.1 Unless otherwise specified in the purchase order or contract, the manufacturer is responsible for the performance

of all inspection and test requirements specified in this specification. Except as otherwise specified in the purchase order or contract, the manufacturer may use any suitable facilities for the performance of the inspection and test requirements unless disapproved by the purchaser at the time the order is placed. The purchaser shall have the right to perform any of the inspection and tests set forth in this specification when such inspections and tests are deemed necessary to assure that the material conforms to prescribed requirements.

## 12. Rejection and Rehearing

12.1 Material that fails to conform to the requirements of this specification may be rejected. Rejection should be reported to the producer or supplier promptly and in writing. In case of dissatisfaction with the results of the test, the producer or supplier may make claim for a rehearing.

## 13. Certification

13.1 When specified in the purchase order or contract, a producer's or supplier's certification shall be furnished to the purchaser that the material was manufactured, sampled, tested, and inspected in accordance with this specification and has been found to meet the requirements. When specified in the purchase order or contract, a report of the test results shall be furnished.

## 14. Packaging and Package Marking

14.1 Unless otherwise specified, packaging, marking, and loading for shipment shall be in accordance with Practices A 700.

14.2 When specified in the contract or order, and for direct procurement by or direct shipment to the U.S. Government, when Level A is specified, preservation, packaging, and packing shall be in accordance with the Level A requirement of MIL-STD-163.

14.3 When specified in the contract or order, and for the direct procurement by or direct shipment to the U.S. Government, marking for shipment, in addition to requirements specified in the contract or order, shall be in accordance with MIL-STD-129 for U.S. military agencies and in accordance with Fed. Std. No. 123 for U.S. Government civil agencies.

## 15. Keywords

15.1 fence fabric; fencing material; metallic coated steel wire; steel wire; wire

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 **A 116**

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# Standard Specification for Metallic-Coated Carbon Steel Barbed Wire<sup>1</sup>

This standard is issued under the fixed designation A 121; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon ( $\epsilon$ ) indicates an editorial change since the last revision or reapproval.

*This standard has been approved for use by agencies of the Department of Defense.*

## 1. Scope

1.1 This specification covers metallic-coated steel barbed wire, consisting of a strand of two wires.

1.2 The barbed wire is available with aluminum, zinc, and zinc-5 % aluminum-mischmetal alloy coatings, with a number of coating weights, in a number of different constructions (designs), and in two grades. Not all designs are available in all coating types.

1.3 The values stated in inch-pound units are to be regarded as the standard. The values given in parentheses are for information only.

1.4 The text of this specification references notes and footnotes that provide explanatory information. These notes and footnotes (excluding those in tables) shall not be considered as requirements of the specification.

## 2. Referenced Documents

### 2.1 ASTM Standards:

- A 90/A 90M Test Method for Weight (Mass) of Coating on Iron and Steel Articles with Zinc or Zinc-Alloy Coatings<sup>2</sup>
- A 428/A 428M Test Method for Weight of Coating on Aluminum-Coated Iron or Steel Articles<sup>2</sup>
- A 641/A 641M Specification for Zinc-Coated (Galvanized) Carbon Steel Wire<sup>2</sup>
- A 700 Practices for Packaging, Marking, and Loading Methods for Steel Products for Domestic Shipment<sup>3</sup>
- A 809 Specification for Aluminum-Coated (Aluminized) Carbon Steel Wire<sup>2</sup>
- A 856/A 856M Specification for Zinc-5 % Aluminum-Mischmetal Alloy-Coated Carbon Steel Wire<sup>2</sup>
- A 902 Terminology Relating to Metallic Coated Steel Products<sup>2</sup>

### 2.2 Federal Standard:

Fed. Std. No. 123 Marking for Shipments (Civil Agencies)<sup>4</sup>

### 2.3 Military Standards:

<sup>1</sup> This specification is under the jurisdiction of ASTM Committee A-5 on Metallic-Coated Iron and Steel Products and is the direct responsibility of Subcommittee A05.12 on Wire Specifications.

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<sup>2</sup> Annual Book of ASTM Standards, Vol 01.06.

<sup>3</sup> Annual Book of ASTM Standards, Vol 01.05.

<sup>4</sup> Available from Standardization Documents Order Desk, Bldg. 4 Section D, 700 Robbins Ave., Philadelphia, PA 19111-5094, Attn: NPODS.

MIL-STD-129 Marking for Shipment and Storage<sup>4</sup>

MIL-STD-163 Steel Mill Products Preparation for Shipment and Storage<sup>4</sup>

## 3. Terminology

3.1 *Definitions*—For definitions of terms used in this specification, refer to Terminology A 902.

## 4. Classification

4.1 The barbed wire covered by this specification is classified as described in this section.

4.2 *Design Number*—Numbers describing standard sizes and constructions, as listed in Table 1.

4.3 *Metallic Coating Type:*

4.3.1 *Coating Type A*—Made from aluminum-coated strand wire.

4.3.2 *Coating Type Z*—Made from zinc-coated strand wire.

4.3.3 *Coating Type ZA*—Made from zinc-5 % aluminum-mischmetal alloy (Zn-5AL-MM) coated strand wire.

4.4 *Metallic Coating Class*—The specified amount of coating (coating weight [mass]) on the strand wire.

4.4.1 For Coating Type A, see 6.3. (Only one coating weight for each wire size.)

4.4.2 For Coating Type Z, see Table 2.

4.4.3 For Coating Type AZ, see Table 3.

4.5 *Grades:*

4.5.1 *Standard Grade*—Barbs spaced on 4 or 5-in. (102 or 127-mm) centers as indicated in Table 1.

4.5.2 *High-Security Grade*—Barbs spaced on 3-in. (76-mm) centers (for Coating Type A only).

NOTE 1—The design numbers are related to the characteristics of the construction of the barbed wire, with the number groups related, in order, to the steel wire gage of the strand wires, number of barb points, spacing of barbs, steel wire gage of the barbs, and a letter indicating the shape of the barbs.

## 5. Ordering Information

5.1 Orders for material under this specification shall include the following information, as necessary to describe the desired product.

5.1.1 Name of material (steel barbed wire),

5.1.2 Quantity (number of spools and length of barbed wire on each, or total length) (see 7.5 for standard size of spools),

5.1.3 Metallic coating type (see 4.3),

**TABLE 1 Standard Sizes and Constructions for Barbed Wire**

Design Number	Size, Steel Wire Gage	Nominal Diameter of Coated Wire, in. (mm)	Number of Barb Points	Spacing of Barbs, in. (mm)	Diameter of Barbs, Steel Wire Gage <sup>A</sup>	Shape of Barbs
Metallic Coating Type A						
12-4-3-14R <sup>B</sup>	12½	0.099 (2.51)	4	3 (76)	14	Round
12-4-5-14R	12½	0.099 (2.51)	4	5 (127)	14	Round
Metallic Coating Type Z and Type ZA						
12-2-4-12F	12½	0.099 (2.51)	2	4 (102)	12½ <sup>C</sup>	Flat
12-2-4-13F	12½	0.099 (2.51)	2	4 (102)	13 <sup>C</sup>	Flat
12-2-4-14R	12½	0.099 (2.51)	2	4 (102)	14	Round
12-2-5-12F	12½	0.099 (2.51)	2	5 (127)	12½ <sup>C</sup>	Flat
12-2-5-14R	12½	0.099 (2.51)	2	5 (127)	14	Round
12-4-5-14H	12½	0.099 (2.51)	4	5 (127)	14 <sup>C</sup>	Half-round
12-4-5-14R	12½	0.099 (2.51)	4	5 (127)	14	Round
13-2-4-14R	13½	0.086 (2.18)	2	4 (102)	14	Round
13-4-5-14R	13½	0.086 (2.18)	4	5 (127)	14	Round
15-2-5-13F	15½	0.067 (1.70)	2	5 (127)	13¾ <sup>C</sup>	Flat
15-2-5-14R	15½	0.067 (1.70)	2	5 (127)	14	Round
15-4-5-16R	15½	0.067 (1.70)	4	5 (127)	16½	Round

<sup>A</sup>The nominal diameter of the wire used in making the barbs shall be as follows:

12½ gage	0.099 in. (2.51 mm)
13 gage	0.092 in. (2.32 mm)
13¾ gage	0.083 in. (2.11 mm)
14 gage	0.080 in. (2.03 mm)
16½ gage	0.058 in. (1.47 mm)

<sup>B</sup>Design Number 12-4-3-12R, Metallic Coated Type A, is High-Security Grade. All other design numbers are for standard grade.

<sup>C</sup>The gage of the half-round and flat barbs is designated by the gage of the round wire from which the barbs are rolled.

**TABLE 2 Minimum Weight of Coating on Type Z Barbed Wire**

Size, Steel Wire Gage	Nominal Diameter of Type Z		Minimum Weight of Coating of Uncoated Wire Surface, oz/ft <sup>2</sup> (g/m <sup>2</sup> )	
	in.	(mm)	Class 1	Class 3
12½	0.099	(2.51)	0.28 (85)	0.80 (245)
13	0.092	(2.32)	0.28 (85)	0.75 (230)
13½	0.086	(2.18)	0.25 (75)	0.70 (215)
13¾	0.083	(2.11)	<sup>A</sup>	0.70 (215)
14	0.080	(2.03)	0.25 (75)	0.70 (215)
15½	0.067	(1.70)	<sup>A</sup>	0.65 (200)
16½	0.058	(1.47)	<sup>A</sup>	0.60 (200)

<sup>A</sup>These sizes only furnished with Class 3 Coating (Section 8).

**TABLE 3 Minimum Weight of Coating on Type ZA Barbed Wire**

Size Wire Gage	Nominal Diameter of Type ZA Wire		Minimum Weight of Coating of Uncoated Wire Surface, oz/ft <sup>2</sup> (g/m <sup>2</sup> ) Class <sup>A</sup>					
	in.	(mm)	20	40	60	80	100	120
12½	0.099	(2.51)	X <sup>B</sup>	X	X	X	X	X
13	0.092	(2.32)	X	X	X	X	X	X
13½	0.086	(2.18)	X	X	X	X	X	X
13¾	0.083	(2.11)	X	X	X	X	X	X
14	0.080	(2.03)	X	X	X	X	X	X
15½	0.067	(1.70)	X	X	X	X	X	X
16½	0.058	(1.47)	X	X	X	X	X	X

<sup>A</sup>Coating Class 20 40 60 80 100 120

Coating Weight						
oz/ft <sup>2</sup>	0.20	0.40	0.60	0.80	1.00	1.20
(g/m <sup>2</sup> )	61	122	183	244	305	366

<sup>B</sup>X denotes availability.

wire, 20 spools of 80 rods each, Coating Type Z, Coating Class 3, Design Number 12-2-4-14R, to ASTM Specification A 121-99, with certification.

5.2 All spools of barbed wire accepted by the purchaser shall be billed on the basis of the original length of the spools before sampling, unless changed by contractual agreement.

## 6. Material

6.1 *Base Metal*—The base metal of the steel strand wires and steel barbs shall be of good commercial quality carbon steel, capable of meeting the breaking strength requirement in 7.7. The base metal for aluminum barbs (permitted with metallic Coating Type A) shall be aluminum alloy wire conforming to Alloy 5000-H38, Alloy 6061-T94, or equal.

6.1.1 For Coating Type A barbed wire, the choice of whether aluminum-coated steel wire or aluminum alloy wire for the barbs shall be that of the manufacturer, unless otherwise specified by the purchaser. If aluminum alloy wire is used, the particular alloy shall be agreed upon between the manufacturer and the purchaser at the time the order is placed.

6.2 *Coating Materials*—The coating on the wire shall conform with the requirements of the following specifications:

6.2.1 *Coating Type A*—Aluminum-coated wire in accordance with Specification A 809.

6.2.2 *Coating Type Z*—Zinc-coated wire in accordance with Specification A 641/A 641M.

6.2.3 *Coating Type ZA*—Zinc-5 % aluminum-mischmetal alloy (Zn-5Al-MM) coated wire in accordance with Specification A 856/A 856M.

6.3 *Coated Wire*—The steel wire shall be coated before fabrication.

6.3.1 *Weight of Coating Requirements for Strand Wires*—The strand wires for Types Z and ZA barbed wire, as represented by the test specimens, shall conform to the requirements of Tables 2 and 3 respectively for the minimum coating weight for the type and class ordered. The strand wires for Type A barbed wire, as represented by the test specimens,

5.1.4 Metallic coating class (for Types Z and ZA) (see Table 2 or Table 3),

5.1.5 Design Number (see Table 1),

5.1.6 For Coating Type A barbed wire, whether aluminum alloy barbs are required or prohibited (see 6.2.1). If not stated, the choice shall be at the manufacturer's option,

5.1.7 ASTM designation and year of issue, and

5.1.8 Certification or test report, or both, if required.

NOTE 2—A typical ordering description is as follows: Steel barbed

shall have a minimum coating weight of 0.30 oz/ft<sup>2</sup> (90 g/m<sup>2</sup>) on the 12½-gage wire.

6.3.2 *Weight of Coating Requirements for Barbs*—The wire for barbs for Types Z and ZA barbed wire, as represented by the test specimens, shall conform to the same coating class requirements as the strand wire. The steel wire for barbs for Type A barbed wire, as represented by the test specimens, shall have a minimum coating weight of 0.25 oz/ft<sup>2</sup> (75 g/m<sup>2</sup>) on the 14-gage wire.

## 7. General Requirements

7.1 The sizes and constructions for barbed wire furnished under this specification shall be in accordance with the requirements of Table 1 for the Design Number specified in the order, within the tolerances stated in Section 8.

7.2 The barbs shall be sharp, well-formed, and tightly wrapped. The barb length, measured from the center of the two strand wires, shall be ⅜ in. (9.5 mm) minimum.

7.3 The strand wires shall be twisted with a uniform length of lay. Type Z and Type ZA barbed wire shall have the twisting consistently in one direction (left or right) or alternating between the left and right directions. Type A barbed wire shall have the twisting consistently in either the left or right direction, with alternating of the twisting prohibited.

7.4 Splicing of individual wires by means of a wrap joint or an electric butt weld is permitted. Not more than three splices or joints shall exist in any spool of barbed wire. Such splices or joints shall be made in a workmanlike manner.

7.5 The barbed wire, for the various types, shall be packaged on spools in lengths as follows:

7.5.1 *Type A*—80 rods (1320 ft) (402 m) or 1000 ft (305 m).

7.6 *Types Z and ZA*—80 rods (1320 ft) (402 m) or 80 rods plus additional increments of 10 rods (165 ft) (50 m).

7.7 *Breaking Strength*—The breaking strength of the stranded barbed wire, for all types, shall be not less than 950 lbf (4230 N). This breaking strength reflects that of both strand wires tested together as one unit.

## 8. Permissible Variations in Dimensions

8.1 *Diameter*—The permissible variation from the nominal diameter of the wire, for both line wires and barbs, for all types, shall be ±0.005 in. (0.13 mm)

8.1.1 Due to the mechanics of manufacture when forming the barbs, a certain amount of out-of-roundness is expected. The size and condition precludes barbs from being subjected to diameter checks.

8.2 *Barb Spacing*—The nominal spacing of the barbs shall be as noted in Table 1. The individual barb spacing shall be measured from the edge of one barb at the strand to the corresponding edge of the adjacent barb. Cumulative spacing is established by counting the total number of barbs in a 25-ft (7.6-m) length of barbed wire. Barbs are subject to relocation during fabrication and handling, potentially leading to rejections with rigid interpretation of the spacing requirement. Therefore, barb spacing shall be considered acceptable under the following conditions:

8.2.1 The sample has 93.5 % of the individual barb spacings conforming to the specified spacing ±¾ in. (19 mm), and

8.2.2 A sample length of 25 ft (7.6 m) of barbed wire contains:

8.2.2.1 A minimum of 86 barbs for 3-in. (76-mm) spacing,

8.2.2.2 A minimum of 69 barbs for 4-in. (102-mm) spacing, or

8.2.2.3 A minimum of 55 barbs for 5-in. (127-mm) spacing.

## 9. Sampling and Testing

9.1 *Sampling*—For the purpose of tests, select one spool at random from every 50 spools or fraction thereof in a lot, or a total of seven samples, whichever is less. A lot shall consist of all spools of a single construction (Design Number) of barbed wire offered for delivery at the same time.

9.2 *Test Specimens for Physical Tests*—Cut a 4-ft (1.2-m) length of barbed wire from the end of each spool for tests prescribed in Sections 6 and 7. Determine the breaking strength value by testing the twisted strand as composite. Test each strand wire individually for weight of coating.

9.3 *Testing for Weight of Coating*—Coating weight for Types Z and ZA shall be determined in accordance with Test Method A 90/A 90M. Coating weight for Type A shall be determined in accordance with Test Method A 428/A 428M. Perform testing either before or after fabrication for the strand wires and for Type A steel barbs. Perform testing prior to fabrication for Type Z and ZA barbs, and certify the test results.

9.4 *Pretesting of Wire*—Instead of testing wire for breaking strength and weight of coating from the completed barbed wire in accordance with 9.2, the manufacturer, at his election, shall establish compliance with the requirements in Sections 6 and 7 by tests made on wire prior to fabrication. If the manufacturer makes this election, the purchaser still has the right to test wire from the completed barbed wire for compliance. It is recognized that during fabrication the barb is mechanically deformed and scraped, and some differences are likely in coating weight results on barbs tested before and after fabrication.

9.5 *Inspection for General Workmanship*—For the purpose of inspection, a maximum of two spools from the lot, as described in 9.1, shall be subjected to observations for barb length and spacing, overall length, and workmanship.

9.5.1 Instead of inspecting for length by unrolling full spools, the purchaser and manufacturer have the option of agreeing on a weight per spool related to wire size or measuring tools employed during manufacturing. The purchaser still reserves the right to confirm the length by actual measurement.

9.5.2 Inspection for barb spacing is normally performed on the outer 25-ft (7.6-m) length of a spool, which permits repacking of the spool. Any other selection shall be as agreed upon between the manufacturer and the purchaser.

## 10. Retests

10.1 *Lot Size for Retests*—If one or more of the individual wire specimens fail the coating weight, or if a strand specimen fails the breaking strength test, the lot shall be subject to retest. For retest purposes, four additional spools of barbed wire for each 50 spools offered shall be sampled. The lot size then becomes 50 spools, except variation in lot size is permitted to accommodate pallet count when the barbed wire is palletized.

10.2 *Retesting for Coating Weight*—If more than two of the



individual strand wires of the retest specimens fail to meet the requirements of 6.3, or if any of the retest specimens has less than 75 % of the specified coating weight, the entire lot represented by the retest shall be rejected.

10.3 *Retesting for Breaking Strength*—If any of the retest specimens fail to meet the minimum breaking strength value in 7.7, the entire lot represented by the specimens shall be rejected.

10.4 *Reinspection for Barb Spacing, Barb Length, and Overall Length*—If either of the sample spools fails to meet the requirements for these dimensions, within the tolerances in Section 8, two additional spools shall be selected for inspection. If either of these spools fails to meet the requirements, the lot shall be rejected.

## 11. Inspection

11.1 Unless otherwise specified in the purchase order or contract, the manufacturer is responsible for the performance of all inspection and test requirements specified in this specification. Except as otherwise specified in the purchase order or contract, the contractor shall use his own or any other suitable facilities for the performance of the inspection and test requirements unless disapproved by the purchaser at the time the order is placed. The purchaser shall have the right to perform any of the inspections and tests set forth in this specification when such inspections and tests are deemed necessary to ensure that the material conforms to the prescribed requirements.

## 12. Rejection and Rehearing

12.1 Material that fails to conform to the requirements of this specification shall be rejected. Rejection shall be reported to the manufacturer or supplier promptly and in writing. In case

of dissatisfaction with the results of the test, the manufacturer or supplier shall make claim for a rehearing.

12.2 Instead of rejecting the entire lot as provided in Section 10, the manufacturer has the option of testing specimens from every spool and rejecting only those spools failing the weight of coating or breaking strength requirements.

## 13. Certification

13.1 When specified in the purchase order or contract, a manufacturer's or supplier's certification stating that the material was manufactured, sampled, tested, and inspected in accordance with this specification and has been found to meet the requirements shall be furnished to the purchaser. When specified in the purchase order or contract, a report of the test results shall be furnished.

## 14. Packing and Package Marking

14.1 Unless otherwise specified, packaging, marking, and loading for shipment shall be in accordance with Practices A 700.

14.2 When specified in the contract or order, and for direct shipment to the U.S. Government, when Level A is specified, preservation, packaging, and packing shall be in accordance with Level A requirement of MIL-STD-163.

14.3 When specified in the contract or order, and for the direct procurement by or direct shipment to the U.S. Government, marking for shipment, in addition to the requirements specified in the contract or order, shall be in accordance with MIL-STD-129 for U.S. military agencies and in accordance with Fed. Std. No. 123 for U.S. Government civil agencies.

## 15. Keywords

15.1 barbed wire; carbon steel wire; metallic coated steel wire; steel barbed wire; wire

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*This standard is subject to revision at any time by the responsible technical committee and must be reviewed every five years and if not revised, either reapproved or withdrawn. Your comments are invited either for revision of this standard or for additional standards and should be addressed to ASTM Headquarters. Your comments will receive careful consideration at a meeting of the responsible technical committee, which you may attend. If you feel that your comments have not received a fair hearing you should make your views known to the ASTM Committee on Standards, 100 Barr Harbor Drive, West Conshohocken, PA 19428.*



# Standard Specification for Zinc (Hot-Dip Galvanized) Coatings on Iron and Steel Products<sup>1</sup>

This standard is issued under the fixed designation A 123/A 123M; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon ( $\epsilon$ ) indicates an editorial change since the last revision or reapproval.

*This standard has been approved for use by agencies of the Department of Defense.*

## 1. Scope

1.1 This specification covers the requirements for zinc coating (galvanizing) by the hot-dip process on iron and steel products made from rolled pressed and forged shapes, castings, plates, bars, and strips.

1.2 This specification covers both unfabricated products and fabricated products, for example, assembled steel products, structural steel fabrications, large tubes already bent or welded before galvanizing, and wire work fabricated from uncoated steel wire. This specification also covers steel forgings and iron castings incorporated into pieces fabricated before galvanizing or which are too large to be centrifuged (or otherwise handled to remove excess galvanizing bath metal).

NOTE 1—This specification covers those products previously addressed in Specifications A 123-78 and A 386-78.

1.3 This specification does not apply to wire, pipe, tube, or steel sheet which is galvanized on specialized or continuous lines, or to steel less than 22 gage (0.0299 in.) [0.76 mm] thick.

1.4 The galvanizing of hardware items that are to be centrifuged or otherwise handled to remove excess zinc (such as bolts and similar threaded fasteners, castings and rolled, pressed and forged items) shall be in accordance with Specification A 153/A 153M.

1.5 Fabricated reinforcing steel bar assemblies are covered by the present specification. The galvanizing of separate reinforcing steel bars shall be in accordance with Specification A 767/A 767M.

1.6 This specification is applicable to orders in either inch-pound units (as A 123) or SI units (as A 123M). Inch-pound units and SI units are not necessarily exact equivalents. Within the text of this specification and where appropriate, SI units are shown in parentheses. Each system shall be used independently of the other without combining values in any way. In the case of orders in SI units, all testing and inspection

shall be done using the metric equivalent of the test or inspection method as appropriate. In the case of orders in SI units, such shall be stated to the galvanizer when the order is placed.

## 2. Referenced Documents

### 2.1 ASTM Standards:

A 47/A 47M Specification for Ferritic Malleable Iron Castings<sup>2</sup>

A 90/A 90M Test Method for Weight [Mass] of Coating on Iron and Steel Articles with Zinc or Zinc-Alloy Coatings<sup>3</sup>

A 143 Practice for Safeguarding Against Embrittlement of Hot-Dip Galvanized Structural Steel Products and Procedure for Detecting Embrittlement<sup>3</sup>

A 153/A 153M Specification for Zinc Coating (Hot-Dip) on Iron and Steel Hardware<sup>3</sup>

A 384/A 384M Practice for Safeguarding Against Warpage and Distortion During Hot-Dip Galvanizing of Steel Assemblies<sup>3</sup>

A 385 Practice for Providing High-Quality Zinc Coatings (Hot-Dip)<sup>3</sup>

A 767/A 767M Specification for Zinc-Coated Galvanized Steel Bars for Concrete Reinforcement<sup>4</sup>

A 780 Practice for Repair of Damaged and Uncoated Areas of Hot-Dip Galvanized Coatings<sup>3</sup>

A 902 Terminology Relating to Metallic Coated Steel Products<sup>3</sup>

B 6 Specification for Zinc<sup>5</sup>

B 487 Test Method for Measurement of Metal and Oxide Coating Thicknesses by Microscopical Examination of a Cross Section<sup>6</sup>

B 602 Test Method for Attribute Sampling of Metallic and Inorganic Coatings<sup>6</sup>

E 376 Practice for Measuring Coating Thickness by

<sup>1</sup> This specification is under the jurisdiction of ASTM Committee A05 on Metallic Coated Iron and Steel Products and is the direct responsibility of Subcommittee A05.13 on Structural Shapes and Hardware Specifications.

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<sup>2</sup> Annual Book of ASTM Standards, Vol 01.02.

<sup>3</sup> Annual Book of ASTM Standards, Vol 01.06.

<sup>4</sup> Annual Book of ASTM Standards, Vol 01.04.

<sup>5</sup> Annual Book of ASTM Standards, Vol 02.04.

<sup>6</sup> Annual Book of ASTM Standards, Vol 02.05.

Magnetic-Field or Eddy-Current (Electromagnetic) Test Methods<sup>7</sup>

3. Terminology (See Fig. 1)

3.1 Definitions:

3.1.1 The following terms and definitions are specific to this specification. Terminology A 902 contains other terms and definitions relating to metallic-coated steel products.

3.2 Definitions of Terms Specific to This Standard:

3.2.1 average coating thickness, *n*—the average of three specimen coating thicknesses.

3.2.2 black, *adj*—denotes the condition of not galvanized or otherwise coated. For purposes of this specification the word “black” does not refer to the color or condition of surface, or to a surface deposit or contamination.

3.2.3 coating thickness grade, *n*—the numerical value from Table 1 at the intersection of a material category and a thickness range.

3.2.4 gross dross inclusions, *n*—the iron/zinc intermetallics present in a galvanized coating in a form other than finely dispersed pimples.

3.2.4.1 Discussion—These inclusions would create an exposed steel spot if they were removed from the coating. These inclusions are raised surfaces and are easily knocked off

<sup>7</sup> Annual Book of ASTM Standards, Vol 03.03.

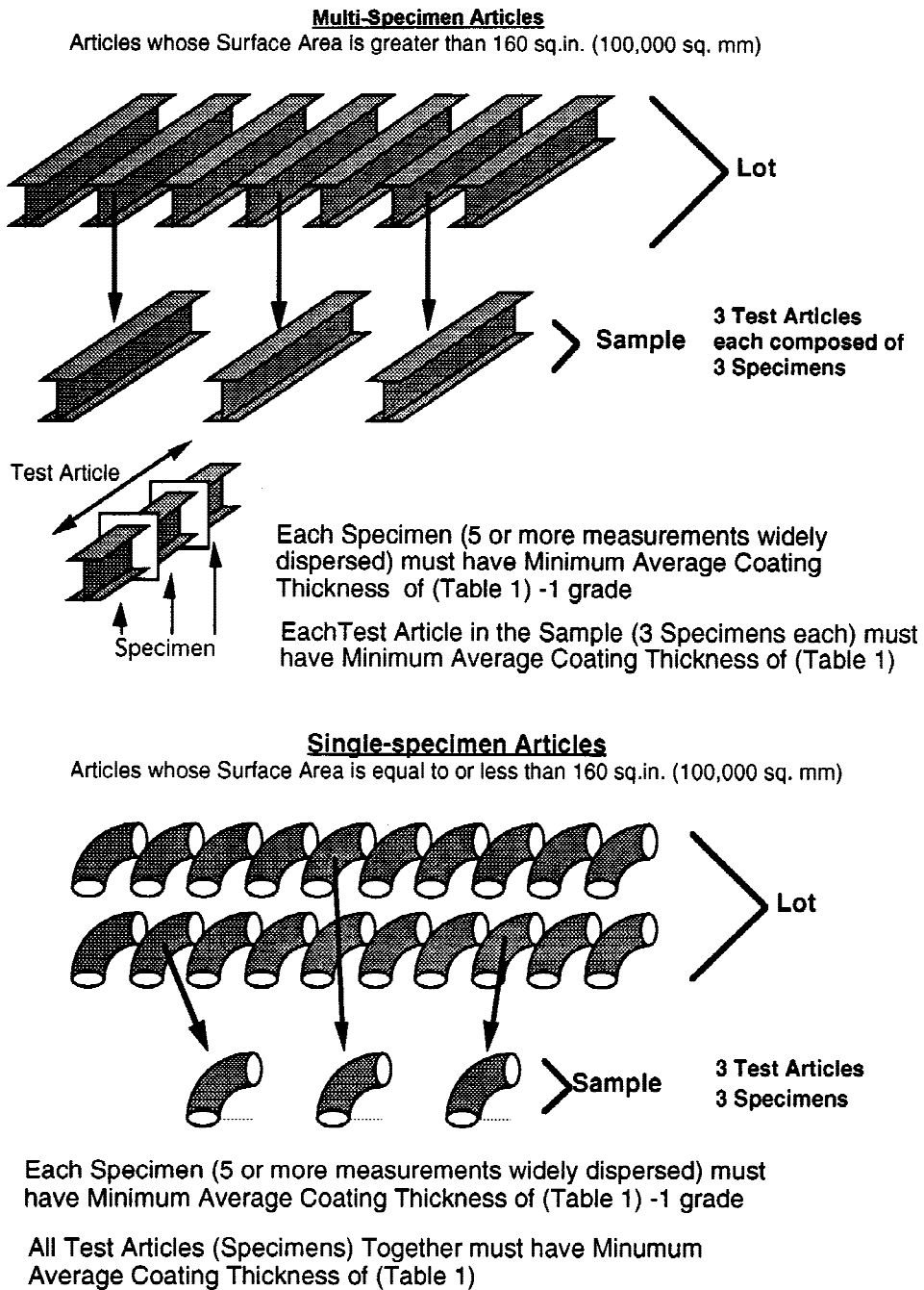


FIG. 1 Single- and Multi-Specimen Articles

**TABLE 1 Minimum Average Coating Thickness Grade by Material Category**

Material Category	All Specimens Tested Steel Thickness Range (Measured), in. (mm)				
	<1/16 (<1.6)	1/16 to <1/8 (1.6 to <3.2)	1/8 to 3/16 (3.2 to 4.8)	>3/16 to <1/4 (>4.8 to <6.4)	≥1/4 (≥6.4)
Structural Shapes and Plate	45	65	75	85	100
Strip and Bar	45	65	75	85	100
Pipe and Tubing	45	45	75	75	75
Wire	35	50	60	65	80

through contact with lifting straps or chains, tools, fixtures, or other galvanized parts.

3.2.5 *material category, n*—the general class or type of material or process of manufacture, or both, that nominally describes a unit of product, or from which a unit of product is made. For example, bar grating belongs to the category “strip,” handrail belongs to the category “pipe,” etc.

3.2.6 *multi-specimen article, n*—a unit of product whose surface area is greater than 160 in.<sup>2</sup> [100 000 mm<sup>2</sup>]. For thickness testing purposes, articles whose surface area is greater than 160 in.<sup>2</sup> are subdivided into three continuous local sections, nominally equal in surface area, each of which constitutes a specimen. In the case of any such local section containing more than one material category or steel thickness range as delineated in Table 1, that section will contain more than one specimen (see Fig. 1).

3.2.7 *sample, n*—a collection of individual units of product from a single lot selected in accordance with Section 7, and intended to represent that lot for acceptance. If a sample is taken as representing the lot for acceptance, the sample shall be taken at random from the lot without regard to the perceived quality or appearance of any individual unit in the lot being sampled. The sample consists of one or more test articles.

3.2.8 *single-specimen article, n*—a unit of product whose surface area is equal to or less than 160 in.<sup>2</sup> [100 000 mm<sup>2</sup>] or that is centrifuged or otherwise similarly handled in the galvanizing process to remove excess galvanizing bath metal (free zinc). For thickness testing purposes, the entire surface area of each unit of product constitutes a specimen. In the case of any such article containing more than one material category or steel thickness range as delineated in Table 1, that article will contain more than one specimen (see Fig. 1).

3.2.9 *specimen, n*—the surface of an individual test article or a portion of a test article, upon which thickness measurements are to be performed, which is a member of a lot, or a member of a sample representing that lot. For magnetic thickness measurements, specimen excludes any area of the surface which is subject to processes (such as flame cutting, machining, threading, etc.) that can be expected to result in surface conditions not representative of the general surface condition of the test article, or is disqualified by the measurement method. The minimum average coating thickness grade for any specimen shall be one coating grade below that required for the appropriate material category and thickness in Table 1. For a unit of product whose surface area is equal to or less than 160 in.<sup>2</sup> [100 000 mm<sup>2</sup>], the entire surface area of each test article constitutes a specimen. In the case of an article containing more than one material category or steel thickness range as delineated in Table 1, that article will contain more than one specimen, as appropriate (see Fig. 1).

3.2.10 *specimen coating thickness, n*—the average thickness from no less than five test measurements on a specimen, when each measurement location is selected to provide the widest dispersion (in all applicable directions) of locations for the steel category of the test article within the confines of the specimen volume.

3.2.11 *test article, n*—an individual unit of product that is a member of the sample and that is examined for conformance to a part of this specification.

#### 4. Ordering Information

4.1 Orders for coatings provided under this specification shall include the following:

- 4.1.1 Quantity (number of pieces to be galvanized) and total weight.
- 4.1.2 Description (type and size of products) and weight.
- 4.1.3 ASTM specification designation and year of issue.
- 4.1.4 Material identification (see 5.1) and surface condition or contamination.
- 4.1.5 Sampling plan, if different from 7.3.
- 4.1.6 Special test requirements (see 8.1).
- 4.1.7 Special requirements (special stacking, heavier coating weight, etc.).
- 4.1.8 Tagging or piece identification method.

#### 5. Materials and Manufacture

5.1 *Steel or Iron*—The specification, grade, or designation and type and degree of surface contamination of the iron or steel in articles to be galvanized shall be supplied by the purchaser to the hot-dip galvanizer prior to galvanizing.

NOTE 2—The presence in steels and weld metal, in certain percentages, of some elements such as silicon, carbon, and phosphorus tends to accelerate the growth of the zinc-iron alloy layer so that the coating may have a matte finish with little or no outer zinc layer. The galvanizer has only limited control over this condition. The mass, shape, and amount of cold working of the product being galvanized may also affect this condition. Practice A 385 provides guidance on steel selection and discusses the effects of various elements in steel compositions (for example, silicon), that influence coating weight and appearance.

5.2 *Fabrication*—The design and fabrication of the product to be galvanized are the responsibilities of the designer and the fabricator. Practices A 143, A 384, and A 385 provide guidance for steel fabrication for optimum hot dip galvanizing and shall be complied with in both design and fabrication. Consultation between the designer, fabricator, and galvanizer at appropriate stages in the design and fabrication process will reduce future problems.

5.3 *Castings*—The composition and heat treatment of iron and steel castings shall conform to specifications designated by the purchaser. Some types of castings have been known to

show potential problems with predisposition to being embrittled during the normal thermal cycle of hot-dip galvanizing. It is the responsibility of the purchaser to heat treat or otherwise allow for the possibility of such embrittling phenomena. The requirements for malleable iron castings to be galvanized shall be as stated in Specification A 47.

5.4 *Zinc*—The zinc used in the galvanizing bath shall conform to Specification B 6. If a zinc alloy is used as the primary feed to the galvanizing bath, then the base material used to make that alloy shall conform to Specification B 6.

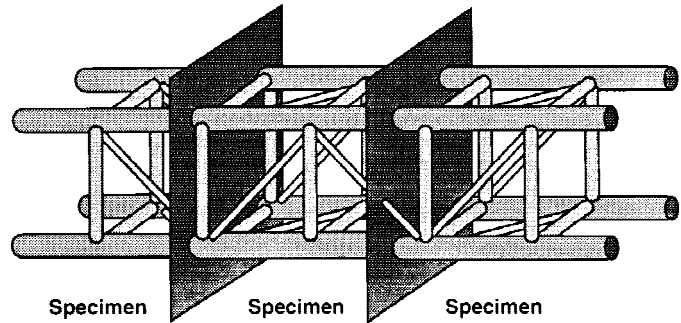
5.5 *Bath Composition*—The molten metal in the working volume of the galvanizing bath shall contain not less than an average value of 98.0 % zinc by weight.

NOTE 3—The galvanizer may choose to add trace amounts of certain elements (for example, aluminum, nickel, and tin) to the zinc bath to help in the processing of certain reactive steels or to enhance the cosmetic appearance of the finished product. The use of these trace elements is permitted provided that the bulk chemistry of the galvanizing bath is at least 98.0 % zinc by weight. The elements can be added to the galvanizing bath as part of a pre-alloyed zinc feed, or they can be added to the bath by the galvanizer using a master feed alloy.

**6. Coating Properties**

6.1 *Coating Thickness*—The average thickness of coating for all specimens tested shall conform to the requirements of Table 1 for the categories and thicknesses of the material being galvanized. Minimum average thickness of coating for any individual specimen is one coating grade less than that required in Table 1. Where products consisting of various material thicknesses or categories are galvanized, the coating thickness grades for each thickness range and material category of material shall be as shown in Table 1. In the case of orders in SI units, the values in Table 1, shall be applicable as metric units in micrometres. In the case of orders in inch-pound units, the measured value shall be converted to coating grade units by the use of Table 2. The specification of coating thicknesses heavier than those required by Table 1 shall be subject to mutual agreement between the galvanizer and the purchaser. (Fig. 2 is a graphic representation of the sampling and specimen delineation steps, and Fig. 3 is a graphic representation of the coating thickness inspection steps.)

6.1.1 For articles whose surface area is greater than 160 in.<sup>2</sup> [100 000 mm<sup>2</sup>] (multi-specimen articles), each test article in the sample must meet the appropriate minimum average coating thickness grade requirements of Table 1, and each specimen coating thickness grade comprising that overall



NOTE 1—Each specimen comprises nominally one third of the total surface area of the article. A minimum of five measurements should be made within the volume of each specimen, as widely dispersed within that volume as is practical, so as to represent as much as possible, the general coating thickness within that specimen volume.

**FIG. 2 Articles Made of Many Components**

average for each test article shall average not less than one coating grade below that required in Table 1.

6.1.2 For articles whose surface area is equal to or less than 160 in.<sup>2</sup> [100 000 mm<sup>2</sup>] (single-specimen articles), the average of all test articles in the sample must meet the appropriate minimum average coating thickness grade requirements of Table 1, and for each test article, its specimen coating thickness shall be not less than one coating grade below that required in Table 1.

6.1.3 No individual measurement, or cluster of measurements at the same general location, on a test specimen shall be cause for rejection under the coating thickness requirements of this specification provided that when those measurements are averaged with the other dispersed measurements to determine the specimen coating thickness grade for that specimen, the requirements of 6.1.1 or 6.1.2, as appropriate are met.

NOTE 4—The coating thickness grades in Table 1 represent the minimum value obtainable with a high level of confidence for the ranges typically found in each material category. While most coating thicknesses will be in excess of those values, some materials in each category may be less reactive (for example, because of chemistry or surface condition) than other materials of the steel category spectrum. Therefore, some articles may have a coating grade at or close to the minimum requirement shown in Table 1. In such cases, the precision and accuracy of the coating thickness measuring technique should be taken into consideration when rejecting such articles for coating thickness below that required by this specification. Purchasers desiring a guarantee of heavier coatings than the minimum thicknesses shown herein should use the special requirements (see 4.1.6) to specify coating thickness grades higher than those shown in

**TABLE 2 Coating Thickness Grade<sup>A</sup>**

Coating Grade	mils	oz/ft <sup>2</sup>	µm	g/m <sup>2</sup>
35	1.4	0.8	35	245
45	1.8	1.0	45	320
50	2.0	1.2	50	355
55	2.2	1.3	55	390
60	2.4	1.4	60	425
65	2.6	1.5	65	460
75	3.0	1.7	75	530
80	3.1	1.9	80	565
85	3.3	2.0	85	600
100	3.9	2.3	100	705

<sup>A</sup> The values in micrometres (µm) are based on the Coating Grade. The other values are based on conversions using the following formulas: mils = µm × 0.03937; oz/ft<sup>2</sup> = µm × 0.02316; g/m<sup>2</sup> = µm × 7.067.

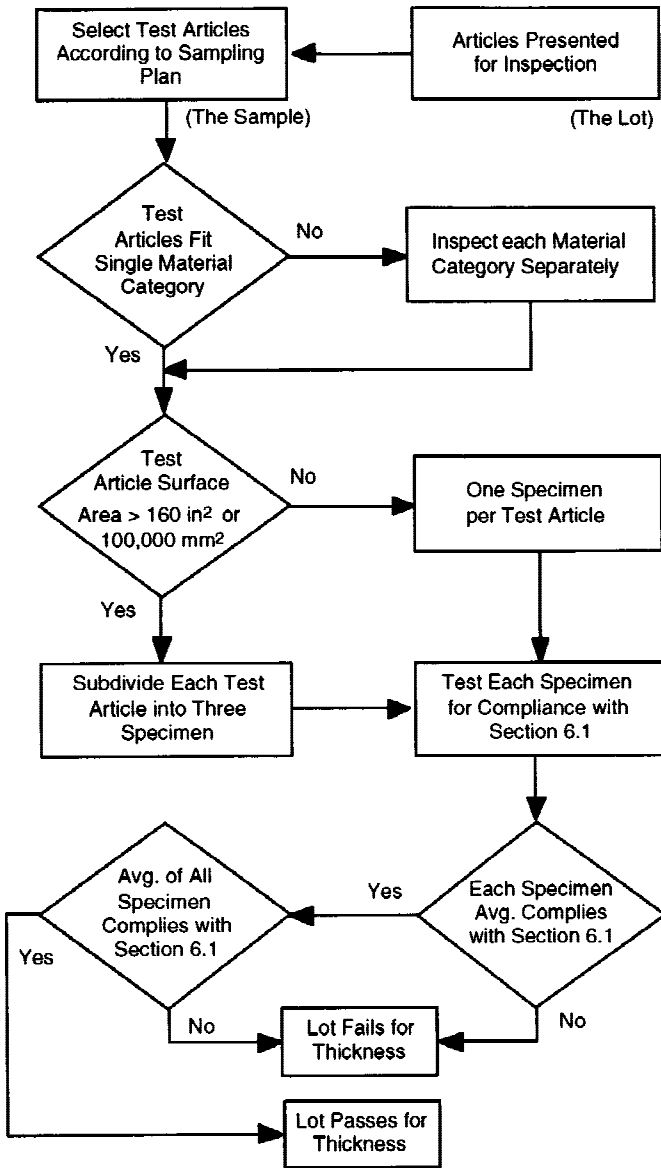


FIG. 3 Coating Thickness Inspection Steps

Table 1. In addition, the purchaser should anticipate the need for test batches or extra preparation steps, or both, such as blasting before galvanizing or other methods, to attempt to reach the higher requirements with consistency. Some higher-than-standard thicknesses may be impractical or unattainable.

6.2 *Finish*—The coating shall be continuous (except as provided below), and as reasonably smooth and uniform in thickness as the weight, size, shape of the item, and necessary handling of the item during the dipping and draining operations at the galvanizing kettle will permit. Except for local excess coating thickness which would interfere with the use of the product, or make it dangerous to handle (edge tears or spikes), rejection for nonuniform coating shall be made only for plainly visible excess coating not related to design factors such as holes, joints, or special drainage problems (see Note 6). Since surface smoothness is a relative term, minor roughness that does not interfere with the intended use of the product, or roughness that is related to the as-received (un-galvanized) surface condition, steel chemistry, or steel reactivity to zinc

shall not be grounds for rejection (see Note 7). Surface conditions related to deficiencies related to design, detailing, or fabrication as addressed by Practice A 385 shall not be grounds for rejection. The zinc coating on threaded components of articles galvanized under this specification shall conform to that required in Specification A 153/A 153M. Surfaces that remain uncoated after galvanizing shall be renovated in accordance with the methods in Practice A 780 unless directed by the purchaser to leave the uncoated areas untreated for subsequent renovation by the purchaser.

6.2.1 Each area subject to renovation shall be 1 in. [25 mm] or less in its narrowest dimension.

6.2.2 The total area subject to renovation on each article shall be no more than 1/2 of 1 % of the accessible surface area to be coated on that article, or 36 in.<sup>2</sup> per short ton [256 cm<sup>2</sup> per metric ton] of piece weight, whichever is less.

NOTE 5—Inaccessible surface areas are those which cannot be reached for appropriate surface preparation and application of repair materials as described in Practice A 780. Such inaccessible areas, for example, would be the internal surfaces of certain tanks, poles, pipes, tubes, and so forth.

6.2.3 The thickness of renovation shall be that required by the thickness grade for the appropriate material category and thickness range in Table 1 in accordance with the requirements of 6.1, except that for renovation using zinc paints, the thickness of renovation shall be 50 % higher than that required by Table 1, but not greater than 4.0 mils.

6.2.4 When areas requiring renovation exceed the criteria previously provided, or are inaccessible for repair, the coating shall be rejected.

NOTE 6—The requirements for the finish of a galvanized product address themselves to a visual type of inspection. They do not address the matter of measured coating thickness variations that can be encountered because of different steels or different thicknesses of a given steel being used in an assembly.

NOTE 7—Items which are prepared for galvanizing by abrasive cleaning will generally develop a thicker coating with a moderately rougher surface.

6.3 *Threaded Components in Assemblies*—The zinc coating on external threads shall not be subjected to a cutting, rolling, or finishing tool operation, unless specifically authorized by the purchaser. Internal threads are not prohibited from being tapped or retapped after galvanizing. Coatings shall conform to the requirements of Specification A 153/A 153M.

6.4 *Appearance*—Upon shipment from the galvanizing facility, galvanized articles shall be free from uncoated areas, blisters, flux deposits, and gross cross inclusions. Lumps, projections, globules, or heavy deposits of zinc which will interfere with the intended use of the material will not be permitted. Plain holes of 1/2-in. [12.5-mm] diameter or more shall be clean and reasonably free from excess zinc. Marks in the zinc coating caused by tongs or other items used in handling the article during the galvanizing operation shall not be cause for rejection unless such marks have exposed the base metal and the bare metal areas exceed allowable maximums from 6.2.1 and 6.2.2. The pieces shall be handled so that after galvanizing they will not freeze together on cooling.

NOTE 8—Depending upon product design or material thickness, or both, filming or excess zinc buildup in plain holes of less than 1/2-in.

[12.5-mm] diameter may occur that requires additional work to make the holes usable as intended.

**6.5 Adherence**—The zinc coating shall withstand handling consistent with the nature and thickness of the coating and the normal use of the article, without peeling or flaking.

**NOTE 9**—Although some material may be formed after galvanizing, in general the zinc coating on the articles covered by this specification is too heavy to permit severe bending without damaging the coating.

## 7. Sampling

7.1 Sampling of each lot shall be performed for conformance with the requirements of this specification.

7.2 A lot is a unit of production or shipment from which a sample is taken for testing. Unless otherwise agreed upon between the galvanizer and the purchaser, or established within this specification, the lot shall be as follows: For testing at a galvanizer's facility, a lot is one or more articles of the same type and size comprising a single order or a single delivery load, whichever is the smaller, or any number of articles identified as a lot by the galvanizer, when these have been galvanized within a single production shift and in the same bath. For test by the purchaser after delivery, the lot consists of the single order or the single delivery load, whichever is the smaller, unless the lot identity, established in accordance with the above, is maintained and clearly indicated in the shipment by the galvanizer.

7.3 The method of selection and number of test specimens shall be agreed upon between the galvanizer and the purchaser. Otherwise, the test specimens shall be selected at random from each lot. In this case, the minimum number of specimens from each lot shall be as follows:

Number of Pieces in Lot	Number of Specimens
3 or less	all
4 to 500	3
501 to 1 200	5
1 201 to 3 200	8
3 201 to 10 000	13
10 001 and over	20

**NOTE 10**—Where a number of identical items are to be galvanized, a statistical sampling plan may be desired. Such a plan is contained in Test Method B 602 which addresses sampling procedures for the inspection of electrodeposited metallic coatings and related finishes. If Test Method B 602 is used, the level of sampling shall be agreed upon between the galvanizer and the purchaser at the time the coating order is placed.

7.4 A test specimen which fails to conform to a requirement of this specification shall not be used to determine the conformance to other requirements.

## 8. Test Methods

8.1 **Test Requirements**—The following tests shall be conducted to ensure that the zinc coating is being furnished in accordance with this specification. The specifying of tests for adhesion and embrittlement shall be subject to mutual agreement between the galvanizer and purchaser. Visual inspection of the coating shall be made for compliance with the requirements.

8.2 **Thickness of Coating Test**—The thickness of coating is determined by one or more of the three methods described as follows.

8.2.1 **Magnetic Thickness Measurements**—The thickness of

the coating shall be determined by magnetic thickness gage measurements in accordance with Practice E 376 unless the methods described in 8.2.2, 8.2.3, or 8.2.4 are used. For each specimen (as described in 3.2.9) five or more measurements shall be made at points widely dispersed throughout the volume occupied by the specimen so as to represent as much as practical, the entire surface area of the test specimen. The average of the five or more measurements thus made for each specimen is the specimen coating thickness.

8.2.1.1 For articles whose surface area is greater than 160 in.<sup>2</sup> [100 000 mm<sup>2</sup>] (multi-specimen articles as described in 3.2.6), the average of the three specimen coating thickness grades comprising each test article is the average coating thickness for that test article. A specimen must be evaluated for each steel category and material thickness within the requirements for each specimen of the test article.

8.2.1.2 For articles whose surface area is equal to or less than 160 in.<sup>2</sup> [100 000 mm<sup>2</sup>] (single-specimen articles as described in 3.2.8), the average of all specimen coating thickness grades is the average coating thickness for the sample.

8.2.1.3 In the case of threaded components, the thickness of coating shall be made on a portion of the article that does not include any threads.

8.2.1.4 The use of magnetic measurement methods is appropriate for larger articles, and is appropriate for smaller articles when there is sufficient flat surface area for the probe tip to sit flat on the surface using Practice E 376.

8.2.2 **Stripping Method**—The average weight of coating shall be determined by stripping a test article, a specimen removed from a test article, or group of test articles in the case of very small items such as nails, etc., in accordance with Test Method A 90/A 90M unless the methods described in 8.2.1, 8.2.3, or 8.2.4 are used. The weight of coating per unit area thus determined is converted to equivalent coating thickness values in accordance with Table 2 (rounding up or down as appropriate). The thickness of coating thus obtained is the test article coating thickness, or in the case of a specimen removed from a test article, is the specimen average coating thickness.

8.2.2.1 The stripping method is a destructive test and is appropriate for single specimen articles, but is not practical for multi-specimen articles.

8.2.3 **Weighing Before and After Galvanizing**—The average weight of coating shall be determined by weighing articles before and after galvanizing, subtracting the first weight from the second and dividing the result by the surface area unless the methods described in 8.2.1, 8.2.2, or 8.2.4 are used. The first weight shall be determined after pickling and drying and the second after cooling to ambient temperature. The weight of coating per unit area thus determined is converted to equivalent coating thickness values according to Table 2 (rounding up or down as appropriate). The thickness of coating thus obtained is the test article coating thickness.

8.2.3.1 The weighing before and after method is appropriate for single-specimen articles, but is not practical for multi-specimen articles.

**NOTE 11**—Both the stripping method and the weighing before and after method do not take into account the weight of iron reacted from the article

that is incorporated into the coating. Thus, the methods may underestimate coating weight (and therefore the calculated thickness) by up to 10 %. The accuracy of both methods will be influenced by the accuracy to which the surface area of the articles tested can be determined.

**8.2.4 Microscopy**—The thickness of coating shall be determined by cross-sectional and optical measurement in accordance with Test Method B 487 unless the methods described in 8.2.1, 8.2.2, or 8.2.3 are used. The thickness thus determined is a point value. No less than five such measurements shall be made at locations on the test article which are as widely dispersed as practical, so as to be representative of the whole surface of the test article. The average of no less than five such measurements is the specimen coating thickness.

**8.2.4.1** The microscopy method is a destructive test and is appropriate for single-specimen articles, but is not practical for multi-specimen articles.

**8.2.5 Referee Method**—In the event of a dispute over thickness of coating measurements, the dispute shall be resolved as follows:

**8.2.5.1** For multi-specimen articles, a new sample shall be taken randomly from the lot of material, which has twice the number of test articles as the sample which failed to conform to this specification. If the lot size is such that the sample size cannot be doubled, then the sample size shall be as previous, but the number of widely dispersed sites at which measurements were made shall be doubled, and these sites will constitute the new sample. This new sample shall be measured using magnetic thickness gages which have been calibrated for accuracy against reference material thickness standards. If the lot is found to be nonconforming by the new sample, the galvanizer has the right to sort the lot for conforming articles by individual test, to re-galvanize non-conforming articles, or to renovate the nonconforming articles in accordance with 6.2.

**8.2.5.2** For single-specimen articles, a new sample shall be taken randomly from the lot of material, which has twice the number of test articles as the sample which failed to conform to this specification. The test method for the new sample shall be selected by mutual agreement between the purchaser and galvanizer. If the lot is found to be nonconforming by the new sample, the galvanizer has the right to sort the lot for conforming articles by individual test, to re-galvanize non-conforming articles, or to renovate the nonconforming articles in accordance with 6.2.

**8.3 Adhesion**—Determine adhesion of the zinc coating to the surface of the base metal by cutting or prying with the point of a stout knife, applied with considerable pressure in a manner tending to remove a portion of the coating. The adhesion shall be considered inadequate if the coating flakes off in the form of a layer of the coating so as to expose the base metal in advance of the knife point. Do not use testing carried out at edges or corners (points of lowest coating adhesion) to determine adhesion of the coating. Likewise, do not use removal of small particles of the coating by paring or whittling to determine failure.

**8.4 Embrittlement**—Test for embrittlement shall be made in

accordance with Practice A 143. These tests shall not be required unless strong evidence of embrittlement is present.

## **9. Inspection, Rejection, and Retest**

**9.1 Inspection by the Galvanizer**—It is the responsibility of the galvanizer to ensure compliance with this specification. This shall be achieved by an in-plant inspection program designed to maintain the coating thickness, finish, and appearance within the requirements of this specification unless the inspection is performed in accordance with 9.2.

**9.2 Inspection By the Purchaser**—The purchaser shall accept or reject material by inspection either through the galvanizer's inspector, the purchaser's inspector, or an independent inspector. The inspector representing the purchaser shall have access at all times to those areas of the galvanizer's facility which concern the application of the zinc coating to the material ordered while work on the contract of the purchaser is being performed. The galvanizer shall afford the inspector all reasonable facilities to satisfy him that the zinc coating is being furnished in accordance with this specification.

**9.3 Location**—The material shall be inspected at the galvanizer's plant prior to shipment. However, by agreement the purchaser is not prohibited from making tests which govern the acceptance or rejection of the materials in his own laboratory or elsewhere.

**9.4 Reinspection**—When inspection of materials to determine conformity with the visual requirements of 6.2 warrants rejection of a lot, the galvanizer is not prohibited from sorting the lot and submit it once again for acceptance after he has removed any nonconforming articles and replaced them with conforming articles.

**9.5** The sampling plan that was used when the lot was first inspected shall be used for resampling of a sorted lot. By mutual agreement, the galvanizer is not prohibited from submitting the lot remaining after sorting and removing nonconforming articles without replacement of the nonconforming articles. In such case, the now-smaller lot shall be treated as a new lot for purposes of inspection and acceptance.

**9.6** Materials that have been rejected for reasons other than embrittlement are not prohibited from being stripped and regalvanized and again submitted for inspection and test at which time they shall conform to the requirements of this specification.

## **10. Certification**

**10.1** When specified in the purchase order or contract, the purchaser shall be furnished certification that samples representing each lot have been either tested or inspected as directed by this specification and the requirements have been met. When specified in the purchase order or contract, a report of the test results shall be furnished.

## **11. Keywords**

**11.1** coatings—zinc; galvanized coatings; steel products—metallic coated; zinc coatings—steel products



 **A 123/A 123M – 02**

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# Standard Practice for Safeguarding Against Embrittlement of Hot-Dip Galvanized Structural Steel Products and Procedure for Detecting Embrittlement<sup>1</sup>

This standard is issued under the fixed designation A 143/A 143M; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon ( $\epsilon$ ) indicates an editorial change since the last revision or reapproval.

*This standard has been approved for use by agencies of the Department of Defense.*

## 1. Scope

1.1 This practice covers procedures that can be followed to safeguard against the possible embrittlement of steel hot-dip galvanized after fabrication, and outlines test procedures for detecting embrittlement. Conditions of fabrication may induce a susceptibility to embrittlement in certain steels that can be accelerated by galvanizing. Embrittlement is not a common occurrence, however, and this discussion does not imply that galvanizing increases embrittlement where good fabricating and galvanizing procedures are employed. Where history has shown that for specific steels, processes and galvanizing procedures have been satisfactory, this history will serve as an indication that no embrittlement problem is to be expected for those steels, processes, and galvanizing procedures.

1.2 This practice is applicable in either inch-pounds or SI units. Inch-pounds and SI units are not necessarily exact equivalents. Within the text of this practice and where appropriate, SI units are shown in brackets.

1.3 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

## 2. Referenced Documents

### 2.1 ASTM Standards:

F 606 Test Methods for Determining the Mechanical Properties of Externally and Internally Threaded Fasteners,

Washers, and Rivets<sup>2</sup>

## 3. Terminology

### 3.1 Definition:

3.1.1 *embrittlement, n*—the loss or partial loss of ductility in a steel where an embrittled product characteristically fails by fracture without appreciable deformation; types of embrittlement usually encountered in galvanized steel are related to aging phenomena, cold working, and absorption of hydrogen.

## 4. Factors in Embrittlement

4.1 Embrittlement or loss of ductility in steel is often associated with strain-aging. Strain-aging refers to the delayed increase in hardness and strength, and loss of ductility and impact resistance which occur in susceptible steels as a result of the strains induced by cold working. The aging changes proceed slowly at room temperature, but proceed at an accelerated rate as the aging temperature is raised and may occur rapidly at the galvanizing temperature of approximately 850°F [455°C].

4.2 Hydrogen embrittlement may also occur due to the possibility of atomic hydrogen being absorbed by the steel. The susceptibility to hydrogen embrittlement is influenced by the type of steel, its previous heat treatment, and degree of previous cold work. In the case of galvanized steel, the acid pickling reaction prior to galvanizing presents a potential source of hydrogen. However, the heat of the galvanizing bath partially expels hydrogen that may have been absorbed. In practice hydrogen embrittlement of galvanized steel is usually of concern only if the steel exceeds approximately 150 ksi [1100 MPa] in ultimate tensile strength, or if it has been severely cold worked prior to pickling.

4.3 Loss of ductility of cold-worked steels is dependent on many factors including the type of steel (strength level, aging characteristics), thickness of steel, and degree of cold work, and is accentuated by areas of stress concentration such as caused by notches, holes, fillets of small radii, sharp bends, etc.

<sup>1</sup> This practice is under the jurisdiction of ASTM Committee A05 on Metallic Coated Iron and Steel Products and is the direct responsibility of Subcommittee A05.13 on Structural Shapes and Hardware Specifications.

Originally Prepared by Subcommittee A05.10 on Embrittlement Investigation of Committee A05 on Corrosion of Iron and Steel and based on an investigation made by Battelle Memorial Institute under American Society for Testing and Materials' sponsorship. See *Proceedings*, Am. Soc. Testing Mats., Vol 31, Part I, 1931, p. 211; also paper by Samuel Epstein, "Embrittlement of Hot-Dip Galvanized Structural Steel," see *Proceedings*, Am. Soc. Testing Mats., Vol 32, Part II, 1932, p. 293.

Current edition approved April 10, 2003. Published May 2003. Originally approved in 1932. Last previous edition approved in 2001 as A 143 – 01.

<sup>2</sup> *Annual Book of ASTM Standards*, Vol 15.08.

4.4 Low temperatures increase the risk of brittle failure of all plain carbon steels including steel that has been galvanized. The rate at which this temperature loss of ductility occurs varies for different steels. The expected service temperature should thus be taken into account when selecting the steel.

## 5. Steels

5.1 Open-hearth, basic-oxygen, and electric-furnace steels shall be used for galvanizing. Other materials that can be galvanized include continuous cast slabs, steel or iron castings, and wrought iron.

## 6. Cold Working and Thermal Treatment

6.1 For intermediate and heavy shapes, plates, and hardware, cold bend radii should not be less than that which is proven satisfactory by practice or by the recommendations of the steel manufacturer. These criteria generally depend on the direction of grain, strength, and type of steel. A cold bending radius of three times ( $3\times$ ) the section thickness, or as recommended in *AISC Manual of Steel Construction*,<sup>3</sup> will ordinarily ensure satisfactory properties in the final product. Although sharper bending on thin sections can usually be tolerated, embrittlement may occur if cold bending is especially severe. If the design requires sharper bending than discussed herein, the bending should be done hot, or if done cold the material should be subsequently annealed or stress relieved as noted in 6.3.

6.2 Smaller shapes, including thickness up to  $\frac{1}{4}$  in. [6.4 mm] may be cold worked by punching without subsequent annealing or stress-relieving. Shapes  $\frac{5}{16}$  to  $\frac{11}{16}$  in. [8 to 18 mm] in thickness are not seriously affected as to serviceability by cold punching or if the punching is done under good shop practice. The heavier shapes,  $\frac{3}{4}$  in. [19 mm] and over, shall be reamed with at least  $\frac{1}{16}$  in. [1.6 mm] of metal removed from the periphery of the hole after punching, or shall be drilled, or thermally treated prior to galvanizing as noted in 6.3.

6.3 Fabrication in accordance with the principles outlined in 6.1 and 6.2 will normally obviate the need for thermal treatment. However, if required, proper thermal treatment shall precede galvanizing of the steel. For heavy cold deformation exemplified by cold rolling, sheared edges, punched holes, or cold-formed rods and bolts, subcritical annealing at temperatures from 1200 to 1300°F [650 to 705°C] should be employed. For less severe cold deformation typified by cold bending, roll forming, etc., it is advisable to limit the thermal treatment to stress relieving at a maximum of 1100°F [595°C] to avoid excessive grain growth or alternatively to fully normalize the steel at temperatures from 1600 to 1700°F [870 to 925°C]. The time at temperature should be approximately 1 h/in. [24 min/cm] of section thickness.

6.4 Flame cut copes on structural beams shall have a minimum radius of 1 in. [2.5 cm]. After cutting, the cut surface shall be ground to remove notches, grooves, and irregular surface features to leave the surface smooth.

## 7. Preparation for Galvanizing

7.1 Hydrogen can be absorbed during pickling and in some instances, as noted in 4.2, may contribute to embrittlement of the galvanized product. The likelihood of this, or of surface cracking occurring, is increased by excessive pickling temperature, prolonged pickling time, and poor inhibition of the pickling acid. Heating to 300°F [150°C] after pickling and before galvanizing in most cases results in expulsion of hydrogen absorbed during pickling.

7.2 Abrasive blast cleaning followed by flash pickling may also be employed when over-pickling is of concern or when very high strength steel, ultimate tensile strength higher than 150 ksi [1100 MPa], must be galvanized. The abrasive blast cleaning does not generate hydrogen while it is cleaning the surface of the steel. The flash pickling after abrasive blast cleaning is used to remove any final traces of blast media before hot-dip galvanizing.

## 8. Responsibility for Avoiding Embrittlement

8.1 Design of the product and selection of the proper steel for its suitability to be fabricated and to withstand normal galvanizing operations without embrittlement is the responsibility of the designer and fabricator. The galvanizer shall employ proper pickling and galvanizing procedures.

## 9. Testing for Embrittlement of Steel Shapes, Steel Castings, Threaded Articles, and Hardware Items

9.1 Subject to base material and dimensional limitations, the tests given in 9.2, 9.3, 9.4, or 9.5, or a combination thereof, shall apply. If one test specimen should be found embrittled by these tests, two additional specimens should be tested. Failure of either the second or the third specimen shall be cause for rejection of the lot (see Note 1) that the samples represent.

NOTE 1—A lot is a unit of production from which a sample may be taken for testing. Unless otherwise agreed upon by the manufacturer and the purchaser, or established within this practice, the lot shall be as follows: For test at a manufacturer's facility, a lot is one or more articles of the same type and size comprising a single order or a single delivery load, whichever is the smaller, or a smaller number of articles identified as a lot by the manufacturer, when these have been galvanized within a single production shift. For test by purchaser after delivery, the lot consists of the single order or the single delivery load, whichever is the smaller, unless the lot identity, established in accordance with the above, is maintained and clearly indicated in the shipment by the manufacturer.

9.2 A convenient bend test for embrittlement of galvanized steel hardware such as bolts, pole and tower steps, braces, rods, reinforcing bars, etc., consists of bending the article and comparing the degree of bending to that which is obtained on a similar ungalvanized article. The article, before and after galvanizing, may be clamped in a vise and using a lever if necessary, bent until cracking of the base steel occurs, or to 90° whichever is less. In the case of previously bent articles such as reinforcing bars, the test shall be accomplished by reverse bending the previously bent section. The galvanized article should withstand a degree of bending substantially the same as the ungalvanized article. Flaking or spalling of the galvanized coating is not to be construed as an embrittlement failure. For threaded articles, the test shall be made on the unthreaded portion.

<sup>3</sup> Available from American Institute of Steel Construction (AISC), One East Wacker Drive, Suite 3100, Chicago, IL 60601-2001. 9<sup>th</sup> Edition.

9.3 Small steel castings and steel hardware of such shape or size that do not permit bending may be struck a sharp blow with a 2-lb [1-kg] hammer and the results for both galvanized and ungalvanized samples compared. If the article withstands such a blow in the ungalvanized condition, but after galvanizing cracks under the blow, it shall be considered embrittled.

9.4 A test for embrittlement of galvanized steel angles is detailed as follows:

9.4.1 *Test Specimen*—A test specimen with a length determined by the table in 9.4.2.1 and by Fig. 1 shall be cut from the steel angle before galvanizing. A hole shall be made in the test specimen at its midlength, using the same procedure as will be employed in the fabricated material which the specimen represents, whether this be by punching, punching and reaming, or drilling. The dimensional values, diameter, and location of hole shall be not less than those employed in the structural details. Care should be taken not to place the hole near stamped or rolled-in identification marks. The specimen shall then be galvanized. For determining the elongation after fracture, a 2-in. [51-mm] gage length (Fig. 1) shall be prick-punched in the middle of the edge of the vertical leg of the galvanized angle along a line parallel to its length and centered directly under the hole. For specimens under 1/2 in. [13 mm] in thickness, or those in which the distance from the edge of the hole to the edge of the angle is less than 3/8 in. [10 mm], a 1-in. [25-mm] gage length shall be used.

9.4.2 *Procedure*:

9.4.2.1 The test shall be made in a universal testing machine, or by other means such as a press with the load applied slowly, until fracture of the galvanized test specimen occurs. The length of the test specimen and the distance between the supports are shown in the following table:

Leg of Angle, <i>l</i> , in. [mm] (see Fig. 1)	Length Between Supports, <i>L</i> <sub>1</sub> , in. [mm]	Minimum Length, <i>L</i> <sub>2</sub> , in. [mm]
Up to 4 [102], incl	14 [356]	18 [457]
Over 4 to 6 [102 to 152], incl	20 [508]	24 [610]
Over 6 to 8 [152 to 203], incl	30 [762]	36 [914]

9.4.2.2 After the test, the distance along the gage length from each punch mark to the corresponding edge of the fracture shall be measured to 0.01 in. [0.25 mm] with a flexible scale and the percentage of elongation calculated from the sum of these distances.

9.4.2.3 For determining the percentage reduction of thickness after fracture, the reduction shall be measured with a ball-point micrometer at the three locations indicated in Fig. 2: namely *a*, outer side of hole; *b*, inner side of hole; and *c*, middle of leg. The percentage reduction of thickness shall be calculated on the basis of the original thickness of the angle and the average of the three values at *a*, *b*, and *c*.

9.4.2.4 The test shall be made upon galvanized specimens having a temperature not below 60°F [16°C] and not over 90°F [32°C] when tested.

9.4.3 *Requirements*—The elongation measured in accordance with 9.4.2.2 shall be not less than 5 % with the following exception: when the specimen does not show 5 % elongation, the reduction in thickness shall be measured in accordance with 9.4.2.3. The sum of the percentage of elongation plus the average percentage reduction of thickness shall not be less than 10.

9.5 For hot-dip galvanized externally threaded fasteners, an alternate test to Section 9.2 for embrittlement is detailed in Test Method F 606.

10. Keywords

10.1 coatings-zinc; galvanized coatings; steel products-metallic coated; zinc coatings-steel products

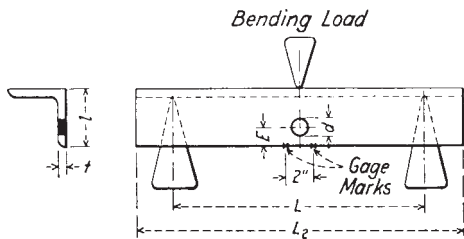


FIG. 1 Specimen for Elongation after Fracture

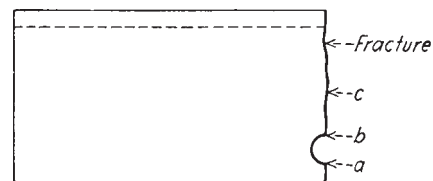


FIG. 2 Measurement of Reduction of Thickness after Fracture

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# Standard Specification for Zinc Coating (Hot-Dip) on Iron and Steel Hardware<sup>1</sup>

This standard is issued under the fixed designation A 153/A 153M; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon ( $\epsilon$ ) indicates an editorial change since the last revision or reapproval.

*This standard has been approved for use by agencies of the Department of Defense.*

## 1. Scope

1.1 This specification covers zinc coatings applied by the hot-dip process on iron and steel hardware.

1.2 This specification is intended to be applicable to hardware items that are centrifuged or otherwise handled to remove excess galvanizing bath metal (free zinc). Coating thickness grade requirements reflect this.

1.3 This specification is applicable to orders in either inch-pound units (as A 153) or in SI units (as A 153M). Inch-pound units and SI units are not necessarily exact equivalents. Within the text of this specification and where appropriate, SI units are shown in brackets. Each system shall be used independently of the other without combining values in any way. In the case of orders in SI units, all testing and inspection shall be done using the metric equivalent of the test or inspection method as appropriate. In the case of orders in SI units, such shall be stated to the galvanizer when the order is placed.

1.4 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

## 2. Referenced Documents

### 2.1 ASTM Standards:

- A 90/A 90M Test Method for Weight of Coating on Zinc-Coated (Galvanized) Iron or Steel Articles<sup>2</sup>
- A 143 Practice for Safeguarding Against Embrittlement of Hot-Dip Galvanized Structural Steel Products and Procedure for Detecting Embrittlement<sup>2</sup>
- A 385 Practice for Providing High-Quality Zinc Coatings (Hot-Dip)<sup>2</sup>
- A 780 Practice for Repair of Damaged and Uncoated Areas of Hot-Dip Galvanized Coatings<sup>2</sup>

A 902 Terminology Relating to Metallic Coated Steel Products<sup>2</sup>

B 6 Specification for Zinc (Slab Zinc)<sup>3</sup>

B 487 Test Method for Measurement of Metal and Oxide Coating Thicknesses by Microscopical Examination of a Cross Section<sup>4</sup>

B 602 Test Method for Attribute Sampling of Metallic and Inorganic Coatings<sup>4</sup>

E 376 Practice for Measuring Coating Thickness by Magnetic-Field or Eddy-Current (Electromagnetic) Test Methods<sup>5</sup>

F 1470 Guide for Fastener Sampling for Specified Mechanical Properties and Performance Inspection<sup>6</sup>

F 1789 Terminology for F16 Mechanical Fasteners<sup>6</sup>

## 3. Terminology

### 3.1 Definitions:

3.1.1 The following terms and definitions are specific to this specification. Terminology A 902 contains other terms and definitions relating to metallic-coated steel products. Terminology F 1789 contains other terms and definitions relating to mechanical fasteners.

### 3.2 Definitions of Terms Specific to This Standard:

3.2.1 *average coating thickness, n*—the average of the specimen coating thickness values for the samples in an inspection lot.

3.2.2 *bare spots, n*—uncoated areas on the surface of the steel part that contain no measurable zinc coating.

3.2.3 *dross inclusions, n*—the iron/zinc intermetallics present in a galvanized coating in a form other than the layer growth of the coating.

3.2.4 *individual measurement, n*—the reading from a magnetic thickness gauge of a single coating spot thickness, or the microscopic reading of a coating thickness as seen in an optical microscope at one spot.

<sup>1</sup> This specification is under the jurisdiction of ASTM Committee A05 on Metallic-Coated Iron and Steel Products and is the direct responsibility of Subcommittee A05.13 on Structural Shapes and Hardware Specifications.

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<sup>2</sup> *Annual Book of ASTM Standards*, Vol 01.06.

<sup>3</sup> *Annual Book of ASTM Standards*, Vol 02.04.

<sup>4</sup> *Annual Book of ASTM Standards*, Vol 02.05.

<sup>5</sup> *Annual Book of ASTM Standards*, Vol 03.03.

<sup>6</sup> *Annual Book of ASTM Standards*, Vol 01.08.

3.2.5 *inspection lot, n*—the quantity of identical parts cleaned, fluxed and galvanized together at one time in an appropriate container that is being submitted for acceptance as a group.

3.2.6 *malleable casting, n*—a steel article that has been subjected to a prolonged anneal to decarburize or graphitize the part to remove as much of the carbon as possible or to convert the carbon to graphite, which permits plastic deformation in compression without rupture.

3.2.7 *sample, n*—a collection of individual units of product from a single inspection lot selected in accordance with Section 6 and intended to represent that inspection lot for acceptance.

3.2.8 *specimen, n*—an individual test article upon which thickness measurements or weight determinations are performed.

3.2.9 *specimen coating thickness, n*—the average thickness from no less than five test measurements on a specimen, when each measurement location is selected to provide the widest dispersion (in all applicable directions) of locations within the specimen volume.

3.2.10 *threaded areas, n*—the sections of a steel part that have threads formed before hot-dip galvanizing.

#### 4. Materials and Manufacture

4.1 *Steel or Iron*—Ferrous articles to be hot-dip zinc coated shall conform to specifications designated by the purchaser.

4.2 *Zinc*—The zinc used for the coating shall conform to Specification B 6 and shall be at least equal to the grade designated as “Prime Western.”

4.2.1 If a zinc alloy is used as the primary feed for the galvanizing bath, then the base material used to make that alloy shall conform to Specification B 6.

4.2.2 The molten metal in the working volume of the galvanizing bath shall contain not less than an average value of 98.0 % zinc by weight [mass].

NOTE 1—The galvanizer may choose to add trace amounts of certain elements (for example, aluminum, nickel, bismuth, or tin) to the zinc bath to help in the processing of certain reactive steels or to enhance the cosmetic appearance of the finished product. The elements can be added

to the galvanizing bath as a master feed alloy, or they can be added to the bath by the galvanizer as individual feeds.

4.3 *Minimum Coating Weight [Mass] or Minimum Coating Thickness*—The minimum coating weight [mass] or the minimum coating thickness shall conform to the requirements prescribed in Table 1 for the material category and thickness of material in which the article belongs.

4.4 *Threaded Articles*—The zinc coating on threads shall not be subjected to a cutting, rolling, or finishing-tool operation, unless specifically authorized by the purchaser. In order to meet overtapping allowances, tapping the threads of nuts or tapped holes after galvanizing is not prohibited.

4.5 *Touch-up and Repair*—Bare spots that are found on parts after galvanizing shall be renovated by use of the methods found in Practice A 780 if the following criteria are met. The bare spots shall have an area totalling not more than 1 % of the surface area to be coated excluding threaded areas of the piece and the bare spots shall not include any threaded areas of the piece. The thickness of the repair shall be equal to the surrounding galvanized coating except for repairs made by paints containing zinc dust in which case the thickness of the repair shall be 50 % greater than the thickness of the galvanized coating required for the class of material, but shall not be greater than 4.0 mils [100 μm]. Repair thickness measurements shall be made in accordance with Practice A 780. The galvanizer shall make repairs unless directed by the purchaser to deliver items unrepaired for subsequent renovation by the purchaser.

#### 5. Workmanship, Finish, and Appearance

5.1 The zinc-coated articles shall be free from uncoated areas, blisters, flux deposits, dross inclusions, and other types of projections that would interfere with the intended use of the articles, or other defects not consistent with good galvanizing practice.

5.2 The zinc coating shall be smooth and reasonably uniform in thickness.

NOTE 2—Smoothness of surface is a relative term. Minor roughness that does not interfere with the intended use of the part, or roughness that

**TABLE 1 Thickness or Weight [Mass] of Zinc Coating for Various Classes of Material**

NOTE 1—Length of the piece, stated in Classes B-1, B-2, and B-3, refers to the finished dimension of the piece after fabrication.

Class of Material	Weight [Mass] of Zinc Coating, oz/ft <sup>2</sup> [g/m <sup>2</sup> ] of Surface, Minimum		Coating Thickness, mils [microns], Minimum	
	Average of Specimens Tested	Any Individual Specimen	Average of Specimens Tested	Any Individual Specimen
<i>Class A</i> —Castings—Malleable Iron, Steel	2.00 [610]	1.80 [550]	3.4 [86]	3.1 [79]
<i>Class B</i> —Rolled, pressed, and forged articles (except those which would be included under Classes C and D):				
B-1— $\frac{3}{16}$ in. [4.76 mm] and over in thickness and over 15 in. [381 mm] in length	2.00 [610]	1.80 [550]	3.4 [86]	3.1 [79]
B-2—under $\frac{3}{16}$ in. [4.76 mm] in thickness and over 15 in. [381 mm] in length	1.50 [458]	1.25 [381]	2.6 [66]	2.1 [53]
B-3—any thickness and 15 in. [381 mm] and under in length	1.30 [397]	1.10 [336]	2.2 [56]	1.9 [48]
<i>Class C</i> —Fasteners over $\frac{3}{8}$ in. [9.52 mm] in diameter and similar articles. Washers $\frac{3}{16}$ in. and $\frac{1}{4}$ in. [4.76 and 6.35 mm] in thickness	1.25 [381]	1.00 [305]	2.1 [53]	1.7 [43]
<i>Class D</i> —Fasteners $\frac{3}{8}$ in. [9.52 mm] and under in diameter, rivets, nails and similar articles. Washers under $\frac{3}{16}$ in. [4.76 mm] in thickness	1.00 [305]	0.85 [259]	1.7 [43]	1.4 [36]

is related to the as-received (ungalvanized) surface condition of the part, shall not be grounds for rejection.

NOTE 3—Since this specification is applicable to items that are centrifuged or otherwise handled to remove excess bath metal (see 1.2), irregular coating distribution is not normally encountered. Drainage problems, which manifest themselves as local excess coating thickness that would interfere with function or as edge tears or spikes that present a safety hazard because of their sharpness, are grounds for rejection under the terms of 5.1.

5.3 Embrittlement is a potential condition of steel that is cold-worked, depending on such factors as the steel type (strength level, aging characteristics), thickness, degree of cold work, and galvanizing process. The galvanizer, the designer and the fabricator shall take precautions against embrittlement. The precautions to fabricate properly and prepare the material for galvanizing to prevent embrittlement are described in Practice A 143.

NOTE 4—Low service temperatures increase the risk of brittle failure of all plain carbon steels including those which have been galvanized. This temperature embrittling effect varies with type of steel. The expected service temperature should thus be taken into account when selecting steels for galvanizing.

5.4 Malleable castings shall be of such composition as will preclude the possibility that they become embrittled by the galvanizing process, or they shall be either cooled from the anneal, or subsequently heat-treated so as to immunize them against embrittlement.

5.5 The zinc coating shall adhere tenaciously to the surface of the base metal.

5.6 If the galvanized material covered by this specification is bent or otherwise fabricated to the degree that causes the zinc coatings to stretch or compress beyond the limit of elasticity, any cracking or flaking of the coating resulting from the bending or fabricating shall not be cause for rejection.

## 6. Sampling

6.1 Test specimens shall be selected at random from each inspection lot.

6.2 The method of selection and sample size shall be agreed upon between the galvanizer and the purchaser. Otherwise, the sample size selected from each lot shall be as follows:

Number of Pieces in Lot	Sample Size
3 or less	all
4 to 500	3
501 to 1200	5
1201 to 3200	8
3201 to 10 000	13
10 001 and over	20

6.3 A specimen that fails to conform to a requirement of this specification shall not be used to determine the conformance to other requirements.

6.4 The method of sampling for fasteners that are required to meet the standards of the Fastener Quality Act is described in Guide F 1470. Sample quantities and definitions of terminology are included in the referenced specification.

## 7. Test Methods

7.1 Tests shall be made to ensure that the zinc coating is being furnished in accordance with this specification and as specified for the following:

7.1.1 Thickness of coating in 4.3.

7.1.2 Finish and appearance in 5.1 and 5.2.

7.1.3 Embrittlement in 5.3 and 5.4.

7.1.4 Adherence in 5.5.

7.2 *Thickness of Coating:*

7.2.1 The average weight of the zinc coating shall be determined by weighing specimens after pickling and drying and again after galvanizing unless the method described in 7.2.2 or 7.2.3 is used.

NOTE 5—This method does not take into account the weight of iron reacted from the article that is incorporated into the coating. It will thus underestimate coating weight by up to approximately 10 %. Base metal reactivity will affect the extent of underestimation.

7.2.2 In the case of materials inspected after galvanizing, the weight of coating shall be determined by stripping one or more specimens in accordance with Test Method A 90/A 90M, or the average thickness of coating shall be determined with the use of a magnetic thickness gage in conformity with Practice E 376, unless the method described in 7.2.1 or 7.2.3 is used.

7.2.2.1 In the case of fasteners such as bolts, nuts, and screws, the determination of the thickness of coating shall be made on a portion of the article that does not include any threads.

7.2.3 The thickness of coating shall be determined by cross section and optical measurement, unless the method described in 7.2.1 or 7.2.2 is used. The thickness thus determined is a point value. No less than five such measurements shall be made at locations on the test article, which are as widely dispersed as practical, so as to be representative of the whole surface of the test article. The average of no less than five such measurements is the specimen coating thickness.

7.3 *Embrittlement*—Hardware that is susceptible to embrittlement shall be tested in accordance with Practice A 143. The tests shall be performed through agreement between the galvanizer and the purchaser.

7.4 *Adherence*—Determine adherence of the zinc coating to the surface of the base metal by cutting or prying with the point of a stout knife, applied with considerable pressure in a manner tending to remove a portion of the coating. The adherence shall be considered inadequate if the coating flakes off in the form of a layer of skin so as to expose the base metal in advance of the knife point. Do not use testing carried out at edges or corners (points of lowest coating adherence) to determine adherence of coating. Likewise, do not use removal of small particles of the coating by paring or whittling to determine failure.

## 8. Inspection

8.1 The inspector representing the purchaser shall have access at all times while work on the contract of the purchaser is being performed, to those areas of the manufacturer's work which concern the application of the zinc coating to the material ordered. The manufacturer shall afford the inspector all reasonable facilities to satisfy him that the zinc coating is being furnished in accordance with this specification. All inspection and tests shall be made at the place of manufacture prior to shipments, unless otherwise specified, and shall be so conducted as not to interfere unnecessarily with the operation of the works.

## 9. Rejection and Retest

9.1 For all galvanized articles except those fasteners that must meet the requirements of the Fastener Quality Act, the following sections are used to determine rejection and retesting.

9.2 When partial inspection of materials to determine conformity with visual requirements of Section 5 warrants rejection of a lot, the galvanizer is not prohibited from sorting the lot and submitting it once again for inspection.

9.3 The number of specimens in a sample of a lot permitted to fail to conformance tests shall be agreed upon between the galvanizer and the purchaser.

9.4 If a set of test specimens fails to conform to the requirements of this specification, two additional sets shall be tested, both of which shall conform to the requirements in every respect, or the lot of material represented by the specimens shall be rejected.

9.5 Materials that have been rejected for reasons other than embrittlement are not prohibited from being stripped, regalvanized, and resubmitted for test and inspection. They shall then conform to the requirements of this specification.

## 10. Packaging

10.1 The supplier shall employ such methods of packaging zinc-coated articles as shall be required to ensure their receipt by the purchaser in satisfactory condition, with the use to be made of the article being taken into consideration.

## 11. Certification

11.1 When specified in the purchase order or contract, the purchaser shall be furnished certification that samples representing each inspection lot have been either tested or inspected as directed by this specification and the requirements have been met. When specified in the purchase order or contract, a report of the test results shall be furnished.

## 12. Keywords

12.1 coatings, zinc; galvanized coatings; steel hardware, zinc coated; steel products, metallic coated; zinc coatings, steel products

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## Standard Practice for Locating the Thinnest Spot in a Zinc (Galvanized) Coating on Iron or Steel Articles<sup>1, 2</sup>

This standard is issued under the fixed designation A 239; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon ( $\epsilon$ ) indicates an editorial change since the last revision or reapproval.

*This standard has been approved for use by agencies of the Department of Defense.*

### 1. Scope

1.1 This practice covers the procedure for locating, by the use of a solution of copper sulfate, the thinnest spot in a zinc coating (hot dipped, electroplated, or sprayed) on iron or steel articles that are coated after the shape is produced by casting, drawing, pressing, or other forming methods. Examples are: electrical metallic tubing and rigid conduit pipe, castings and forgings, and structural steel; on special hardware, such as poleline, builder's, and farm implement hardware; bolts, nuts, screws, and other miscellaneous general hardware.

1.2 The use of this practice with zinc coating deposited through different processes (such as hot dipped, electroplated, or sprayed) requires caution in interpretation since the end point may vary considerably between different zinc-coating systems.

1.3 Excluded from this practice is sheet steel from hot-dip or electrocoating lines as the sheet products are normally subject to additional forming after the coating process. Also excluded from this practice are all zinc-coated wire and wire products either continuously or batch coated before or after forming.

NOTE 1—**Caution:** Past research (dating from around 1963) has indicated that this practice can be influenced by operator technique. Variations can be due to the difference in hand pressure used to wipe the sample or the inability of the operator to recognize the end point.

1.4 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

<sup>1</sup> This practice is under the jurisdiction of ASTM Committee A05 on Metallic Coated Iron and Steel Products and is the direct responsibility of Subcommittee A05.07 on Methods of Testing.

Current edition approved Oct. 10, 1995. Published December 1995. Originally published as A 239 – 40 T. Last previous edition A 239 – 89.

<sup>2</sup> This practice is used to locate the thinnest spot only, and is not intended as a test for coating weight. This practice is to be used only within the limits of Section 1, Scope.

### 2. Significance and Use

2.1 This practice is designed to locate the thinnest portions of the zinc coating on newly coated items (see Appendix X1). Variations in coating thickness can be due to the process by which the zinc is applied (hot dipped, electroplated, or sprayed) or by the geometry of the part that is coated. During hot-dip galvanizing, the coating thickness is affected by the drainage pattern of the molten zinc, while during zinc spraying (metalizing), coating thickness can be dependent on the operator's manipulation of the spray nozzle. The geometry of the part can also influence coating thickness especially during hot-dip galvanizing, where peaks and valleys on the part can cause molten zinc to build up or thin out. This practice is designed to identify those areas of the part where the coating is thin.

### 3. Copper Sulfate Solution

3.1 The copper sulfate solution shall be made by dissolving approximately 36 parts by weight of commercial cupric sulfate crystals ( $\text{CuSO}_4 \cdot 5\text{H}_2\text{O}$ ) in 100 parts by weight of distilled water (see 3.1.1). Heat may be used to complete the solution of cupric sulfate crystals. If heated, the solution shall be allowed to cool. The solution shall then be agitated with an excess of powdered cupric hydroxide ( $\text{Cu}(\text{OH})_2$ ), about 0.13 oz/gal (1.0 g/L) of solution. The presence of an excess of cupric hydroxide will be shown by the sediment of this reagent at the bottom of the vessel. The neutralized solution shall be allowed to stand for 24 h and then filtered or decanted.

3.1.1 Cupric oxide ( $\text{CuO}$ ), 0.11 oz/gal (0.8 g/L) may be substituted for cupric hydroxide, provided the solution is allowed to stand not less than 48 h after this addition before decanting or filtering.

3.2 The solution shall have a specific gravity of 1.186 at 18°C (65°F). To adjust a solution of improper specific gravity, add distilled water when the specific gravity is high, and add a copper sulfate solution of a higher specific gravity when the solution is low in specific gravity.

#### 4. Specimen Rinse Water

4.1 Ordinary, clean tap water may be used for rinsing specimens. If no running tap water is available, the rinse water shall be changed after each dip. The temperature of the rinse water shall be from 15 to 21°C (60 to 70°F).

#### 5. Quantity of Copper Sulfate Solution

5.1 *Hardware and Similar Articles*— For evaluating hardware and similar articles, the quantity of copper sulfate solution required for each evaluation will depend on the superficial area of the specimen being evaluated and the weight of coating. The quantity should not be less than 1.2 qt/oz/ft<sup>2</sup> (40.5 mL/g/m<sup>2</sup>) of zinc coating on the specimen (Note 2) and shall be sufficient to cover the specimen so that the top surface of the solution is at least ½ in. (12.7 mm) above the top of the section of the specimen under evaluation. The solution shall be discarded after completion of the evaluation, and fresh solution shall be used for any additional evaluations.

NOTE 2—The theoretical minimum amount of copper sulfate solution required to dissolve zinc is 0.4 qt/oz (13.5 mL/g). The quantity specified in 5.1 is three times this minimum to ensure adequate rate of solution.

#### 6. Preparation of Specimens

6.1 The specimens selected for evaluation shall be free of abrasion or cuts in the zinc coating, except those which may occur during manufacture of the specimen. Where the area of uncoated surface to be immersed is more than 10 % of the total immersed surface area, precautions, such as plugs for tubular material, or lacquer, paraffin, or other suitable coatings for the uncoated surfaces must be taken so as not to deplete the strength of copper sulfate solution.

6.2 Clean the specimens with a suitable volatile organic solvent and finally, thoroughly wash with clean water and wipe dry with a clean cotton cloth. Unless otherwise specified, remove lacquer or varnish coatings with a suitable clean, volatile organic solvent such as acetone, which will not attack the zinc coating or leave a greasy or waxy deposit. Thoroughly rinse the specimens in clean water and wipe dry with a clean cotton cloth. Bring the specimens to a temperature between 15 and 21°C (60 and 70°F) prior to the beginning of the immersion series.

6.3 Abnormal cases may arise when, by reason of unusual surface conditions, the copper sulfate solution will not act normally on the zinc coating. For example, the solution may have no apparent attack on all or part of the surface, or false deposits of copper may appear on the zinc coating. If there is any question of abnormality of performance of specimens, discard the specimens and select new ones. Clean the new specimens in alcohol, rinse, and wipe dry. Then immerse for 3 min in a solution consisting of 1 part by volume of ammonium hydroxide (sp gr 0.90) and 9 parts of water. The specimens may be scrubbed with a cotton cloth during this immersion. After cleaning, wash the specimens and wipe dry, then subject them to the procedure described in Section 7.

#### 7. Procedure

7.1 Immerse the specimens in the copper sulfate solution, which shall be maintained at a temperature of 16 to 20°C (61

to 68°F). Allow the specimens to remain in a fixed position in the solution for exactly 1 min. Do not agitate the solution during the immersion period, nor allow the specimens to touch each other or the sides of the container. After each 1-min immersion, wash the specimens immediately in the rinse water, and use a fiber bristle brush to remove any copper deposit that may have formed on the zinc coating. Before returning the specimens to the copper sulfate solution, drain thoroughly of excess rinse water and wipe dry with a clean cloth.

7.2 Continue successive immersions of 1 min each, washing and wiping the specimens after each immersion until the end point has been reached (see Appendix X2).

NOTE 3—Zinc coatings on threads are usually difficult to test. It has been found advantageous to saw female-threaded parts longitudinally, exposing the threads to full view and facilitating cleaning to remove sponge copper after each immersion in the copper sulfate solution. Brushing should be parallel to the threads.

#### 8. End Point

8.1 The end point shall be recognized by the appearance of bright, adherent copper deposits. However, if such a deposit fails to form after the complete disappearance of the zinc coating, the immersion succeeding the disappearance of the zinc shall be recognized as representing the end point.

8.2 Confirm adherence of the bright copper deposit by a peeling test. If it is possible to remove the copper with an ink eraser or to peel the copper with the edge of a blunt tool such as the back of a knife blade, and zinc appears underneath the copper, such an appearance of deposited copper shall not be construed as an end point.

8.3 A fine line appearance of copper on the top of screw threads or on sharp edges of articles, or within 1 in. (25 mm) of a cut portion of a specimen, shall not be judged as an end point. Likewise, the indication of bright adherent deposits of copper at or adjacent to any cut or abrasion present on the original specimen shall not be considered an end point.

#### 9. Supplementary Tests

9.1 If at any time during the immersion procedure there is any doubt as to the presence of exposed base metal, as determined by visual inspection, there are several supplementary tests described in Section 10, one or more of which may be used depending on the type of coating being evaluated.

#### 10. Supplementary Test for All Types of Zinc Coatings

10.1 *Microscopical Test*—Section the specimen through the copper deposit, mount, and polish it for metallographic analysis. Etch the polished surface using an etching solution composed of 20 g of chromic acid, 1.5 g of sodium sulfate, and 100 mL of distilled water (Palmerton reagent). After etching, wash the specimen with alcohol. Examine the etched specimen under a microscope, using a magnification of 100 diameters or greater if necessary.

10.2 *Qualitative Test for Zinc*<sup>3</sup>—Apply a drop (or several drops) of diluted hydrochloric acid to the area in question

<sup>3</sup> Only an outline of the test is given. The details of the test may be found in technical literature.

(depending on its size). The presence of zinc is indicated by immediate vigorous effervescence (evolution of hydrogen). If no appreciable zinc is present, the effervescence will be mild. By carefully removing the acid, a confirming test for zinc may be made as follows: neutralize the acid with ammonium hydroxide, acidify with acetic acid, and pass hydrogen sulfide

into the solution; a white precipitate (zinc sulfide, ZnS) confirms the presence of zinc.

## 11. Keywords

11.1 bolts; electroplated; hardware; hot dipped; nuts; screws; thinnest spot; zinc coating thickness

## APPENDIXES

### (Nonmandatory Information)

#### X1. APPLICATION OF THIS PRACTICE TO WEATHERED GALVANIZED WARE

X1.1 This practice is not applicable to aged or weathered material because of the corrosion film present on the zinc coating. If it is desired to use this practice on such material, the corrosion film should be removed before conducting this procedure by immersing the specimens for 3 min in an

ammonium hydroxide solution (1 part by volume of ammonium hydroxide (sp gr 0.90) to 9 parts by volume of distilled water) then rinsing the specimens in clean water and wiping them dry.

#### X2. STANDARD FOR COMPARISON

X2.1 If it is desired to show the character of the bright metallic copper deposit on an exposed iron or steel surface, a reference standard for comparison may be prepared as follows: Partially submerge a zinc-coated specimen in strong hydrochloric acid until violent action ceases. Immediately remove the specimen, wash, and wipe it dry. The specimen with an area

of bare surface thus exposed, including a portion with zinc coating intact, is then dipped for a few seconds in the copper sulfate solution at a temperature of 16 to 20°C (61 to 68°F), removed, washed, and wiped dry. This copper-coated reference standard should be prepared at the time this practice is being conducted.

#### X3. ACTION OF COPPER SULFATE SOLUTION ON ZINC COATINGS

X3.1 The fact that this practice cannot be used for determining the weight of zinc coating is due to the wide variation in the rate of solubility of the various types of coating resulting from differences in the composition and structure of the coatings. For instance, electroplated and sprayed-zinc coatings consist essentially of pure zinc; the outer part of hot-dipped coatings consists of nearly pure zinc; whereas, the portion next to the steel base is composed of zinc-iron alloys; in the case of hot-dipped coatings heated after galvanizing, the coating consists almost entirely of zinc-iron alloys.

coatings applied by the different processes, it has been found by Groesbeck and Walkup<sup>4</sup> in tests on a limited number of samples that electroplated and flame-sprayed coatings, by reason of their high pure-zinc content, dissolve rather rapidly in the copper sulfate solution; that the conventional hot-dip coatings dissolve only about two thirds as fast as the pure zinc coatings; and that the hot-dip coatings heated after galvanizing dissolve only about half as fast as the pure zinc coatings.

X3.2 In view of these differences in the makeup of the zinc


<sup>4</sup> For further information on this test method, reference may be made to the following papers:

Walkup, H. H., and Groesbeck, E. C., "Some Factors Affecting the Preece Test for Zinc Coatings," *Proceedings*, ASTM, Vol 32, Part II, 1932, p. 453.

Groesbeck, E. C., and Walkup, H. H., "Preece Test (Copper Sulphate Dip) for Zinc Coatings," *National Institute of Standards and Technology Journal of Research*, Vol 12, No. 6, June 1934, p. 785 (Research Paper RP688).

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# Standard Specification for Steel Sheet, Terne (Lead-Tin Alloy) Coated by the Hot-Dip Process<sup>1</sup>

This standard is issued under the fixed designation A 308/A 308M; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon ( $\epsilon$ ) indicates an editorial change since the last revision or reapproval.

*This standard has been approved for use by agencies of the Department of Defense.*

## 1. Scope\*

1.1 This specification covers sheet steel in coils and cut lengths coated with lead-tin alloy (terne metal, see 3.2.3) by the hot-dip process. This material is commonly known as terne and is used where ease of solderability and a degree of corrosion resistance are desirable. It is especially suitable where resistance to gasoline is required. Terne-coated sheet is also used for stamping, where the coating acts as a lubricant in the die, lessening difficulties in drawing. The weight of coating, always expressed as total coating on both sides, shall be specified in accordance with Table 1.

1.2 Material furnished under this specification shall conform to the applicable requirements of the latest issue of Specification A 924/A 924M, unless otherwise provided herein.

1.3 Terne-coated steel is available in a number of designations, types, and grades.

1.4 This specification is applicable to orders in either inch-pound units (as A 308) or SI units (as A 308M). Values in inch-pound and SI units are not necessarily equivalent. Within the text, SI units are shown in brackets. Each system shall be used independently of the other.

1.5 Unless the order specifies the “M” designation (SI units), the product shall be furnished to inch-pound units.

1.6 The text of this specification references notes and footnotes that provide explanatory material. These notes and footnotes, excluding those in tables and figures, shall not be considered as requirements of this specification.

1.7 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

## 2. Referenced Documents

### 2.1 ASTM Standards:<sup>2</sup>

A 309 Test Method for Weight and Composition of Coating on Terne Sheet by the Triple Spot Test

A 902 Terminology Relating to Metallic Coated Steel Products

A 924/A 924M Specification for General Requirements for Steel Sheet, Metallic Coated by the Hot Dip Process

E 517 Test Method for Plastic Strain Ratio  $R$  for Sheet Metal

E 646 Test Method for Tensile Strain-Hardening Exponents ( $n$  Values) of Metallic Sheet Materials

## 3. Terminology

3.1 *Definitions*—For definitions of terms and abbreviations used in this specification, see Terminology A 902.

### 3.2 Definitions of Terms Specific to This Standard:

3.2.1 *electrolytic nickel plate, n*—a nickel coating predeposited on steel sheet; used to promote a more uniform and more corrosion-resistant hot-dipped, long terne coating.

3.2.2 *terne-coated sheet, n*—steel sheet coated by immersion in molten terne metal; the steel sheet prior to immersion in the terne metal is either bare (uncoated) or with a predeposited electrolytic nickel coating.

3.2.3 *terne metal, n*—an alloy of lead with a small percentage of tin sufficient to obtain a smooth continuous coating.

3.2.3.1 *Discussion*—The minimum tin content is normally 8 %, with higher percentages used depending on the type of coating equipment used.

## 4. Classification

4.1 The material is available in four designations, as follows:

4.1.1 Commercial steel (CS Types A, B, and C),

<sup>1</sup> This specification is under the jurisdiction of ASTM Committee A05 on Metallic-Coated Iron and Steel Products and is the direct responsibility of Subcommittee A05.11 on Sheet Specifications.

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<sup>2</sup> For referenced ASTM standards, visit the ASTM website, [www.astm.org](http://www.astm.org), or contact ASTM Customer Service at [service@astm.org](mailto:service@astm.org). For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

\*A Summary of Changes section appears at the end of this standard.

**TABLE 1 Weight [Mass] of Coating (Total Both Sides)<sup>A,B</sup>**

NOTE 1—*Coating Thickness/Weight [Mass] Equivalence*—The coating thickness may be estimated from the coating weight [mass] by using the following relationship: 0.25 oz/ft<sup>2</sup> [75 g/m<sup>2</sup>] total both sides (LT25 [LTZ75]) is equal to 0.00027 in. or 0.27 mils [0.00508 mm] total both sides. This formula is not to be used for calculation of tensile strength of the base metal, which must be based on actual base metal thickness measurement.

Coating Designation	Minimum Requirements	
	Triple-Spot Test	Single-Spot Test
	Inch-Pound Units	
	oz/ft <sup>2</sup>	oz/ft <sup>2</sup>
LT01	no minimum <sup>C</sup>	no minimum <sup>C</sup>
LT25	0.25	0.20
LT35	0.35	0.25
LT40	0.40	0.30
LT55	0.55	0.40
LT85	0.85	0.70
LT110	1.10	0.90
SI Units		
	g/m <sup>2</sup>	g/m <sup>2</sup>
LTZ01	no minimum <sup>C</sup>	no minimum <sup>C</sup>
LTZ75	75	60
LTZ110	110	75
LTZ120	120	90
LTZ170	170	120
LTZ260	260	215
LTZ335	335	275

<sup>A</sup> The coating designation number is the term by which this material is specified. The weight [mass] of coating in ounces per square foot [grams per square metre] of sheet refers to the total coating on both surfaces. Because of the many variables and changing conditions that are characteristic of continuous terne coating, the terne coating is not always evenly divided between the two surfaces of the terne-coated sheet, nor is the terne coating always evenly distributed from edge to edge. However, it can normally be expected that not less than 40 % of the single-spot check limit will be found on either surface.

<sup>B</sup> As the performance for the long terne-coated sheet is related to the coating thickness, material carrying the statement “meets ASTM A 308 [A 308M] requirements” should also specify the particular coating designation.

<sup>C</sup> “No minimum” means that there are no established minimum requirements for triple- and single-spot tests.

4.1.2 Deep drawing steel (DDS),

4.1.3 Extra deep drawing steel (EDDS), and

4.1.4 Structural steel (SS).

4.2 Structural steel is available in several grades.

4.3 The material is available with several coating weights [masses] (coating designations) as shown in Table 1.

## 5. Ordering Information

5.1 Terne-coated sheet in coils or cut lengths is produced to thickness requirements expressed to 0.001 in. [0.01 mm]. The thickness of the sheet includes both the base metal and the coating.

5.2 Orders for material under this specification shall include the following information, as necessary, to describe adequately the required material:

5.2.1 Name of material (long terne-coated steel sheet),

5.2.2 Designations of sheet steel (CS (Types A, B, and C) DDS, EDDS, and SS including grade or SS),

5.2.2.1 When a CS type is not specified, Type B will be furnished.

5.2.3 ASTM designation number and year of issue,

5.2.4 Coating designation (see 8.1.1 and Table 1),

5.2.5 Nickel plating; specify with or without (if unspecified, the sheet steel would usually be supplied without nickel plating),

5.2.6 Specify whether oiled or not oiled,

5.2.7 Dimensions (show thickness, minimum or nominal width, and length, if cut length). The purchaser shall specify the appropriate table of thickness tolerances in Specification A 924/A 924M that applies to the order, that is, the table of thickness tolerances for 3/8-in. [10-mm] edge distance, or the table of thickness tolerances for 1-in. [25-mm] edge distance.

5.2.8 Coil size requirements (specify maximum outside diameter (OD), acceptable inside diameter (ID), and maximum weight),

5.2.9 Certification, if required, and heat analysis and mechanical property report,

5.2.10 Application (part identification and description), and

5.2.11 Special requirements (if any).

NOTE 1—Typical ordering descriptions are as follows: terne-coated sheet, Deep Drawing Steel (DDS), ASTM A 308 – \_\_\_\_; coating designation LT25, oiled 0.024 in. minimum by 32 in. by coil, 24 in. ID, 15 000-lb max for fuel tank—upper half, or terne-coated sheet, Deep Drawing Steel (DDS), ASTM A 308M—coating designation LTZ75, oiled, 0.60 mm minimum by 810-mm by coil, 600-mm ID, 7000-kg max for fuel tank upper half.

## 6. Chemical Composition, Base Metal

6.1 The heat analysis of the base metal furnished under this specification shall conform to the requirements shown in Table 2.

6.1.1 Include in the report of the heat analysis, each of the elements in Table 2. When the amount of copper, nickel, chromium, or molybdenum is less than 0.02 %, report the analysis as <0.02 % or the actual determined value. When the amount of vanadium, titanium, or columbium is less than 0.008 %, report the analysis as <0.008 % or the actual determined value.

## 7. Mechanical Properties

7.1 Structural steel sheet shall conform to the mechanical property requirements in Table 3 for the type, grade, or class specified, or combination thereof.

7.2 The typical mechanical properties for CS (Types A, B, and C), DDS, and EDDS sheet designations are listed in Table 4. These mechanical properties are nonmandatory. They are intended solely to provide the purchaser with as much information as possible to make an informed decision on the steel to be specified. Values outside of these ranges are to be expected.

7.3 When base metal mechanical properties are required, all tests shall be conducted in accordance with the methods specified in Specification A 924/A 924M.

7.4 *Bending Properties:*

7.4.1 *Minimum Cold-Bending Radii*—Structural steel sheet is commonly fabricated by cold bending. There are many interrelated factors that affect the ability of a steel to cold form over a given radius under shop conditions. These factors

**TABLE 2 Chemical Requirements<sup>A</sup>**

Designation	Composition, %—Heat Analysis													
	Element, max (unless otherwise shown)													
	C	Mn	P	S	Al	Cu	Ni	Cr	Mo	V	Cb	Ti <sup>B</sup>	N	
CS Type A <sup>C,D,E</sup>	0.10	0.60	0.030	0.035	...	0.20	0.20	0.15	0.06	0.008	0.008	0.025	...	
CS Type B <sup>F,C</sup>	0.02–0.15	0.60	0.030	0.035	...	0.20	0.20	0.15	0.06	0.008	0.008	0.025	...	
CS Type C <sup>C,D,E</sup>	0.08	0.60	0.10	0.035	...	0.20	0.20	0.15	0.06	0.008	0.008	0.025	...	
DDS <sup>D,E</sup>	0.06	0.50	0.020	0.030	0.01, min	0.20	0.20	0.15	0.06	0.008	0.008	0.025	...	
EDDS <sup>G</sup>	0.02	0.40	0.020	0.025	0.01, min	0.20	0.20	0.15	0.06	0.10	0.10	0.15	...	
SS:														
Grades 25, 30, 33 (Type 1) and 80	0.20	0.60	0.04	0.04	...	0.20	0.20	0.15	0.06	0.008	0.008	0.025	...	
Grade 40 (Type 1)	0.20	0.90	0.04	0.04	...	0.20	0.20	0.15	0.06	0.008	0.008	0.025	...	
Grades 33 (Type 2) and 40 (Type 2)	0.15	0.60	0.20	0.04	...	0.20	0.20	0.15	0.06	0.008	0.008	0.025	...	

<sup>A</sup> Where an ellipsis ( . . . ) appears in the table, there is no requirement, but the analysis shall be reported.

<sup>B</sup> For steels containing more than 0.02 % carbon, titanium is permitted to 0.025 % provided the ratio of % titanium to % nitrogen does not exceed 3.4.

<sup>C</sup> When a deoxidized steel is required for the application, the purchaser has the option to order CS and SS to a minimum of 0.01 % total aluminum.

<sup>D</sup> Steel is permitted to be furnished as a vacuum degassed or chemically stabilized steel, or both, at the producer's option.

<sup>E</sup> For carbon levels less than or equal to 0.02 %, vanadium, columbium, or titanium, or combinations thereof, are permitted to be used as stabilizing elements at the producer's option. In such cases, the applicable limit for vanadium and columbium shall be 0.10 % max. and the limit for titanium shall be 0.15 % max.

<sup>F</sup> For CS, specify Type B to avoid carbon levels below 0.02 %.

<sup>G</sup> Shall be furnished as a stabilized steel.

**TABLE 3 Mechanical Requirements, Base Metal<sup>A</sup>**

Inch-Pound Units			
Structural Steel (SS) Grade	Yield Strength, min, ksi	Tensile Strength, min, ksi	Elongation in 2 in., min %
25	25	42	26
30	30	45	24
33 (Types 1 and 2)	33	48	22
40 (Types 1 and 2)	40	52	20
80 <sup>B</sup>	80	82	...
SI Units			
	Yield Strength, min, MPa	Tensile Strength, min, MPa	Elongation in 50 mm, min %
	170	290	26
	205	310	24
230 (Types 1 and 2)	230	330	22
275 (Types 1 and 2)	275	360	20
550	550	565	...

<sup>A</sup> Longitudinal sample direction (for example, test sample taken in the direction of rolling).

<sup>B</sup> On the full-hard product, the yield point approaches the tensile strength and since there is no halt in the gage or drop in the beam, the yield point shall be taken as the yield stress at 0.5 % extension under load. If hardness result is 85 Hardness Rockwell B (HRB) or higher, no tension test is required.

include: thickness, strength level, degree of restraint, relationship to rolling direction, chemistry, and base metal microstructure. Table 5 lists the suggested minimum inside radius for 90° cold bending for structural steel. They presuppose “hard way” bending (bend axis parallel to rolling direction) and reasonably good shop forming practices. Where possible, the use of larger radii or “easy way” bends are recommended for improved performance.

## 8. Coating Properties

### 8.1 Coating Weight [Mass]:

8.1.1 Coating weight [mass] shall conform to the requirements as shown in Table 1 for the specific coating designation.

### 8.2 Coating Weight [Mass] Tests:

**TABLE 4 Typical Ranges of Mechanical Properties (Nonmandatory) (Longitudinal Direction)<sup>A,B</sup>**

Designation	Yield Strength	Elongation	$r_m$	$n$
	ksi [MPa]	in 2 in. [50 mm], %	Value <sup>C</sup>	Value <sup>D</sup>
CS Type A	20/40 [140/275]	≥30	<i>E</i>	<i>E</i>
CS Type B	24/42 [165/290]	≥28	<i>E</i>	<i>E</i>
CS Type C	20/40 [140/275]	≥30	<i>E</i>	<i>E</i>
DDS <sup>F</sup>	22/35 [150/240]	≥36	1.3/1.7	0.17/0.22
EDDS <sup>G</sup>	15/25 [105/170]	≥40	1.7/2.1	0.23/0.27

<sup>A</sup> The typical mechanical property values presented here are nonmandatory. They are intended solely to provide the purchaser with as much information as possible to make an informed decision on the steel to be specified.

<sup>B</sup> These typical mechanical properties apply to the full range of steel sheet thicknesses. The yield strength tends to increase and some of the formability values tend to decrease as the steel sheet thickness decreases.

<sup>C</sup>  $r_m$  Value—Average plastic strain rates as determined by Test Method E 517.

<sup>D</sup>  $n$  Value—Strain hardening exponent as determined by Test Method E 646.

<sup>E</sup> No typical mechanical properties have been established.

<sup>F</sup> The DDS designation encompasses the previous drawing quality, special killed product.

<sup>G</sup> Furnish EDDS as a stabilized steel. It will be free from changes in mechanical properties over time, that is, nonaging.

**TABLE 5 Coating Bend Test Requirements**

Designation	Grade	Ratio of the Inside Bend Diameter to Thickness of the Specimen (Any Direction)
Structural steel	25 [170]	1/2 <i>t</i>
Structural steel	30 [205]	1 <i>t</i>
Structural steel	33 [230] (Types 1 and 2)	1 1/2 <i>t</i>
Structural steel	40 [275] (Types 1 and 2)	2 <i>t</i>
Structural steel	80 [550]	not applicable

8.2.1 Coating weight [mass] tests shall be performed in accordance with the requirements stated in Specification A 924/ A 924M.

8.2.2 The referee method to be used shall be Test Method A 309.

### 8.3 Coating Bend Test:

8.3.1 For all designations other than structural steel, the coated sheet shall be capable of being bent through 180° flat on itself in any direction without flaking of the coating on the outside of the bend only. Flaking of the coating within ¼ in. [6 mm] of the edge of the bend specimen shall not be a cause for rejection.

8.3.1.1 For structural steel, the bend test inside diameter shall have a relation to the thickness of the specimen as shown in Table 5.

## 9. Dimensions and Permissible Variations

9.1 All dimensions and permissible variations shall comply with the requirements of Specification A 924/A 924M.

## 10. Keywords

10.1 lead-tin coating; steel sheet; terne; terne coating

# APPENDIX

## (Nonmandatory Information)

### X1. RATIONALE FOR CHANGES IN PRODUCT DESIGNATIONS

X1.1 Subcommittee A05.11 has revised the designations used to classify the various products available in each hot-dip coated specification. The previous “quality” designations have been replaced with designations and descriptions more closely related with product characteristics. Many of the former “quality” specifications described the steel only in terms of limited chemical composition, which in some cases was identical for two or more qualities. The former designations also did not reflect the availability of new steels which are the result of the use of new technologies such as vacuum degassing and steel ladle treatments.

X1.1.1 The former “quality” designators, defined in very broad qualitative terms, did not provide the user with all the information needed to select the appropriate steel for an application. The new designations are defined with technical information such as specific chemical composition limits and typical nonmandatory mechanical properties. These steel characteristics are important to users concerned with the weldability and formability of the coated steel products. The typical mechanical properties included in the new designation system are those indicated by the tension test. These properties are more predictive of steel formability than other tests such as the

hardness test which may not compensate adequately for product variables such as substrate thickness and coating weight.

X1.1.2 The new designations also provide the user with the flexibility to restrict the steels applied on any order. For example, a user can restrict the application of ultra low carbon steels on an application through the selection of an appropriate “type” designator.

X1.1.3 There is a limited relationship between the former and current systems of designation. Some of the reasons for this limited relationship are: addition of steels not previously described in ASTM specifications, restrictions placed on ranges of chemical composition, the addition of typical mechanical properties, and the enhanced capability of steel producers to combine chemical composition and processing methods to achieve properties tailored to specific applications.

X1.1.4 The changes in designation are significant which may create transition issues that will have to be resolved. Continued dialogue between users and producers will have to be maintained to assist with the transition to the new system of designations. A user with concerns about the appropriate coated steel to order for a specific application should consult with a steel supplier or producer.

## SUMMARY OF CHANGES

Committee A05 has identified the location of selected changes to this standard since the last issue (A 308 – 02) that may impact the use of this standard.

*A 308/A 308M - 03:*

(1) Converted specification from an English inch-pound standard to a Dual, English/metric standard.

(2) The Scope was changed to allow either set of units.

(3) Metric units were added to Section 5 and Tables 1, 3, and 5.

(4) Summary of Changes section was added.



 **A 308/A 308M – 03**

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# Standard Test Method for Weight and Composition of Coating on Terne Sheet by the Triple-Spot Test<sup>1</sup>

This standard is issued under the fixed designation A 309; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon ( $\epsilon$ ) indicates an editorial change since the last revision or reapproval.

*This standard has been approved for use by agencies of the Department of Defense. This test method replaces Method 511.1 of Federal Test Method Standard No. 151b.*

## 1. Scope

1.1 This test method covers the determination of the weight and composition of coating on terne sheet by the triple-spot method. The following three procedures are described:

1.1.1 *Procedure A*—Stripping with sulfuric acid.

1.1.2 *Procedure D*—Stripping with hydrochloric acid and antimony trichloride.

1.1.3 *Procedure E*—Stripping with hydrobromic acid-bromine solution.

NOTE 1—Procedure B (Electrolytic Stripping) and Procedure C (Stripping with Silver Nitrate Solution), formerly in this test method, were discontinued because lack of usage. The designation for Procedure D and Procedure E are retained to avoid future confusion when reference is made only to the procedure designation.

1.2 If the percent of tin in the coating is required, stripping with hydrobromic acid-bromine is the preferred procedure. Steel with a predeposited electrolytic nickel coating requires a two-stage stripping method to determine total tin content. If both the tin and lead percentage are required, stripping with sulfuric acid is recommended, but caution is advised since the sulfuric acid procedure has been found to produce high tin results (see Section 11).

1.3 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.* For specific hazards statements, see Section 5, Note 2, and Section 17.

## 2. Referenced Documents

### 2.1 ASTM Standards:

A 308 Specification for Steel Sheet, Terne (Lead-Tin Alloy) Coated by the Hot-Dip Process<sup>2</sup>

E 50 Practices for Apparatus, Reagents, and Safety Consid-

erations for Chemical Analysis of Metals, Ores, and Related Materials<sup>3</sup>

E 57 Method for Chemical Analysis of White Metal Bearing Alloys<sup>4</sup>

E 173 Practices for Conducting Interlaboratory Studies of Methods for Chemical Analysis of Metals<sup>5</sup>

## 3. Significance and Use

3.1 A coating of terne metal on iron or steel articles is intended to provide drawability, solderability, or corrosion resistance, or combination thereof, which can require different amounts of coating. Specifications for terne-coated sheets frequently provide for these different classes (weights) of coating so that purchasers can select that most suitable for their needs. This test method provides a means of determining the weight of coating for comparison with the material specification requirements.

## 4. Reagents

4.1 *Purity of Reagents*—Reagent grade chemicals shall be used in all tests. Unless otherwise indicated, it is intended that all reagents shall conform to the specifications of the Committee on Analytical Reagents of the American Chemical Society, where such specifications are available.<sup>6</sup> Other grades may be used, provided it is first ascertained that the reagent is of sufficiently high purity to permit its use without lessening the accuracy of the determination.

## 5. Hazards

5.1 For precautions to be observed in the use of certain reagents in this test method, reference shall be made to Practices E 50. Particular precaution should be observed when

<sup>3</sup> *Annual Book of ASTM Standards*, Vol 03.05.

<sup>4</sup> Discontinued; see *1985 Annual Book of ASTM Standards*, Vol 03.05.

<sup>5</sup> Discontinued; see *1996 Annual Book of ASTM Standards*, Vol 03.05.

<sup>6</sup> *Reagent Chemicals, American Chemical Society Specifications*, American Chemical Society, Washington, DC. For suggestions on the testing of reagents not listed by the American Chemical Society, see *Analar Standards for Laboratory Chemicals*, BDH Ltd., Poole, Dorset, U.K., and the *United States Pharmacopeia and National Formulary*, U.S. Pharmacopeial Convention, Inc. (USPC), Rockville, MD.

<sup>1</sup> This test method is under the jurisdiction of ASTM Committee A05 on Metallic-Coated Iron and Steel Products and is the direct responsibility of Subcommittee A05.07 on Methods of Testing.

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<sup>2</sup> *Annual Book of ASTM Standards*, Vol 01.06.

using the hydrobromic acid-bromine stripping solution (Procedure E) as described in Section 17.

## 6. Test Specimens

6.1 Test specimens for weight of coating shall be obtained as prescribed in Specification A 308.

6.2 Specimens shall be  $2.25 \pm 0.01$  in. ( $57.15 \pm 0.25$  mm) square or  $2.54 \pm 0.01$  in. ( $64.52 \pm 0.25$  mm) in diameter, except that for material narrower than 2.25 in. in width, test specimens shall be of such a length that the area of the specimen is equal to  $5.08 \text{ in.}^2$  ( $3277 \text{ mm}^2$ ). The weight of coating in grams on a specimen  $5.08 \text{ in.}^2$  in area is numerically equal to the weight of coating in ounces per square foot of sheet. When it is not possible to secure a specimen of  $5.08 \text{ in.}^2$  in area, a smaller size may be used, but it is recommended that a specimen of not less than  $3 \text{ in.}^2$  ( $2000 \text{ mm}^2$ ) be used.

NOTE 2—The area of  $5.08 \text{ in.}^2$  is achieved by a specimen 2.25 in. square or having a diameter of 2.54 in. within the tolerances of the procedure.

6.3 The specimens shall be clean; if necessary, they shall be washed with solvent naphtha or other suitable solvent, then with alcohol, and dried thoroughly.

## PROCEDURE A—STRIPPING WITH SULFURIC ACID

### 7. Reagents and Materials

7.1 *Hydrochloric Acid* (sp gr 1.12)—Mix 500 mL of HCl (sp gr 1.19) with 400 mL of distilled water.

7.2 *Mercuric Chloride Solution*—Prepare a saturated solution of mercuric chloride ( $\text{HgCl}_2$ ) in water.

7.3 *Potassium Dichromate, Standard Solution* (0.1 N, 1 mL = 0.00559 g Fe)—Prepare and standardize as prescribed for Reagent 10 in Practices E 50.

7.4 *Potassium Iodate, Standard Solution* (0.05 N, 1 mL = 0.003 g Sn)—Prepare and standardize as prescribed for Reagent 12 in Practices E 50, making suitable adjustments in the quantities of reagents and water used so that the solution will be 0.05 N.

7.5 *Sodium Bicarbonate Solution* (saturated)—Saturate freshly boiled distilled water with  $\text{NaHCO}_3$ .

7.6 *Sodium Bicarbonate Solution* (dilute)—Dissolve about 10 g of  $\text{NaHCO}_3$  in 1 L of freshly boiled distilled water.

7.7 *Sodium Diphenylamine Sulfonate Indicator Solution*—Dissolve 0.20 g of sodium diphenylamine sulfonate in 100 mL of water. Store in a dark-colored bottle.

7.8 *Stannous Chloride, Reducing Solution*—Dissolve 100 g of  $\text{SnCl}_2 \cdot 2\text{H}_2\text{O}$  in 500 mL of HCl (sp gr 1.19), dilute to 1 L, and mix. Preserve in a dark-colored bottle containing a small amount of granular or mossy tin metal.

7.9 *Starch Solution*—Prepare solution as prescribed for Reagent 110 in Practices E 50.

7.10 *Sulfuric Acid* (sp gr 1.84).

7.11 *Sulfuric-Phosphoric Acid Mixture*—Pour 150 mL of concentrated sulfuric acid ( $\text{H}_2\text{SO}_4$ , sp gr 1.84) into 300 mL of water while stirring. Cool, add 150 mL of concentrated phosphoric acid ( $\text{H}_3\text{PO}_4$ , sp gr 1.69), dilute to 1 L with water, and mix.

## 8. Procedures for Stripping

8.1 After cleaning as described in 6.3, weigh each test specimen separately to the nearest 0.001 g. Wrap a stiff platinum or nickel wire about each specimen in such a manner that it may be held firmly in an acid solution in a horizontal position. Using a 600-mL beaker, heat 60 mL of  $\text{H}_2\text{SO}_4$  (sp gr 1.84) to  $250^\circ\text{C}$  (**Warning**, see Note 3). Immerse each specimen for about  $1\frac{1}{2}$  min (see Note 4) in the hot acid; then remove and momentarily immerse in 50 mL of distilled water contained in a 600-mL beaker. Rub the surface of the specimen with a policeman while washing with about 50 mL of distilled water from a wash bottle. Dry the specimen. If the coating has not been completely removed, again immerse in the acid and repeat the procedure. Thoroughly dry and reweigh the specimen. The loss in weight represents the weight of coating together with iron dissolved from the steel sheet.

NOTE 3—**Warning**—A suitable face shield should be worn in order to protect the operator from accidental splashing or popping of hot sulfuric acid.

NOTE 4—The stripping must be conducted in a manner to ensure that the temperature of the stripping solution is maintained at a minimum of  $250^\circ\text{C}$  for at least  $1\frac{1}{2}$  min after immersing the test panel. Successive strippings (at  $250^\circ\text{C}$ ) may be necessary to remove all of the coating completely.

## 9. Chemical Analysis

9.1 Cool the  $\text{H}_2\text{SO}_4$  solution in which the specimen was stripped and combine with the washings obtained in the 600-mL beaker while stripping the specimen. Pour the solution into a 500-mL volumetric flask, and rinse the beaker with HCl (sp gr 1.12). Add the rinsings to the flask and dilute to the 500-mL mark with HCl (sp gr 1.12), again diluting to the mark after cooling, if necessary. (In the case of lead-coated sheets it may be necessary to dilute to 1 L with HCl (sp gr 1.12) to ensure complete solution of lead, in which case appropriate changes shall be made in the aliquot portions taken for the subsequent tests described in 9.2, 9.3, and 9.4.) The solution must now be analyzed for iron and, if desired, lead and tin.

9.2 *Determination of Iron*—Transfer a 100-mL aliquot of the solution in the 500-mL volumetric flask (see 9.1) to a 400-mL beaker. Heat to boiling, rinse the cover and the sides of the beaker with water, and immediately reduce the iron by the dropwise addition of the  $\text{SnCl}_2$  reducing solution. Add 3 drops in excess after the disappearance of the ferric iron color. Cool and dilute to about 175 mL with water. Add to the solution, all at once, 10 mL of the saturated  $\text{HgCl}_2$  solution. Mix gently by stirring the solution. Let stand for 3 to 5 min. Add 20 mL of the sulfuric-phosphoric acid mixture and 5 to 6 drops of the sodium diphenylamine sulfonate indicator solution. Titrate with the standard  $\text{K}_2\text{Cr}_2\text{O}_7$  solution to a purple end point. Calculate the grams of iron in the stripping solution as follows:

$$\text{Iron, g} = 5 AB$$

where:

A = millilitres of  $\text{K}_2\text{Cr}_2\text{O}_7$  standard solution required to titrate to a purple end point and

B = iron equivalent of the  $\text{K}_2\text{Cr}_2\text{O}_7$  solution, kg/L.

9.3 *Determination of Tin*—Transfer a 200-mL aliquot of the solution in the 500-mL volumetric flask (see 9.1) to a 300-mL Erlenmeyer flask. Add 3 g of iron in the form of fine wire or thin sheet and 1 g of powdered antimony. Fit the flask with a one-hole rubber stopper containing a glass tube bent twice at right angles, with the end of the short bend projecting through the stopper, the other end being long enough to reach almost to the bottom of a beaker placed on a level with the flask. Pour about 300 mL of a dilute solution of NaHCO<sub>3</sub> into this beaker. Place the flask on a hot plate, with the glass tube extending into the beaker containing the dilute solution of NaHCO<sub>3</sub>. After boiling the solution in the flask for about 5 min, remove the beaker containing the dilute NaHCO<sub>3</sub> solution and substitute another containing about 50 mL of a saturated solution of NaHCO<sub>3</sub>. Move both the beaker and the flask to a cool place. This will cause a small amount of the saturated solution of NaHCO<sub>3</sub> to enter the flask and exclude the air. Finally cool the solution to about 10°C. Add 5 mL of starch solution and titrate with KIO<sub>3</sub> solution. It is desirable to run a duplicate analysis for tin, adding the KIO<sub>3</sub> solution quickly to a point slightly less than the end point found in the previous determination, then finishing the titration more slowly. This duplicate analysis may be run using one of the other triple-spot test specimens. Calculate the grams of tin stripped from the test specimen from the number of millilitres of KIO<sub>3</sub> solution used for the titration, as follows:

$$\text{Tin, g} = 5AB/2$$

where:

A = KIO<sub>3</sub> solution required to titrate the samples, mL and  
 B = tin equivalent of the KIO<sub>3</sub> solution, kg/L.

9.4 *Determination of Lead*—After ascertaining that all the PbCl<sub>2</sub> is in solution, remove a 100-mL aliquot from the 500-mL volumetric flask (see 9.1) and place in a 400-mL beaker. Add 10 mL of H<sub>2</sub>SO<sub>4</sub>(sp gr 1.84), cover, and evaporate to fumes of SO<sub>3</sub>. Cool and dilute to 200 mL with water. Allow to settle and then filter on a weighed Gooch crucible, washing with H<sub>2</sub>SO<sub>4</sub>(1 + 19). Dry and ignite at a dull red heat. Cool and reweigh. Calculate the grams of lead stripped from the test specimen, as follows:

$$\text{Lead, g} = 5(A - B) \times 0.6831$$

where:

A = weight of Gooch crucible and ignited precipitate, and  
 B = weight of Gooch crucible.

## 10. Calculation

10.1 *Weight of Coating*—Calculate the weight of coating in ounces per square foot as follows:

$$\text{Weight of coating} = A - B$$

where:

A = loss in weight of specimen, g (see Section 8), and  
 B = iron stripped from the test specimen (see 9.2), when a specimen of 5.08 in.<sup>2</sup>(3277 mm<sup>2</sup>) in area is used, g. For specimens of other sizes, a suitable correction factor must be applied.

10.2 *Percent of Tin in Coating*—Calculate the percent of tin in the coating as follows:

$$\text{Tin, \%} = [T/(T + L)] \times 100$$

where:

T = tin stripped from the test specimen (see 9.3), g and  
 L = lead stripped from the test specimen (see 9.4), g.

10.3 *Percent of Lead in Coating*—Calculate the percent of lead in the coating by subtracting the percentage of tin from 100 %.

## 11. Precision and Bias

11.1 Due to the limited number of laboratories participating in the cooperative testing of this procedure, a precision statement conforming to the requirements of Practices E 173 cannot be furnished. Comparison of the percent tin found by the three cooperating laboratories (Table 1) with the known tin value in the samples indicates that the sulfuric acid procedure (Procedure A) yields high tin results. It is therefore advised that caution be exercised when reporting percent tin values obtained using the sulfuric acid method. The weight of coating results (Table 2) generally agreed to within 0.01 oz/ft<sup>2</sup> between replicate samples and between different laboratories.

## PROCEDURE D—STRIPPING WITH HYDROCHLORIC ACID AND ANTIMONY TRICHLORIDE

### 12. Reagent

12.1 *Antimony Trichloride-Hydrochloric Acid Solution*—Dissolve approximately 40 g of SbCl<sub>3</sub> in HCl (sp gr 1.19) and dilute to 1 L with the HCl.

### 13. Procedure for Stripping

13.1 After cleaning as described in 6.3, weigh each test specimen separately to the nearest 0.001 g. Immerse in the cold SbCl<sub>3</sub>-HCl solution until the coating is removed and all action ceases. The reaction will leave the specimen coated with antimony. Wash thoroughly to remove the loosely adherent antimony, dry, and reweigh. The loss in weight in grams is the weight of coating in ounces per square foot of sheet when a

**TABLE 1 Tin Determination**

Sample	Assumed Tin Value <sup>A</sup>	Sulfuric Acid Method (Procedure A) <sup>B</sup>			Hydrobromic Acid-Bromine Method (Procedure E) <sup>B</sup>		
		Laboratory 1	Laboratory 2	Laboratory 3	Laboratory 1	Laboratory 2	Laboratory 3
A	8.6	9.9	10.2	9.2 <sup>C</sup>	8.3	8.8	8.6
B	12.4	14.5	14.5	13.0 <sup>C</sup>	12.2	12.7	12.2

<sup>A</sup> Values obtained using Method E 57.

<sup>B</sup> All values represent an average of three determinations.

<sup>C</sup> Calculated using coating weight instead of method used in 10.2.

**TABLE 2 Weight of Coating, oz/ft<sup>2</sup> of Sheet**

Sample	Hydrochloric Acid-Antimony Trichloride Method (Procedure D)			Sulfuric Acid Method (Procedure A)			Hydrobromic Acid-Bromine Method (Procedure E)		
	Laboratory 1	Laboratory 2	Laboratory 3	Laboratory 1	Laboratory 2	Laboratory 3	Laboratory 1	Laboratory 2	Laboratory 3
1A	0.16	0.16	0.16	0.16	0.15	0.16	0.16	0.16	0.17
2A	0.16	0.16	0.16	0.16	0.15	0.16	0.16	0.16	0.17
1B	0.34	0.32	0.33	0.33	0.28 <sup>A</sup>	0.31	0.35	0.33	0.35
2B	0.33	0.33	0.32	0.32	0.29 <sup>A</sup>	0.32	0.33	0.34	0.33

<sup>A</sup>Procedural error—results not considered valid.

specimen of 5.08 in.<sup>2</sup>(3277 mm<sup>2</sup>) in area is used. For specimens of other sizes a suitable correction factor must be applied.

#### 14. Precision and Bias

14.1 Due to the limited number of laboratories participating in the cooperative testing of this procedure, a precision statement conforming to the requirements of Practices E 173 cannot be furnished. Comparison of the weight of coating results, Table 2, indicates that generally the results agreed to within 0.01 oz/ft<sup>2</sup> between replicate samples and between different laboratories.

### PROCEDURE E—STRIPPING WITH HYDROBROMIC ACID-BROMINE SOLUTION

#### 15. Apparatus and Materials

15.1 *Atomic Absorption Spectrophotometer*—The instrument shall consist of an atomizer and burner, suitable pressure-regulating devices capable of maintaining constant oxidant and fuel pressure for duration of the test, a hollow cathode lamp for each metal to be tested, an optical system capable of isolating the desired line of radiation, an adjustable slit, a photomultiplier tube or other photosensitive device as a light-measuring and amplifying device, and a readout device for indicating the amount of absorbed radiation.

15.1.1 *Hollow Cathode Lamps*—A single element (tin) lamp is available and has been found satisfactory for tin analysis.

##### 15.2 Oxidant :

15.2.1 *Air*—Use clean, dry air. A filter capable of removing oil, water, and other foreign substances may be used.

15.2.2 *Nitrous Oxide*—Laboratory and industrial high-purity grade nitrous oxide has been used satisfactorily.

##### 15.3 Fuel :

15.3.1 *Acetylene*—Standard, commercially available acetylene is satisfactory (**Warning**, see 17.1). However, since all acetylene cylinders contain acetone, no more than three fourths of the volume of the tank should be used in order to prevent carryover of the acetone into the equipment.

15.3.2 *Pressure-Reducing Valves*—The supplies of fuel and oxidant shall be maintained at pressures somewhat higher than the controlled operating pressure of the instrument by means of suitable pressure-reducing valves.

#### 16. Reagents

16.1 *Hydrochloric Acid (1+1)*—Mix 1 volume of concentrated hydrochloric acid (sp gr 1.19) with 1 volume of water.

16.2 *Hydrochloric Acid (1+20)*—Mix 1 volume of concentrated hydrochloric acid (sp gr 1.19) with 20 volumes of water.

16.3 *Hydrobromic Acid-Bromine Stripping Solution*—Mix 9 volumes of hydrobromic acid (sp gr 1.49) with 1 volume of bromine liquid (**Caution**, see 17.2).

16.4 *Lead Solution Stock*—Prepare stock lead solution by dissolving 1.500 g of pure lead in 50 mL of hydrobromic acid-bromine stripping solution (from 16.3). Dilute to 200 mL in a volumetric flask with the hydrobromic acid-bromine stripping solution and mix (1 mL = 7.5 mg Pb).

16.5 *Mercuric Chloride Solution*—Prepare a saturated solution of mercuric chloride (HgCl<sub>2</sub>) in water.

16.6 *Perchloric Acid* (sp gr 1.67) (**Caution**, see 17.3).

16.7 *Potassium Dichromate, Standard Solution (0.1 N, 1 mL = 0.00559 g iron)*—Prepare and standardize as prescribed for Reagent 10 in Practices E 50.

16.8 *Sodium Diphenylamine Sulfonate Indicator Solution*—Dissolve 0.20 g of sodium diphenylamine sulfonate in 100 mL of water. Store in a dark-colored bottle.

16.9 *Stannous Chloride, Reducing Solution*—Dissolve 100 g of SnCl<sub>2</sub>·2H<sub>2</sub>O in 500 mL of HCl (sp gr 1.19), dilute to 1 L, and mix. Preserve in a dark-colored bottle containing a small amount of granular or mossy tin metal.

16.10 *Sulfuric-Phosphoric Acid Mixture*—Pour 150 mL of concentrated sulfuric acid (H<sub>2</sub>SO<sub>4</sub>, sp gr 1.84) into 300 mL of water while stirring. Cool, add 150 mL of concentrated phosphoric acid (H<sub>3</sub>PO<sub>4</sub>, sp gr 1.69), dilute to 1 L with water, and mix.

16.11 *Tin Standard, Stock Solution*—Prepare stock standard solution by dissolving 1.000 g of pure tin in 100 mL of HCl (1+1). Dilute to 1000 mL in a volumetric flask using HCl (1+1). Concentration: 1 mL = 1000 µg tin. Commercial tin standards are available.

#### 17. Hazards

17.1 *Acetylene*—**Warning**: “Purified” grade acetylene contains a special proprietary solvent rather than acetone, which can weaken the walls of poly(vinyl chloride) tubing that carries acetylene to the burner, causing a potentially hazardous situation and should not be used.

##### 17.2 Hydrobromic Acid-Bromine Solution:

17.2.1 The handling of bromine, either as a liquid or in the vapor form, is a *health hazard*. Therefore, the following minimum precautions should be taken:

17.2.2 Extreme care should be taken to avoid inhaling the corrosive fumes: conduct all mixing, stripping, and evaporating operations in a well-ventilated hood.

17.2.3 Avoid skin contact with the liquid or fumes: rubber gloves may be worn as protection from accidental spillage or splashes.

17.2.4 If liquid should come into contact with bare skin, immediately wash the affected area thoroughly with water. Medical attention may be necessary if burns are severe.

17.2.5 Before disposal, neutralize all bromine-containing solutions using a 10 % solution of sodium thiosulfate ( $\text{Na}_2\text{S}_2\text{O}_3$ ). Add thiosulfate solution and stir until the bromine color disappears.

17.3 *Perchloric Acid*—The handling and storage of perchloric acid should be conducted in accordance with the precautions given in Practices E 50, Safety Precautions.

## 18. Procedure for Stripping

18.1 After cleaning in accordance with 6.3, weigh the test specimen to the nearest 0.001 g. Place the specimen in a suitable stripping dish. Add 40 mL of stripping solution (**Warning**, see 17.2), and immediately begin polishing both sides of the specimen. After 30 s, remove the specimen using TFE-fluorocarbon forceps and place it in a filter funnel that has been inserted into a 200-mL volumetric flask. Rinse the specimen with HCl (1+1), catching and saving all rinsings in the volumetric flask. Inspect the surface of the specimen for unremoved coating by using a “scratch” test. (Scratching the specimen surface with a fingernail leaves a noticeable metallic scratch if any coating is left on the surface. The base metal will not leave such a mark.) If the scratch test reveals residual coating, repeat the stripping (using original solution) and rinsing steps until the surface is free of coating. Rinse the stripped test specimen with water, dry, and reweigh. The loss in weight represents the weight of coating together with iron dissolved from the steel sheet.

## 19. Chemical Analysis

19.1 Transfer the sample stripping solution to the 200-mL flask that contains the rinsings and dilute to volume with HCl (1+1).

19.2 *Determination of Iron*—Transfer a 50-mL aliquot into a 250-mL beaker. Add 10 mL of  $\text{HClO}_4$  and take to fumes on a hot plate (**Warning**, see 17.3). Cool solution, then add 100 mL of water, 5 mL of HCl, and heat to boiling. Immediately reduce the iron with addition of the  $\text{SnCl}_2$  reducing solution. Add 3 drops in excess after the disappearance of the ferric iron color. Cool and dilute to about 175 mL with water. Add to the solution, all at once, 10 mL of the saturated  $\text{HgCl}_2$  solution. Mix gently by stirring the solution. Let stand for 3 to 5 min. Add 20 mL of the sulfuric-phosphoric acid mixture and 5 to 6 drops of the sodium diphenylamine sulfonate indicator solution. Titrate with the standard  $\text{K}_2\text{Cr}_2\text{O}_7$  solution to a purple end point. Calculate the grams of iron in the stripping solution as follows:

$$\text{Iron, g} = 4AB$$

where:

A =  $\text{K}_2\text{Cr}_2\text{O}_7$  standard solution required to titrate to a purple end point, mL and

B = iron equivalent of the  $\text{K}_2\text{Cr}_2\text{O}_7$  solution, kg/L.

### 19.3 Determination of Tin:

19.3.1 *Terne-Coated Sheet Without Predeposited Electrolytic Nickel Coating*—Use Procedure E.

19.3.2 *Terne-Coated Sheet With Predeposited Electrolytic Nickel Coating*:

19.3.2.1 Use a combination of Procedure E (to strip coating overlay) and an additional alloy layer stripping procedure to determine total tin content. Strip terne coating with reagent grade hydrobromic acid (48 %) containing 10 mL/L of a 10 % antimony trichloride/hydrochloric acid solution. (Dissolve 10 g antimony trichloride in 100 mL of concentrated hydrochloric acid, sp gr 1.19.) Reduce with aluminum wire and titrate with potassium iodate solution. Strip alloy layer in a 1:3 nitric acid solution, reduce with aluminum wire and titrate in potassium iodate solution. Total tin content is equal to the tin in the coating plus the tin in the alloy layer.

19.3.3 *Calibration and Standardization*:

19.3.3.1 Prepare tin standards ranging from 0 to 200 mg/L by transferring the required amounts of standard, 1000 mg/L tin solution (from 16.11) to 100-mL volumetric flasks (0, 1.0, 2.0, 5.0, 10.0, 15.0, and 20.0 mL). Add 20 mL of the stock lead solution (from 16.4) to each flask, dilute to volume with HCl (1+1), and mix.

19.3.3.2 The exact operation of different instruments varies; hence no attempt is made here to describe in detail the steps for putting the instrument into operation. However, the following parameters have been found suitable for some types of instruments.

Lamp current, mA	10
Main air supply, psi	40
Air flow, standard ft <sup>3</sup> /h	10
Main acetylene supply, psi	10
Acetylene flow, standard ft <sup>3</sup> /h	approximately 8
Main nitrous oxide ( $\text{N}_2\text{O}$ ) supply, psi	40
Nitrous oxide ( $\text{N}_2\text{O}$ ) flow, standard ft <sup>3</sup> /h	approximately 10
Slit band width, Å	4
Wavelength, Å	2863 (0 to 200 mg/L)

Consult manufacturer’s manual for the equivalent operating parameters for the instrument in use.

19.3.3.3 Atomize the standards and record the instrument readings expressed in absorbance units. Aspirate water between each standard.

19.3.3.4 Prepare a calibration curve by plotting on linear graph paper the absorbance versus standard concentration for each standard.

19.3.4 *Procedure*:

19.3.4.1 Atomize the sample stripping solution under the conditions in 19.3.3.

19.3.4.2 Determine concentration of the stripped sample solution using the calibration curve. Determine concentration in milligrams per litre.

## 20. Calculation

20.1 *Weight of Coating*—Calculate the weight of coating in ounces per square foot of sheet as follows:

$$\text{Weight of coating, oz/ft}^2 = A - B$$

where:

A = loss in weight of specimen, g, and

$B$  = grams of iron stripped from the test specimen (from 19.2), when a specimen of 5.08 in.<sup>2</sup> (3277 mm<sup>2</sup>) in area is used. For specimens of other sizes, a suitable correction factor must be applied.

20.2 *Percentage of Tin in Coating*—Calculate the tin content as follows:

$$\text{Tin, \%} = \text{mg/L tin}/50 [A - B]$$

where:

$A - B$  = weight of coating, oz/ft<sup>2</sup>, when a specimen of 5.08 in.<sup>2</sup> (3277 mm<sup>2</sup>) in area is used. For specimens of other sizes, a suitable correction factor must be applied.

## 21. Precision and Bias <sup>7</sup>

21.1 Due to the limited number of laboratories participating in the cooperative testing of the tin analysis procedure, a precision statement conforming to the requirements of Practices E 173 cannot be furnished. Comparison of the percentage tin found by the three cooperating laboratories (Table 1) with the known tin value in the samples indicates an error of approximately 0.2 to 0.3 % tin. Therefore, this procedure can be expected to be within 3 % of the expected tin value.

## 22. Keywords

22.1 coating composition; coating weight; metallic coatings; steel sheet—terne coated; terne coating

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<sup>7</sup> Supporting data are available from ASTM Headquarters. Request RR: A05-1001.

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# Standard Specification for Zinc-Coated (Galvanized) Steel Overhead Ground Wire Strand<sup>1</sup>

This standard is issued under the fixed designation A 363; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon ( $\epsilon$ ) indicates an editorial change since the last revision or reapproval.

## 1. Scope\*

1.1 This specification covers high-strength, extra-high-strength, and utilities grades of concentric lay steel wire strand composed of three wires or seven wires with Class A, Class B, or Class C zinc coatings specifically intended for use as overhead ground wires or static wires for electric power transmission lines.

1.2 The values stated in inch-pound units are to be regarded as the standard. The SI units given in brackets are for information only.

## 2. Referenced Documents

### 2.1 ASTM Standards:

- A 90/A 90M Test Method for Weight [Mass] of Coating on Iron and Steel Articles with Zinc or Zinc-Alloy Coatings
- A 902 Terminology Relating to Metallic-Coated Steel Products
- B 6 Specification for Zinc

## 3. Terminology

3.1 *Definitions*—For definitions of terms used in this specification, refer to Terminology A 902.

## 4. Ordering Information

4.1 Orders for strand purchased under this specification shall include the following information:

- 4.1.1 Quantity of each size,
- 4.1.2 Size and grade of strand (Table 1), and
- 4.1.3 Class of zinc coating (Section 11 and Table 2).
- 4.1.4 ASTM designation and year of issue.

## 5. Materials and Manufacture

5.1 The base metal shall be steel produced by any commercially accepted steel making process and shall be of such quality and purity that when drawn to the size of wire specified

and coated with zinc, the finished strand will have the properties and characteristics prescribed in this specification.

5.2 The slab zinc when used for the coating shall be any grade of zinc conforming to Specification B 6.

## 6. Stranding

6.1 The strand shall have a left lay with a uniform pitch of not more than 16 times the nominal diameter of the strand. A left lay is defined as a counter-clockwise twist away from the observer. Stranding shall be sufficiently close to ensure no significant reduction in diameter when stressed to 10 % of the minimum breaking strength.

## 7. Preforming Strand

7.1 Preformed strand shall be supplied when so specified by the purchaser. Strand is preformed when the component wires are set to the helical form which they assume in the product by any means of process other than by merely laying them about the strand core.

## 8. Breaking Strength and Weight

8.1 The approximate weight per unit length of strand and the minimum breaking strength of the finished strand shall be as specified in Table 1.

8.2 A test in which the breaking strength is below the minimum specified and which may have been caused by the slipping of the specimen in the jaws of the testing machine, by breaking within the jaws or within 1 in. [25.4 mm] of the jaws, or by the improper socketing of a specimen shall be disregarded and another sample from the same coil or reel shall be tested.

## 9. Elongation

9.1 The elongation of the strand in 24 in. [610 mm], determined as specified in 9.2, shall be not less than 5 % for the high-strength and for the  $\frac{5}{16}$ -in. [7.94-mm], 3-wire utilities grades, and 4 % for the extra-high-strength and for the  $\frac{3}{8}$ -in. [9.52-mm], 7-wire Utilities grades.

9.2 The elongation shall be measured as the percentage increase in separation between the jaws of the testing machine from the position after application of the initial load, to the position at initial failure in the test specimen. The separation of

<sup>1</sup> This specification is under the jurisdiction of ASTM Committee A05 on Metallic Coated Iron and Steel Products and is the direct responsibility of Subcommittee A05.12 on Wire Specifications.

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\*A Summary of Changes section appears at the end of this standard.



**TABLE 1 Physical Properties of Zinc-Coated Steel Overhead Ground Wire Strand**

Nominal Diameter of Strand, in. [mm]	Number of Wires in Strand	Nominal Diameter of Coated Wire in Strand, in. [mm] <sup>A</sup>	Approximate Weight of Strand, lb/1000 ft [kg/km]	Minimum Breaking Strength of Strand, lbf [kN]		
				High-Strength Grade	Extra-High-Strength Grade	Utilities Grade
5/16 [7.94]	3	0.145 [3.68]	171 [255]	...	...	6500 [28.9]
5/16 [7.94]	7	0.104 [2.64]	205 [305]	8000 [35.6]	11 200 [49.8]	...
3/8 [9.52]	7	0.120 [3.05]	273 [407]	10 800 [48.0]	15 400 [68.4]	11 500 [51.2]
7/16 [11.11]	7	0.145 [3.68]	399 [595]	14 500 [64.5]	20 800 [92.5]	...
1/2 [12.7]	7	0.165 [4.19]	517 [770]	18 800 [83.6]	26 900 [119.6]	...

<sup>A</sup> It is recognized that the surfaces of heavy zinc coating, particularly those produced by hot galvanizing, are not perfectly smooth and devoid of irregularities. If the tolerances shown above are rigidly applied to such irregularities that are inherent to the product, unjustified rejections of wire that would actually be satisfactory for use could occur. Therefore, it is intended that these tolerances be used in gauging the uniform areas of the galvanized wire.

**TABLE 2 Minimum Weights of Coating**

Nominal Diameter of Coated Wire, in. [mm]	Minimum Weight of Coating, oz/ft <sup>2</sup> [kg/m <sup>2</sup> ] of Uncoated Wire Surface		
	Class A	Class B	Class C
0.104 [2.64]	0.80 [0.24]	1.60 [0.49]	2.40 [0.73]
0.120 [3.05]	0.85 [0.26]	1.70 [0.52]	2.55 [0.78]
0.145 [3.68]	0.90 [0.27]	1.80 [0.55]	2.70 [0.82]
0.165 [4.19]	0.90 [0.27]	1.80 [0.55]	2.70 [0.82]

the jaws of the testing machine shall be approximately 2 ft [0.61 m] when under an initial load equal to 10 % of the required minimum breaking strength of the strand. The elongation values shall be recorded only for specimens that break over 1 in. [25.4 mm] from jaws of the testing machine.

## 10. Ductility of Steel

10.1 The individual wires of the completed strand shall not fracture when wrapped at a rate not exceeding 15 turns per minute in a close helix of at least two turns around a cylindrical mandrel equal to three times the nominal diameter of the wire under test.

## 11. Weight of Coating

11.1 The weight of zinc coating shall not be less than that specified in Table 2.

11.2 *Weight of Coating Test*—The zinc coating shall be tested for weight by a stripping test in accordance with Test Method A 90/A 90M.

## 12. Adherence of Coating

12.1 The zinc coating shall adhere to the wire without delaminating and without being removable by rubbing with the bare fingers after the individual wires have been wrapped at a rate not exceeding 15 turns per minute, in a close helix of at least two turns around a cylindrical mandrel equal to three times the nominal diameter of the wire under test. Loosening or detachment during the adhesion tests of superficial, small particles of zinc formed by mechanical polishing of the surface of zinc-coated wire shall not be considered cause for rejection.

## 13. Joints and Splices

13.1 There shall be no joints of any kind made in the finished wire entering into the construction of the strand.

13.2 Electric-welded butt joints made prior to the start of cold drawing of the wire are permitted; however, no electric-welded butt joints of the wire shall be made during the cold drawing application.

13.3 There shall be no strand joints or strand splices in any length of the completed strand.

## 14. Permissible Variations in Wire Size

14.1 The diameter of the zinc-coated wire forming the strand shall conform to the nominal diameter shown in Table 1 within a tolerance of  $\pm 0.004$  in. [0.102 mm] for Wire Sizes 0.104 in. [2.642 mm] and 0.120 in. [3.048 mm] and  $\pm 0.005$  in. [0.127 mm] for Wire Sizes 0.145 in. [3.683 mm] and 0.165 in. [4.191 mm].

## 15. Workmanship, Finish, and Appearance

15.1 The zinc-coated wire shall be uniform in diameter and shall be free from splints, scales, inequalities, flaws, and other imperfections not consistent with good commercial practice. The coating shall be continuous and reasonably uniform.

## 16. Sampling

16.1 The number of samples to be taken shall be determined by lot size as follows:

Lot Size	Number of Samples
1 to 3 reels	1 from each reel
4 to 30 reels	3 min
31 reels or greater	4 min

16.2 Each sample taken shall be subjected to all tests prescribed in Sections 6, 8, and 9.

16.3 In addition to the strand testing in 16.2 the individual wires from the strand samples shall be tested for compliance with Sections 10, 11, 12, and 14. Select all three wires in three-wire strand, and four of the wires in seven-wire strand. Individual wire samples selected for compliance to Section 14 shall be discarded if any distortion of the wire occurred during the stranding operation.

16.4 Instead of testing the wires from the completed strand in accordance with 16.3, the producer may elect to establish compliance with Sections 10, 11, 12, and 14 of this specification by tests made on the wires prior to stranding, unless otherwise stipulated by the purchaser. However, if the producer makes this election, the purchaser shall still reserve the right to test wires from the completed strand for compliance.

## 17. Inspection

17.1 The manufacturer shall afford the inspector representing the purchaser all reasonable facilities to satisfy him that the material is being furnished in accordance with this specification. All tests and inspection shall be made on the finished strand at the place of manufacture prior to shipment and shall be so conducted as not to interfere unnecessarily with the operation of the works.

## 18. Rejection

18.1 In case there is a reasonable doubt in the first trial as to the failure of the wire or strand to meet any requirement of this specification, two additional tests shall be made on samples of wire or strand from the same coil or reel, and if failure occurs in either of these tests, the strand shall be rejected.

## 19. Packaging and Package Marking

19.1 The completed strand shall be furnished on reels sufficiently sturdy to withstand normal service incident to shipping, hauling, and field erection.

19.2 The completed strand shall be furnished in random lengths. At least 95 % of the lengths shall be within the minimum and maximum limits shown in Table 3. Not more than 5 % of a total length ordered may be furnished in lengths

**TABLE 3 Range of Strand Lengths per Reel for at Least 95 % of the Completed Strand**

Nominal Diameter of Strand, in. [mm]	Number of Wires in Strand	Length in Feet [metres] of Strand Per Reel for at Least 95 % of the Order	
		Min	Max
5/16 [7.94]	3	4700 [1430]	7900 [2410]
3/8 [9.52]	7	4800 [1460]	7700 [2350] <sup>A</sup>
7/16 [11.11]	7	3600 [1100]	5800 [1770] <sup>A</sup>
1/2 [12.7]	7	4700 [1430]	7900 [2410]
		3600 [1100]	6100 [1860]

<sup>A</sup> Purchasers may procure maximum lengths up to 12 000 ft [3660 m] for 5/16-in. [7.94-mm] diameter strand and up to 9400 ft [2860 m] for 3/8-in. [9.52-mm] diameter strand.

which are below the minimum limits shown in Table 3 but which are not less than 1500 ft [457 m] long. Each reel shall be clearly marked to show the length of the strand contained thereon.

19.3 Each reel shall have a strong tag securely fastened to it showing the name of the material “ground wire strand,” the length, size, grade of the strand, class of coating, ASTM Specification A 363, and the name or mark of the manufacturer.

## 20. Keywords

20.1 coated overhead strand; steel wire strand; zinc-coated overhead strand

## SUMMARY OF CHANGES

Committee A05 has identified the location of selected changes to this standard since the last issue (A 363 - 98) that may impact the use of this standard.

A 363 - 03:

- (1) Renumbered sections to meet Form & Style requirements.
- (2) Deleted “Size of Strand” section.
- (3) Added paragraph 4.1.4.
- (4) Changed base metal in 5.1 to any commercially accepted steel making process.
- (5) Combined old “Physical Properties” section into new

- Section 8 (Breaking Strength and Weight).
- (6) Editorial changes in sections 11.1-12.1-18.
- (7) Made Note 1 part of 12.1.
- (8) Made Note 2 part of 16.3.
- (9) Changed kg/m to kg/km in Table 1.
- (10) Added Summary of Changes section.

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# Standard Practice for Safeguarding Against Warpage and Distortion During Hot-Dip Galvanizing of Steel Assemblies<sup>1</sup>

This standard is issued under the fixed designation A 384/A 384M; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon ( $\epsilon$ ) indicates an editorial change since the last revision or reapproval.

## 1. Scope

1.1 Steel assemblies and subassemblies fabricated by welding, such as composite structural members, sash, weldments, etc., that are to be hot-dip galvanized after fabrication, are subject to warpage and distortion of the material due to the heating and cooling incidental to the galvanizing operation, particularly when it is necessary for the assembly to be dipped more than once to cover the entire surface.

1.2 This specification is applicable in either inch pounds or SI units. Inch pounds and SI units are not necessarily exact equivalents. Within the text of this specification and where appropriate, SI units are shown in parentheses.

## 2. Referenced Documents

### 2.1 ASTM Standards:

A 143 Practice for Safeguarding Against Embrittlement of Hot-Dip Galvanized Structural Steel Products and Procedure for Detecting Embrittlement<sup>2</sup>

A 385 Practice for Providing High-Quality Zinc Coatings (Hot-Dip)<sup>2</sup>

## 3. Factors in Warpage and Distortion

3.1 One of the most commonly distorted and warped members of assemblies is that of sheets or plates from No. 20 gage [0.812 mm] to ¼ in. [6.35 mm] in thickness which are assembled by welding or riveting to bar-size shapes, angles, channels, tees, etc.

3.2 Warpage is accentuated by the use of nonsymmetrical sections such as channels. In nearly every case, regardless of size, channels require straightening after galvanizing. This is not true of an I-beam, pipe, H-column, or any other section that is symmetrical about both its major axes. Channels and other nonsymmetrical sections should be avoided for the framework of a sheet metal assembly that is to be hot-dip galvanized whenever it is possible to use symmetrical shapes or sections.

3.3 The use of wide radii bends in corners is recommended. In the case of sheet metal, the product which has a right-angle bend in the sheet metal itself will remain flatter and be freer from distortion if the radius of the bend is as large as practicable.

3.4 Certain welding practices, weld sizes and configurations, and thickness differences between welded components can introduce imbalanced stresses into the weldments. If these stresses are combined with other stresses during hot-dip galvanizing, the stress relieving effect of galvanizing may permit distortion to occur.

3.5 When two pieces of steel are seal welded in an overlapping joint, the overlapping section must be properly vented per Practice A 385. If the overlapped area is not properly vented or if it is incorrectly sealed, the pressure from the expansion of the trapped gases in the overlapped area can distort the two pieces of steel that are welded together and, in the worst case, can cause an explosion underneath the zinc bath surface destroying the parts and causing a potential safety problem at the hot-dip galvanizing facility.

## 4. Suggested Corrections for Panel Fabrication

4.1 The angles selected should be in as perfect alignment as it is practical to obtain.

4.2 The angles should be placed in position without clamping or pulling prior to welding so that the corners of abutting edges will lie in position without restraint. Clamps may be applied to prevent shifting or movement during the welding operation.

4.3 The stiffening angles should be placed in position and held down to prevent their being moved when in contact with the electrode during the welding operation. In welding any intermediate lengths along one side of a common member, care should be taken to prevent warpage of the common member due to the application of high heat on the same side at various intervals along its length.

4.4 All edges of tightly contacting surfaces should be completely sealed by welding unless the area exceeds the recommended size detailed in Practice A 385. This will prevent the rusting of the surfaces that are so connected that molten zinc cannot circulate through the crevices to galvanize the contacting surfaces.

4.5 The sheet steel should not be welded to the angle steel

<sup>1</sup> This practice is under the jurisdiction of ASTM Committee A05 on Metallic Coated Iron and Steel Products and is the direct responsibility of Subcommittee A05.13 on Structural Shapes and Hardware Specifications.

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This practice is based upon the work of the Technical Services Committee of the American Galvanizers Association.

<sup>2</sup> *Annual Book of ASTM Standards*, Vol 01.06.

frame prior to galvanizing if the galvanizing kettle is not of sufficient size to permit the total immersion in one dip. If the frame has to be dipped one half at a time, it will be better to have the sheets galvanized, rolled flat after galvanizing, and assembled to the galvanized frame by the use of aluminum alloy or galvanized rivets. These rivets can be countersunk or flat head if the protruding head of the ordinary button or round head rivet is objectionable. If the angle steel frame and sheets are punched prior to galvanizing (the recommended procedure), the use of drift pins to bring the holes into alignment should be avoided as far as possible at the time the sheets and frame are assembled.

4.6 If the galvanizing kettle is of sufficient size to permit total immersion of the assembly in one dip, the riveting of fabricated parts prior to galvanizing is not recommended because contacting surfaces will not be coated and rusting will occur due to entrapped pickling acid.

4.7 Unequal thickness of metal should be avoided wherever possible due to the different rates of heating and cooling during

the galvanizing operation and the effect of unequal expansion and contraction.

## 5. Embrittlement

5.1 Cold working before galvanizing (straightening, springing into position, reforming, etc.) of various steel parts in making up an assembly, or in the cold working of the individual members of an assembly, punching, cutting, etc., may result in embrittlement of the base metal following the hot galvanizing operation. Necessary precautions to fabricate properly and prepare the material for galvanizing to prevent embrittlement are described in Practice A 143.

NOTE 1—Welding, if improperly performed, may induce embrittlement. It is recommended that welding procedures be carried out in conformance with the pertinent specifications of the American Welding Society.

## 6. Keywords

6.1 coatings-zinc; galvanized coatings; steel products-metallic coated; zinc coatings-steel products

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## Standard Practice for Providing High-Quality Zinc Coatings (Hot-Dip)<sup>1</sup>

This standard is issued under the fixed designation A 385; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon ( $\epsilon$ ) indicates an editorial change since the last revision or reapproval.

*This standard has been approved for use by agencies of the Department of Defense.*

### 1. Scope

1.1 This practice indicates the precautions that should be taken to obtain high-quality hot-dip galvanized coatings.

1.2 Where experience on a specific product indicates a relaxing of any provision, the mutually acceptable change shall be a matter for agreement between the manufacturer and purchaser.

1.3 The values stated in inch-pound units are to be regarded as the standard.

### 2. Referenced Documents

#### 2.1 ASTM Standards:

A 143/A 143M Practice for Safeguarding Against Embrittlement of Hot-Dip Galvanized Structural Steel Products and Procedure for Detecting Embrittlement<sup>2</sup>

A 153/A 153M Specification for Zinc Coating (Hot-Dip) on Iron and Steel Hardware<sup>2</sup>

A 384 Practice for Safeguarding Against Warpage and Distortion During Hot-Dip Galvanizing of Steel Assemblies<sup>2</sup>

A 563 Specification for Carbon and Alloy Steel Nuts<sup>3</sup>

### 3. Steel Selection

3.1 The production of a galvanized coating has as its basis the metallurgical reaction between the steel and the molten zinc, resulting in the formation of several iron-zinc compound layers, for example, gamma (not always visible microscopically), delta, and zeta in Fig. 1. In addition, a layer of the molten zinc adheres to the surface of the compound layers as the steel is withdrawn from the galvanizing bath. Upon solidification, this adherent zinc forms the eta layer.

3.2 It is known that the exact structural nature of the galvanized coating, as typified by Fig. 1, may be modified according to the exact chemical nature of the steel being galvanized. Certain elements found in steels are known to have an influence on the coating structure. The elements carbon in

excess of about 0.25 %, phosphorus in excess of 0.04 %, or manganese in excess of about 1.3 % will cause the production of coatings different from the coating typified by Fig. 1. Steels with silicon in the range 0.04 % to 0.15 % or above 0.22 % can produce galvanized coating growth rates much higher than those for steels with silicon levels below 0.04 % and between 0.15 % and 0.22 %. Recent studies have shown that even in cases where the silicon and phosphorus are individually held to desirable limits, a combined effect between them can produce a coating as shown in Fig. 2, which typically would have a mottled or dull gray appearance.

3.3 These elements manifest their structural effect as an accelerated growth of the compound layers, particularly the zeta layer, and the virtual elimination of the eta layer. Cosmetically this accelerated growth is seen as a gray matte finished coating as opposed to the usual bright and smooth appearance of galvanized coatings. Sometimes, a large surface may have adjacent areas of matte finish and bright finish leading to a mottled appearance.

3.4 There is some evidence that the coatings resulting from this accelerated growth are more brittle and less adherent than normal coatings. There is also evidence that these coatings are subject to a premature red staining in atmospheric exposure; however, this staining has been found not to be associated with corrosion of the substrate steel.

3.5 A problem with steel chemistry is not usually apparent until after an item has been galvanized. Not all combinations of silicon, phosphorus, carbon, and manganese can be galvanized successfully. When the steel chemistry is known beforehand, experienced galvanizers can in some, but not all, instances exercise limited control over the coatings as shown in Fig. 2. Also, the combination of two different steel types or thicknesses in one item may result in a nonuniform galvanizing finish. The experience of the steel supplier, designer, manufacturer, and galvanizer should determine the steel selection.

3.6 In general, galvanized coatings are specified because of their corrosion resistance, not because of their appearance. The relative corrosion resistance of the normal and abnormal coatings is, for all practical purposes, equal.

<sup>1</sup> This practice is under the jurisdiction of ASTM Committee A05 on Metallic Coated Iron and Steel Products and is the direct responsibility of Subcommittee A05.13 on Structural Shapes and Hardware Specifications.

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<sup>2</sup> Annual Book of ASTM Standards, Vol 01.06.

<sup>3</sup> Annual Book of ASTM Standards, Vol 15.08.

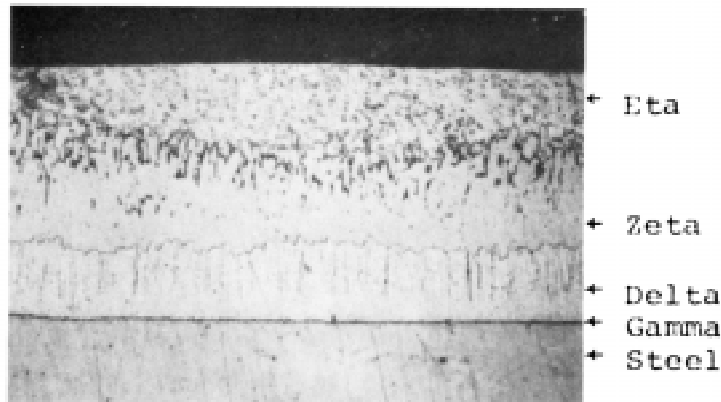


FIG. 1 Photomicrograph of Normal Galvanized Coating (X 400)

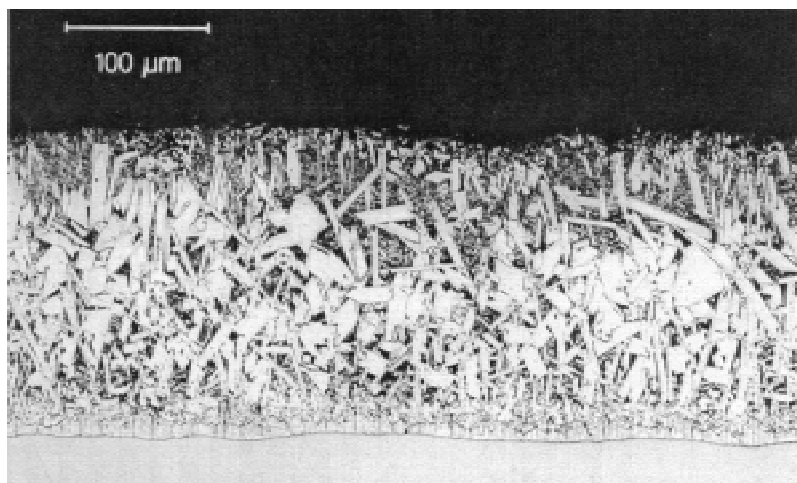


FIG. 2 Photomicrograph of Dull Gray, Thick-Galvanized Coating (X 200)

#### 4. Assemblies of Different Materials or Different Surfaces or Both

4.1 Whenever possible, assemblies should consist of elements of similar steel chemistry and surface condition.

4.2 Whenever different analyses of steel or different surfaces of steel are united in an assembly the galvanized finish is not generally uniform in appearance. These differences include:

- 4.2.1 Excessively rusted surfaces.
- 4.2.2 Pitted surfaces.
- 4.2.3 Machined surfaces.
- 4.2.4 Cast iron (especially with sand inclusion).
- 4.2.5 Cast steel.
- 4.2.6 Malleable iron.
- 4.2.7 Hot-rolled steel.
- 4.2.8 Cold-rolled steel.
- 4.2.9 Steel containing chemical elements in excess of those recommended in 3.2.

4.3 Where combinations are unavoidable, thorough abrasive blasting of the entire assembly will normally improve galvanizing quality.

#### 5. Overlapping or Contacting Surfaces

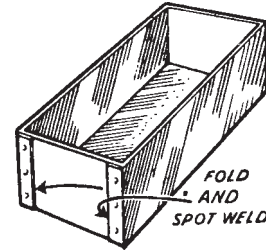
5.1 Overlapping or contacting surfaces that have not had all edges seal welded are undesirable.

5.2 When the distance between the overlapping surfaces is less than  $\frac{3}{32}$  in. [2.38 mm], these surfaces will not normally be wet by molten zinc. Furthermore, cleaning solution compounds that remain on these surfaces volatilize during the galvanizing process and may interfere with zinc wetting in adjacent areas. Such uncoated surfaces cause a rust staining after exposure to the environment. Traditionally however, steel grating has been manufactured without seal welding and when properly executed, this manufacturing means has permitted the galvanized coating to satisfy the quality requirements of the applicable ASTM specifications.

5.3 When the overlap surface area is large and the edges have been seal welded, air or moisture or both entrapped therein can develop destructive pressures when the assembly is heated to the galvanizing temperature, which is nominally 850°F [454°C]. Vent holes or unwelded area around the adjoining surfaces should be provided through one or both sides into the lapped area per the following tables.

**TABLE 1 Vent Holes for Overlapped Areas for Steels ½ in. [12.75 mm] or Less in Thickness**

Overlapped Area in. <sup>2</sup> [cm <sup>2</sup> ] under 16 [103]	Vent Holes None	Unwelded Area None
16 [103] to under 64 [413]	One ⅜ in. [1 cm]	1 in. [2.5 cm]
64 [413] to under 400 [2580]	One ½ in. [1.25 cm]	2 in. [5.1 cm]
400 [2580] and greater, each 400 [2580]	One ¾ in. [1.91 cm]	4 in. [10.2 cm]



**FIG. 4 Folded Surfaces**

**TABLE 2 Vent Holes for Overlapped Areas for Steels Greater than ½ in. [12.75 mm] in Thickness**

Overlapped Area in. <sup>2</sup> [cm <sup>2</sup> ] under 16 [103]	Vent Holes None	Unwelded Area None
16 [103] to under 64 [413]	None	None
64 [413] to under 400 [2580]	One ½ in. [1.25 cm]	2 in. [5.1 cm]
400 [2580] and greater, each 400 [2580]	One ¾ in. [1.91 cm]	4 in. [10.2 cm]

**6. Sheet Steel Rolled Over a Wire or Rod Stiffener**

6.1 All oil or grease should be removed from both the sheet steel and wire or rod before rolling (Fig. 3). Grease or oil becomes volatile at the galvanizing temperature and will generate gas which will prevent zinc from sealing the contact edges. All steel should be degreased before pickling and in the case of folded assemblies, before folding and assembling (Fig. 4).

**7. Weld Flux Removal and Welding Rods**

7.1 Welding flux residues are chemically inert in normal pickling solutions. Thus, they will not be removed by standard galvanizing cleaning techniques and are best removed at the time of fabrication by grit or sand-blasting or by a wire needle gun.

7.2 It is desirable to choose a welding rod with a chemical composition as close as possible to the parent metal.

7.3 Welding rods high in silicon may cause excessively thick or darkened coatings or both to form in the welded area.

**8. Cold Forming Before Galvanizing**

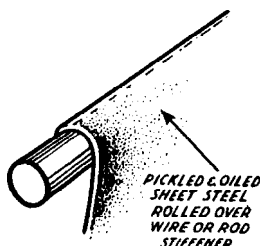
8.1 Refer to the latest edition of Recommended Practice A 143.

**9. Shearing, Cutting and Punching Before Galvanizing**

9.1 Refer to the latest edition of Recommended Practice A 143.

**10. Warpage and Distortion**

10.1 Refer to the latest edition of Practice A 384.



**FIG. 3 Rolled Surfaces**

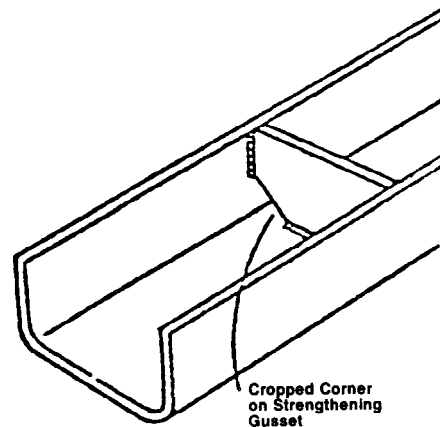
**11. Design Recommendations for Providing for the Free Flow of Cleaning Solutions, Fluxes, Air, and Zinc**

11.1 All fabricated assemblies shall be so designed with vent and drain holes such that no air is trapped during the immersion of the assemblies into cleaning solutions or molten zinc. Similarly these holes shall allow all solutions and molten zinc to drain freely from the assemblies. Failure to follow this practice will result in areas that will not galvanize properly, or that may retain entrapped flux or excessive amounts of zinc.

11.2 Free flow of cleaning solutions and molten zinc shall also be provided for in assemblies of hot-rolled shapes. This is accomplished by cropping the corner to provide an opening with a minimum area of 0.3 in.<sup>2</sup>[1.9 cm<sup>2</sup>] at the corners of all stiffeners (Fig. 5), gussets, or bracing (Fig. 6).

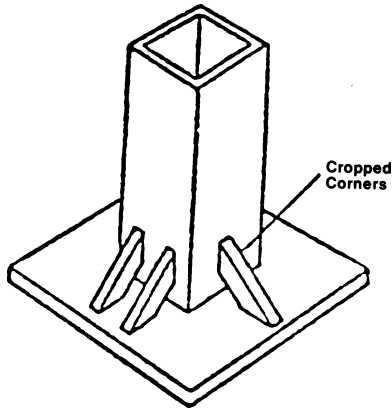
11.3 Air or moisture, or both, entrapped within closed fabricated pipework, such as handrail, can develop destructive pressures when heated to the galvanizing temperature. Pipe handrail shall preferably be vented full open internally, as shown in Fig. 7. In addition, there shall be one ⅜ -in. [9.5-mm] minimum diameter external hole at each intersection to prevent any possible explosions in the event that the fabricator neglects to provide internal venting. Where internal venting is not possible, external vents shall be provided with one vent hole in each side of each intersection. The vent openings shall be a minimum of ⅜ in. in diameter or 25 % of the diameter of the pipe that is used, whichever is larger (Fig. 8).

11.4 Figs. 9-12 show most of the conditions encountered with tubular product assemblies. The venting shall open wherever possible. This is the most desirable situation. A



NOTE 1—Strengthening gussets in channel sections should be cropped for zinc drainage.

**FIG. 5 Cropped Corners—Channel Sections**



NOTE 1—Crop corners of gussets on fabricated columns.  
**FIG. 6 Cropped Corners—Fabricated Columns**

minimum vent opening of 25 to 30 % of the cross-sectional area of tubular structure shall be specified where full-open venting is not possible. For small cross sections, larger percent vent openings are recommended. See attached drawings for specific recommendations. In box sections (Fig. 9) where gusset plates are used, the gusset plates shall be clipped at the four corners. In addition, a center hole shall be provided so that the cumulative area of the vent holes meets the recommended minimum. Gusset plates shall not be spaced closer than 36 in. [914 mm] apart. In the case of columns with end plates (Fig. 10) where the end plate must be closed, the shaft of the column shall be vented. The vent opening shall be a half circle with its diameter at the base plate ( $D$ , Fig. 10). This is much superior to putting a hole with the circumference of the hole tangential to the base plate. On trusses (Fig. 11 and Fig. 12) where tubular members intersect, vent holes are recommended at both sides of the intersection.

## 12. Moving Parts

12.1 When a galvanized assembly incorporates moving parts (such as drop handles, shackles, and shafts) a radial clearance of not less than  $\frac{1}{16}$  in. [1.59 mm] must be allowed to ensure full freedom of movement following galvanizing.

12.2 Moving parts such as handles or hinges should be galvanized separately and assembled after galvanizing. It may be necessary to post heat these parts in order to have them function freely. This heating may cause discoloration of the galvanized coating near the heated area.

## 13. Marking for Identification

13.1 Paint is not removed by pickling and must not be used when marking for identification material to be galvanized.

13.2 Satisfactory identification may be provided by welding the identifying marks on the material, by embossing the identifying marks on a steel tag of no less than No. 12 gage (0.105 in. [2.69 mm]) and securing to the material with a heavy wire such as No. 9 gage (0.148 in. [3.76 mm]), or by die stamping the identifying marks into the material with characters  $\frac{1}{2}$  in. [12.7 mm] high and a minimum of  $\frac{1}{32}$  in. [0.79 mm] deep.

13.3 All markings shall remain legible after galvanizing.

## 14. Galvanized Nuts, Bolts, and Tapped Holes in Galvanized Products

14.1 Oversize tapping or retapping of nuts and tapped holes is required when the bolt or male thread is galvanized. While tapping or retapping after galvanizing results in uncoated female threads, the zinc coating on the engaged male thread will retard corrosion of both components.

14.2 Refer to the sections on dimensions of zinc-coated nuts in Specification A 563.

14.3 Manufacturers or specifiers are cautioned to consider the plus tolerance that has been taken on the nominal pitch diameter of the bolt when establishing the degree of oversize tapping of the nut that is required for proper fit.

14.4 Hot-formed heading or bending may cause development of a scale that requires an extended time of pickling to remove. Should this occur on screws, scale removal prior to threading is desirable in order to avoid overpickling of the threaded area.

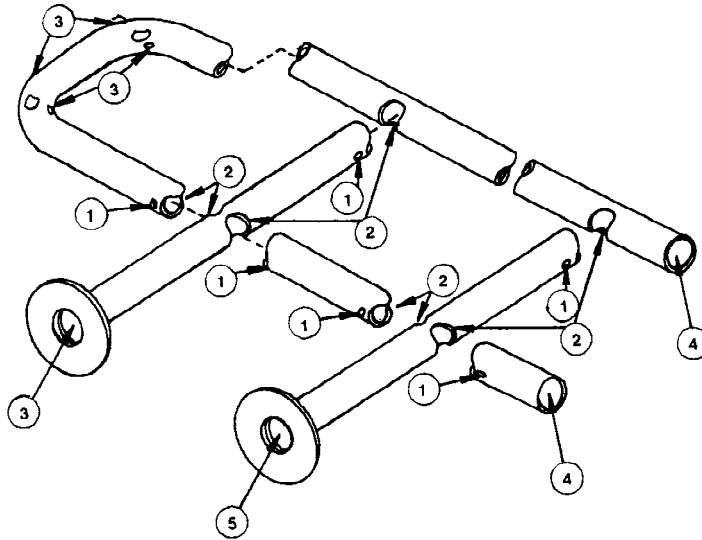
## 15. Critical Dimensions

15.1 When an assembly of steel parts or an individual steel part has been designed and fabricated with critical dimensions and must be subsequently hot-dip galvanized, the designer should be aware that the hot-dip galvanizing process uses chemical cleaning to prepare the surfaces for coating and this may alter the critical dimensions. In addition the hot-dip galvanized coating can increase the base steel material thickness from 2.0 to over 10.0 thousandths of an inch [50 to over 250 micrometres] depending on the steel chemistry as described in Section 3. This should be accounted for in the critical dimension design. Re-machining or otherwise reprocessing of critical dimensions after hot-dip galvanizing may be required.

## 16. Keywords

16.1 coatings-zinc; galvanized coatings; steel products-metallic coated; zinc coatings-steel products





The above drawing illustrates desirable design features for fabrication of handrail that requires galvanizing.

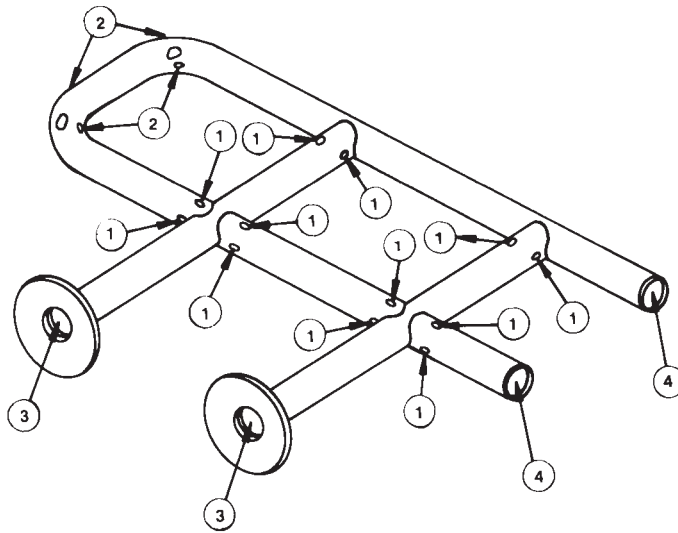
- ① Vent holes shall be as close to the weld as possible and not less than  $\frac{3}{8}$  in. (9.5 mm) in diameter.
- ② Internal holes shall be the full inside diameter of the pipe for best galvanizing quality and lowest galvanizing cost.
- ③ Vent holes in end sections or similar section shall be

a minimum  $\frac{1}{2}$  in. (12.7 mm) in diameter.

- ④ and ⑤ Any device used for erection in the field that prevents full openings on ends of horizontal rails and vertical legs shall be attached after galvanizing.

Vent holes should be visible on the outside of any pipe assembly.

FIG. 7 Handrail



The above drawing illustrates an acceptable alternative if full internal holes (the full inside diameter of the pipe) are not incorporated in the design of the handrail.

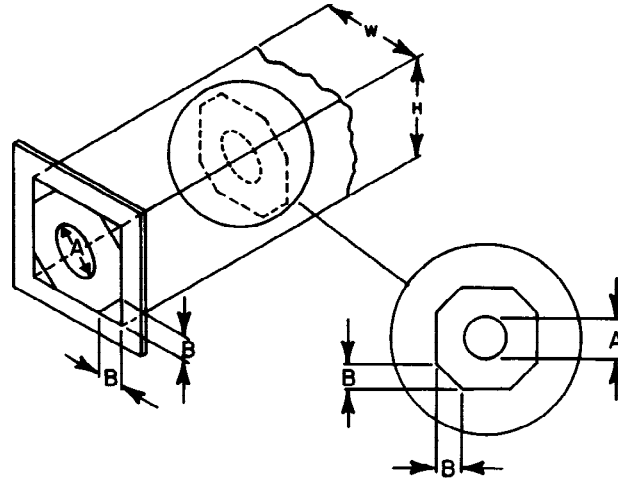
- ① Each vent hole shall be as close to the weld as possible, must be 25% of the inside diameter of the pipe, but not less than  $\frac{3}{8}$  in. (9.5 mm) in diameter. The two holes at each end and at each intersection shall be 180° apart and in the proper location as shown.

- ② Vent holes in end sections or in similar sections shall be at least  $\frac{1}{2}$  in. (12.7 mm) in diameter.

- ③ and ④ Any device used for erection in the field that prevents full openings on end of horizontal rails and vertical legs shall be attached after galvanizing.

Vent holes shall be visible on the outside of any pipe assembly.

FIG. 8 Handrail—Alternative



Drawing shows location of holes and clipped corners, which must be flush. Using the following formulas, the chart shows typical sizes of holes and clipped corners.

Internal Gussets—Should be spaced a minimum of 36 in. [914 mm].

Box Sections— $H + W = 24$  in. [610 mm] or larger—Area of hole plus clips shall be at least equal 25 % of the area of the box ( $H \times W$ ).

Box Sections— $H + W$  less than 24 in. to and including 16 in. [384 mm]—use 30 %.

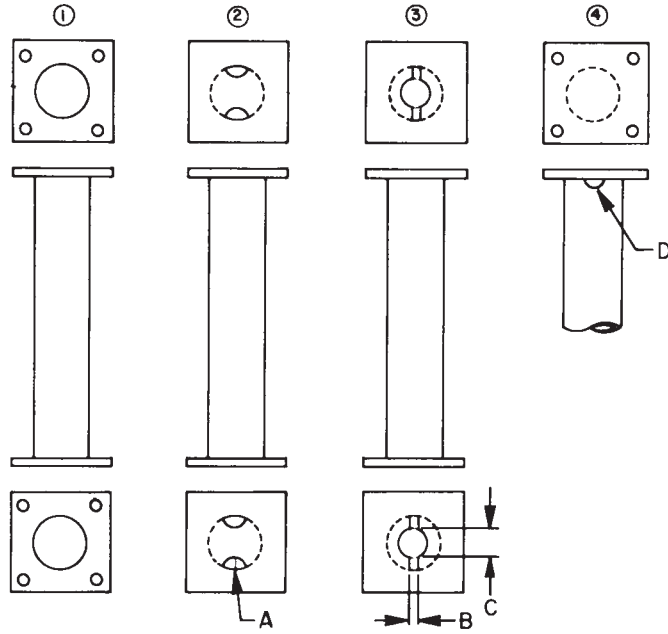
Box Sections— $H + W$  less than 16 in. to and including 8 in. [192 mm]—use 40 %.

Box Sections— $H + W$  under 8 in. leave completely open; no end plates or internal gussets.

The following chart is for *square box sections only*. For rectangular sections, calculate required area and check with galvanizer for positioning of openings.

Box Size $H+W$ , in. [mm]	Holes $A$ -Diameter, in. [mm]	Clipped Corners $B$ in. [mm]
48 [1219]	8 [203]	6 [152]
36 [914]	6 [152]	5 [127]
32 [813]	6 [152]	4 [102]
28 [711]	6 [152]	3 [76]
24 [610]	5 [127]	3 [76]
20 [508]	4 [102]	3 [76]
16 [406]	4 [102]	2 [51]
12 [305]	3 [76]	2 [51]

FIG. 9 Box Section

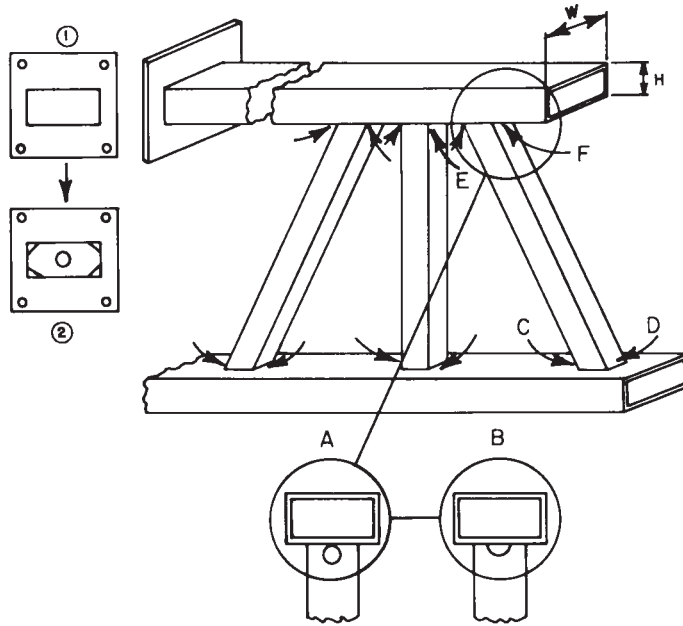


- Location of Openings:*
- ① Most desirable-completely open "same diameter" as section top and bottom.
  - ② and ③ Equal substitutes if full opening not allowed.
  - ④ Must be used together with ② or ③ if holes are not allowed on top of sections. Two half circles 180° apart in line with cutouts on ② and ③.

*Dimensions:*  
 Openings each end shall be at least 30 % of inside diameter

- area of pipe for over 3-in. (76-mm) pipe and 45 % of area for 3-in. pipe or smaller.
- The following is an example of sizes for a 6-in. (152-mm) diameter section: Allow 30 % of the area of the inside diameter for hole sizes each end.
- ② Half circle *A* = 1 3/4-in. (44-mm) radius
  - ③ Slot *B* = 3/4 in. (19 mm) -- Center hole *C* = 3 in. (76 mm) Diameter
  - ④ Half circle *D* = 1 3/4-in. (41-mm) radius

**FIG. 10 Pipe Columns, Pipe Girders, Street Light Poles, and Transmission Poles with Base Plates with or without Cap Plates**



*Vertical and Angled Sections:*

Hole location for vertical and angled sections shall be located as shown in Examples A and B, and by arrows on drawing.

Each vertical and angled section shall have two holes at the top and bottom, 180° apart in line with horizontal members as indicated by arrows. Size of holes preferably should be equal and the combined area of the two holes at either end of the vertical and angled sections (that is, area C and D, or area E and F) should be at least 30 % of the cross-sectional area.

*End Plate—Horizontal:*

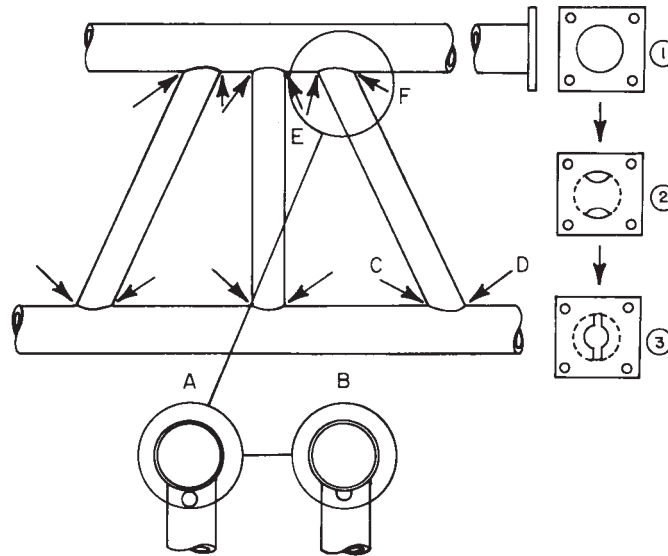
- ① Most desirable - completely open.
- ② If  $H+W = 24$  in. (610 mm) or larger, area of hole plus clips should equal 25 % of the area of the tube ( $H \times W$ ).

If  $H+W$  less than 24 in. (610 mm) to and including 16 in. (406 mm) -- use 30%.

If  $H+W$  less than 16 in. to and including 8 in. (203 mm) -- use 40 %.

If  $H+W$  under 8 in. -- leave open.

**FIG. 11 Rectangular Tube Truss**



Hole location for vertical and angled sections shall be located as shown in examples A and B and by arrows on drawing.

Each vertical and angled section shall have two holes at the top and bottom, 180° apart in line with horizontal members as indicated by arrows. Size of holes preferably should be equal and the combined area of the two holes at

either end of the vertical and angled sections (that is, area C and D, or area E and F) should be at least 30% of the cross-sectional area.

*End Plates - Horizontal:*

- ① Most desirable - completely open "same diameter."
- ② and ③ Equal substitutes -- openings as shown should be 30 % of the areas of the inside diameter.

**FIG. 12 Pipe Truss 3 in. [76 mm] and Larger**

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# Standard Specification for Zinc-Coated (Galvanized) Steel Poultry Fence Fabric (Hexagonal and Straight Line)<sup>1</sup>

This standard is issued under the fixed designation A 390; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon ( $\epsilon$ ) indicates an editorial change since the last revision or reapproval.

## 1. Scope

1.1 This specification covers zinc-coated fence fabric intended for enclosure of poultry, or to prevent entry into special areas. It is available in three styles as:

1.1.1 *Poultry Netting*, consisting of a mesh of woven wire with openings hexagonal in shape,

1.1.2 *Poultry-and-Garden Fence Fabric*, consisting of a series of horizontal (line) wires with vertical (stay) wires wrapped around the line wires, forming rectangular openings, and

1.1.3 *Chick Fence Fabric*, similar to poultry-and-garden fabric except that the wires at the bottom of the fabric are placed at a closer spacing.

1.2 The values stated in inch-pound units are to be regarded as the standard. The values given in parentheses are for information only.

## 2. Referenced Documents

### 2.1 ASTM Standards:

A 90/A90M Test Method for Weight [Mass] of Coating on

Iron and Steel Articles with Zinc or Zinc-Alloy Coatings<sup>2</sup>

A 700 Practices for Packaging, Marking, and Loading

Methods for Steel Products for Domestic Shipment<sup>3</sup>

A 902 Terminology Relating to Metallic Coated Steel Products<sup>2</sup>

B 6 Specification for Zinc<sup>4</sup>

### 2.2 U.S. Federal Standard:

Fed. Std. No. 123 Marking for Shipment (Civil Agencies)<sup>5</sup>

### 2.3 U.S. Military Standards:

MIL-STD-129 Marking for Shipment and Storage<sup>5</sup>

MIL-STD-163 Steel Mill Products, Preparation for Shipment and Storage<sup>5</sup>

## 3. Terminology

3.1 *Definitions*—For definitions of terms used in this specification, see Terminology A 902.

NOTE 1—The following term used in this specification is defined in Terminology A 902: *base metal*.

3.2 *Definitions of Terms Specific to This Standard*: Descriptions of Terms Specific to This Standard:

3.2.1 *netting*—a mesh of woven wire with openings hexagonal in shape. The style is as designated by design numbers shown in Table 1. The mesh may be further strengthened by addition of straight line wires spaced approximately 12 in. (305 mm) apart, except spaced at approximately 6-in. (152-mm) intervals for 12 and 18-in. (305 and 457-mm) netting heights. Design numbers are used in ordering the netting style desired.

3.2.2 *poultry-and-garden fence fabric and chick fence fabric*—fence styles constructed by a series of horizontal (line) wires with vertical (stay) wires wrapped around the line wires, forming rectangular openings. Table 2 and Table 3 along with Fig. 1 and Fig. 2 are intended to show the characteristics of each design number. Design numbers are used for ordering the desired fence style.

## 4. Ordering Information

4.1 Orders for poultry netting shall include the following information:

4.1.1 Name of material (poultry netting),

4.1.2 Quantity (number of rolls),

4.1.3 Design number (see 6.2),

4.1.4 Class of coating (see 10.1),

4.1.5 Certification if required (see Section 14), and

4.1.6 ASTM designation and year of issue.

4.2 Orders for poultry-and-garden fence fabric or chick fence fabric shall include the following information:

4.2.1 Name of material (poultry-and-garden fence fabric or chick fence fabric),

4.2.2 Style of fence fabric (see 3.2),

4.2.3 Quantity (number of rolls),

<sup>1</sup> This specification is under the jurisdiction of ASTM Committee A05 on Metallic Coated Iron and Steel Products and is the direct responsibility of Subcommittee A05.12 on Wire Specifications.

Current edition approved Aug. 15, 1995. Published October 1995. Originally published as A 390 – 66. Last previous edition A 390 – 92a.

<sup>2</sup> *Annual Book of ASTM Standards*, Vol 01.06.

<sup>3</sup> *Annual Book of ASTM Standards*, Vol 01.05.

<sup>4</sup> *Annual Book of ASTM Standards*, Vol 02.04.

<sup>5</sup> Available from Standardization Documents Order Desk, Bldg. 4 Section D, 700 Robbins Ave., Philadelphia, PA 19111-5094, Attn: NPODS.

**TABLE 1 Design Numbers for Poultry Netting  
(Furnished in 150-ft Rolls)**

NOTE 1—*Design Numbers:* In accordance with trade practice, each design of netting is expressed by a combination of three numbers. The first designates the mesh opening in inches, the second, is the wire gage size, and the third is the height in inches. For convenience, the information contained in the design number is repeated in separate columns.

Design Number, in./gage/in.	Mesh Size, in.	Wire Gage	Height of Netting, in.
1 x 20 x 12	1	20	12
1 x 20 x 18	1	20	18
1 x 20 x 24	1	20	24
1 x 20 x 36	1	20	36
1 x 20 x 48	1	20	48
1 x 20 x 60	1	20	60
1 x 20 x 72	1	20	72
2 x 20 x 24	2	20	24
2 x 20 x 36	2	20	36
2 x 20 x 48	2	20	48
2 x 20 x 60	2	20	60
2 x 20 x 72	2	20	72

4.2.4 Design (see 6.2),

4.2.5 Certification if required (see Section 14), and

4.2.6 ASTM designation and year of issue.

4.3 All rolls of poultry netting and poultry-and-garden fence fabric and chick fence fabric accepted by the purchaser shall be billed to him on the basis of the number and original length of the rolls before sampling unless changed by contractual arrangement. Poultry netting covered by this specification shall be furnished in 150-ft (46-m) rolls, poultry-and-garden fence fabric and chick fence fabric shall be furnished in 10-rod (50-m) rolls.

NOTE 2—A typical ordering description is as follows: Netting: 50 rolls 1 x 20 x 48 in., Class 1, galvanize before weaving certified to Specification A 390 dated , Poultry fence: 50 rolls poultry-and-garden fence fabric 1948-6-14½ Class 1 Galvanizing certified to Specification A 390 dated .

## 5. Zinc for Coating

5.1 The zinc used for the coating shall be any grade of zinc conforming to Specification B 6.

## 6. Manufacture

6.1 The base metal of the fabric shall be of a good commercial quality of steel wire.

6.2 The designs of netting, poultry-and-garden fence fabric, and chick fence fabric covered by this specification shall be in accordance with those shown in Table 1, Table 2, and Table 3.

## 7. Dimensions and Permissible Variations

7.1 The size of the mesh openings in the netting shall be 1 in. (25 mm) or 2 in. (51 mm) as specified (see Table 1). The opening tolerance shall be  $\pm \frac{1}{8}$  in. (3.2 mm) when measured across the flats.

7.2 The height of the netting and fence fabrics (center to center distance between top and bottom wires) shall not vary more than  $\pm 1$  in. (25 mm).

7.3 The tolerance for fence fabrics individual line and stay wire spacing shall be  $\pm \frac{3}{8}$  in. (9.5 mm). This does not alter the overall height of the fabric as designated in 7.2.

7.4 The length tolerance for all styles of netting and fence fabric covered by this specification shall be  $-0, +3$  %.

7.5 Due to the mechanics of the manufacturing process, a certain amount of out-of-roundness can be expected on stay wires of the finished fence fabric. No limits are placed on out-of-roundness of wire in the fabric.

## 8. Workmanship

8.1 Splicing of individual line wires by means of a wrap joint or an electric butt weld is permitted. The maximum number of line wire splices or joints shall not exceed one half of the number of line wires in any roll of fence. Such splices or joints shall be made in a workmanlike manner.

8.2 Patching of voids in the poultry netting by means of hand weaving is permitted. Such repair shall be made in a workmanlike manner.

8.3 The fence fabrics shall have uniformly wrapped joints and all stay wires shall be properly spaced and substantially perpendicular to the line wires.

## 9. Sampling

9.1 *Samples*—For the purpose of tests, select at random, one roll from every 50 rolls or fraction thereof in a lot or a total of seven rolls, whichever is less. A lot shall consist of all the rolls of a single design offered for delivery at the same time.

9.2 *Test Specimens for Poultry Netting*—Specimens for testing shall consist of 1 ft<sup>2</sup>(0.09 m<sup>2</sup>) selected at any point in the width of the netting and taken from the end of the roll, but not to include the selvage. Subject a specimen from each sample to tests for weight of coating in accordance with Section 10.

9.3 *Test Specimens for Fence Fabric*—Cut a length of fabric, approximately 3 ft or 1 m long, from the end of the sample roll to include at least three of the vertical (stay) wires. The test specimens for weight of coating determination shall consist of a number of lengths cut from a single wire, excluding all wire knots, wraps, and welded sections, such that the total length of wire test is at least 6 in. (152 mm), but preferably about 12 in. (305 mm). Test at least six test specimens for weight of coating in accordance with Section 10.

9.3.1 Select as follows:

9.3.1.1 One specimen from the top or bottom wires,

9.3.1.2 Three specimens from horizontal (line) wires other than the top or bottom wires, and

9.3.1.3 Two specimens from vertical (stay) wires.

9.4 Instead of testing wire from the completed fence fabric in accordance with 9.2 or 9.3, the manufacturer may elect to establish compliance with Section 10 of this specification by tests made on wire prior to fabrication. If the manufacturer makes this election, the purchaser still reserves the right to test wire from the completed fence fabric.

## 10. Weight of Coating

10.1 The class of coating for netting shall be specified by the purchaser and shall be in accordance with the classes of coating prescribed in Table 4.

10.2 The weight of coating for the various gages of wire composing the fence fabric shall be in accordance with the weights specified in Table 4.





**TABLE 4 Minimum Weights of Coating Zinc-Coated Steel Poultry Netting and Fence Fabric**

Size, Steel Wire Gage	Nominal Diameter of Zinc-Coated Wire, in. (mm)	Minimum Weight of Coating oz/ft <sup>2</sup> (g/m <sup>2</sup> ) of Uncoated Wire Surface	
		Class 1, Galvanized Before Weaving	Class 3, Galvanized After Weaving
		No. 11	0.120 (3.05)
No. 12½	0.099 (2.52)	0.28 (85)	
No. 13	0.092 (2.32)	0.28 (85)	
No. 14½	0.076 (1.93)	0.25 (76)	
No. 15½	0.067 (1.70)	0.20 (61)	
No. 20	0.034 (0.86)	0.10 (31)	0.40 (122)

$$\text{Surface area, ft}^2 = W/10.188 d$$

where:

$W$  = weight of stripped sample, pounds, and

$d$  = diameter of stripped (bare) wire, inches

### 11. Retests and Rejection

11.1 *Retests*—If 20 % or more of the specimens tested fail for weight of coating, or any sample fails dimensional requirements, four additional rolls shall be taken at random from each 50 rolls or fraction thereof and tested for conformance.

11.2 *Rejection*—If 20 % or more of the total number of retest specimens fail for weight of coating, or any sample fails dimensional requirements, the entire lot represented by the samples may be rejected.

11.3 Instead of rejecting the entire lot as provided for in 11.2, the producer may test specimens from every roll as provided for in Section 7 and 9.2 or 9.3 and reject only those rolls failing to meet the requirements of this specification.

### 12. Inspection

12.1 Unless otherwise specified in the purchase order or contract, the manufacturer is responsible for the performance of all inspection and test requirements specified in this specification. Except as otherwise specified in the purchase order or contract, the manufacturer's own or any other suitable facility may be used for the performance of the inspection and test requirements unless disapproved by the purchaser at the time

the order is placed. The purchaser shall have the right to perform any of the inspection and tests set forth in this specification when such inspections and tests are deemed necessary to ensure that the material conforms to prescribed requirements.

### 13. Rejection and Rehearing

13.1 Material that fails to conform to the requirements of this specification may be rejected. Rejection should be reported to the producer or supplier promptly and in writing. In case of dissatisfaction with the results of the test, the producer or supplier may make claim for a rehearing.

### 14. Certification

14.1 When specified in the purchase order or contract, a producer's or supplier's certification shall be furnished to the purchaser that the material was manufactured, sampled, tested, and inspected in accordance with this specification and has been found to meet the requirements. When specified in the purchase order or contract, a report of the test results shall be furnished.

### 15. Packaging and Marking

15.1 Unless otherwise specified, packaging, marking, and loading for shipment shall be in accordance with Practices A 700.

15.2 When specified in the contract or order, and for direct procurement by or direct shipment to the U.S. Government, when Level A is specified, preservation, packaging, and packing shall be in accordance with the Level A requirement of MIL-STD-163.

15.3 When specified in the contract or order, and for the direct procurement by or direct shipment to the U.S. Government, marking for shipment, in addition to requirements specified in the contract or order, shall be in accordance with MIL-STD-129 for U.S. military agencies and in accordance with Fed. Std. No. 123 for U.S. Government civil agencies.

### 16. Keywords

16.1 fence fabric; woven wire; fencing material; steel wire; zinc coated; zinc-coatings; steel wire products

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## Standard Specification for Zinc-Coated Steel Chain-Link Fence Fabric<sup>1</sup>

This standard is issued under the fixed designation A 392; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon ( $\epsilon$ ) indicates an editorial change since the last revision or reapproval.

### 1. Scope

1.1 This specification covers zinc-coated steel chain-link fence fabric, zinc coated either before or after weaving.

1.2 The values stated in inch-pound units are to be regarded as the standard.

### 2. Referenced Documents

#### 2.1 ASTM Standards:

A 90 Test Method for Weight (Mass) of Coating on Iron or Steel Articles with Zinc or Zinc-Alloy Coatings<sup>2</sup>

A 370 Test Methods and Definitions for Mechanical Testing of Steel Products<sup>3</sup>

A 700 Practices for Packaging, Marking, and Loading Methods for Steel Products for Domestic Shipment<sup>4</sup>

A 817 Specification for Metallic-Coated Steel Wire for Chain Link Fence Fabric<sup>2</sup>

B 6 Specification for Zinc<sup>5</sup>

#### 2.2 Federal Standard:

Fed. Std. No. 123 Marking for Shipments (Civil Agencies)<sup>6</sup>

#### 2.3 Military Standards:

MIL-STD-129 Marking for Shipment and Storage<sup>6</sup>

MIL-STD 163 Steel Mill Products, Preparation for Shipment and Storage<sup>6</sup>

### 3. Terminology

#### 3.1 Definitions of Terms Specific to This Standard:

3.1.1 *chain-link fence fabric*—a fencing material made from steel wire helically wound and interwoven in such a manner as to provide a continuous mesh without knots or ties except in the form of knuckling or of twisting the ends of the wires to form the selvage of the fabric. Variations to knuckled or twisted selvages are permissible.

3.1.2 *diamond count*—the number of diamond openings from one edge of the fabric to the other. The diamond count of a given fabric shall begin at the first completed diamond at one edge and continue to the unfinished ( $\frac{1}{2}$ ) or full opening at the other edge.

3.1.3 *knuckling*—the type of selvage obtained by interlocking adjacent pairs of wire ends and then bending the wire ends back into a loop. The loop shall be closed or nearly closed to a measurement less than the diameter of the wire.

3.1.4 *twisting*—the type of selvage obtained by twisting adjacent pairs of wire ends together in a close helix of  $1\frac{1}{2}$  machine turns, which is equivalent to 3 full twists, and cutting the wire ends at an angle. The wire ends beyond the twist shall be at least  $\frac{1}{4}$  in. [6.4 mm] long. This type of selvage is not used on fabric with a mesh size of less than 2 in. [50.8 mm].

### 4. Ordering Information

4.1 Orders for chain-link fence fabric purchased to this specification shall include the following information:

4.1.1 Quantity (Section 14),

4.1.2 Zinc coated after weaving or before weaving (Section 5),

4.1.3 Size of mesh (Section 7),

4.1.4 Size of wire (Section 8),

4.1.5 Height of fabric (Section 9),

4.1.6 Diamond count, if specified (Section 6),

4.1.7 Type of selvage (Section 10),

4.1.8 Class of coating (Section 11),

4.1.9 ASTM designation and year of issue, and

4.1.10 Certification if required (Section 17).

4.2 All rolls of fencing accepted by the purchaser shall be billed on the basis of the original footage of the rolls before sampling, unless changed by contractual arrangement.

NOTE 1—A typical ordering description is as follows: 25 rolls, 50 ft each, chain-link fence fabric, zinc coated after weaving, 2-in. mesh, 0.148-in. wire, 60 in. high, knuckled both selvages, Class 2 coating to ASTM A 392 - XX.

### 5. Materials

5.1 If zinc-coated before weaving, the wire from which the fabric is woven shall conform to all requirements of Specification A 817 for Type II coating, in the class of coating specified (Class 1 or Class 2).

<sup>1</sup> This specification is under the jurisdiction of ASTM Committee F14 on Fences and is the direct responsibility of Subcommittee F14.40 on Chain Link Fabric and Wire Accessories.

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<sup>2</sup> Annual Book of ASTM Standards, Vol 01.06.

<sup>3</sup> Annual Book of ASTM Standards, Vol 01.03.

<sup>4</sup> Annual Book of ASTM Standards, Vol 01.05.

<sup>5</sup> Annual Book of ASTM Standards, Vol 02.04.

<sup>6</sup> Available from Standardization Documents Order Desk, Bldg. 4 Section D, 700 Robbins Ave., Philadelphia, PA 19111-5094, Attn: NPODS.

5.2 If zinc-coated after weaving, the base metal shall be steel of such quality and purity that, when drawn to the size of wire specified and coated with zinc after fabrication, the finished fencing shall be of uniform quality and have the properties and characteristics as prescribed in this specification.

5.3 *Zinc for Coating*—The slab zinc, when used for the coating, shall be any grade of zinc conforming to Specification B 6.

**6. Weave**

6.1 The wire shall be woven throughout in the form of approximately uniform square mesh, having parallel sides and horizontal and vertical diagonals of approximately uniform dimensions. The top and bottom of the fabric shall be knuckled or twisted as specified in Section 10.

6.2 A typical diamond count for each standard height is shown in Table 1. Other diamond counts are permissible provided that they are consistent within a lot. The purchaser has the option to specify the diamond count (see 4.1.6).

**7. Size of Mesh**

7.1 The size of mesh shall be as indicated in Table 2.

7.2 The permissible variation from the specified size of mesh shall be ± 1/8 in. [3.2 mm] for all mesh sizes except 1 in., and ± 1/16 in. [±1.6 mm] for 1 in. mesh size.

7.3 The size of mesh shall be determined by measuring the minimum clear distance between the wires forming the parallel sides of the mesh, and determined as the average of two readings taken at right angles to each other.

**8. Size of Wire**

8.1 Chain-link fabric shall be fabricated from wire diameters as listed in Specification A 817, with a permissible variation from the specified diameter of the coated wire of ±0.005 in. [±0.13 mm].

**9. Height of Fabric**

9.1 Chain-link fabric shall be furnished in the standard heights shown in Table 2. Custom order fabric is available in heights to and including 20 ft. [6.56 m]. The height of fabric shall be the overall dimension from ends of twists or knuckles.

**TABLE 2 Sizes of Wire and Mesh<sup>A</sup>**

NOTE 1— For fabrics heights over 144 in., see 9.1.

Specified Diameter of Coated Wire, in.	Size, Coated Wire Gage	Size of Mesh, in.	Height of Fence Fabric, in.									
			36	42	48	60	72	84	96	108	120	144
0.192	6	2	36	42	48	60	72	84	96	108	120	144
0.148	9	2	36	42	48	60	72	84	96	108	120	144
0.148	9	1	36	42	48	60	72	84	96	108	120	144
0.120	11	2	36	42	48	60	72	84	...	...	...	...
0.120	11	1 3/4	...	...	...	...	...	...	96	108	120	144
0.120	11	1	36	42	48	60	72	84	96	108	120	144
0.113	11 1/2	2 1/8	36	42	48	60	72	...	...	...	...	...

<sup>A</sup>See Appendix X1 for metric equivalents.

Permissible variation from the specified height shall be ± 1 in. [±25 mm] for standard selvage.

**10. Selvage**

10.1 Unless otherwise specified by the purchaser, fabrics with 2 or 2 1/8 in. [50 or 54 mm] mesh, in heights 60 in. [1520 mm] and under shall be knuckled at both selvages. Fabric 72 in. [1830 mm] high and over shall be knuckled at one selvage and twisted at the other.

10.2 The selvages of fabrics with meshes of less than 2 in. [50 mm] shall be knuckled.

10.3 **Caution:** Twisted selvages for fence fabric under 72 in. [1830 mm] in height are not recommended because of consumer safety considerations.

**11. Weight of Zinc Coating**

11.1 The weight of zinc coating on the fabric may be ordered in two coating weight classes as follows:

11.1.1 *Class 1*—The weight of zinc coating shall not be less than 1.2 oz/ft<sup>2</sup> [366 g/m<sup>2</sup>] of uncoated wire surface.

11.1.2 *Class 2*—The weight of zinc coating shall not be less than 2 oz/ft<sup>2</sup> [610 g/m<sup>2</sup>] of uncoated wire surface, on wire of fabric coated before weaving. On fabric coated after weaving, the weight of zinc coating shall be not less than 2.0 oz/ft<sup>2</sup> [610 g/m<sup>2</sup>] of uncoated wire surface as determined from the average of two or more specimens, and not less than 1.8 oz/ft<sup>2</sup> [500 g/m<sup>2</sup>] of uncoated wire surface for any individual specimen.

**TABLE 1 Typical Diamond Count<sup>A</sup>**

NOTE 1—Other diamond counts are permitted (see 6.2).

NOTE 2— For fabric heights over 144 in., see 6.2.

NOTE 3—Variations to knuckled or twisted selvage may affect diamond count (see 6.2).

Nominal Diameter Coated Wire, in.	Size of Mesh, in.	Height of Fence Fabric, in.									
		36	42	48	60	72	84	96	108	120	144
0.192	2	10 1/2	12 1/2	13 1/2	17 1/2	20 1/2	24 1/2	27 1/2	31 1/2	34 1/2	41 1/2
0.148	2	10 1/2	12 1/2	13 1/2	17 1/2	20 1/2	24 1/2	27 1/2	31 1/2	34 1/2	41 1/2
0.148	1	20	23	27	33	39	45	53	61	67	79
0.120	2	10 1/2	12 1/2	14 1/2	17 1/2	20 1/2	24 1/2	...	...	...	...
0.120	1 3/4	...	...	...	...	...	...	31 1/2	35 1/2	39 1/2	47 1/2
0.120	1	20	23	27	33	39	45	53	61	67	79
0.113	2 1/8	9 1/2	11 1/2	13 1/2	16 1/2	19 1/2	...	...	...	...	...

<sup>A</sup>See Appendix X1 for metric equivalents.

NOTE 2—Fabric galvanized after fabrication is normally not produced with a Class 2 coating on 0.120-in. [3.05-mm] or 0.113-in. [2.87-mm] wire.

11.2 On fabric galvanized after weaving, the weight of coating shall be determined on one or more pieces of wire removed from the fabric. These specimens may be of any length over 12 in. [300 mm] and shall include both bends and straight sections, but shall not include either twists or knuckles.

11.3 The weight of coating shall be determined in accordance with Test Method A 90.

## 12. Breaking Strength

12.1 Wire constituting the fabric shall meet the minimum breaking strength listed in the Breaking Strength table of Specification A 817 when tested in accordance with Test Methods and Definitions A 370. Specimens to establish conformance to this requirement shall consist of individual pickets from a section of the fence fabric. The specimens shall be of sufficient length so as to be firmly gripped in the testing machine after straightening. The actual gage length (distance between jaws) of the specimen shall be limited to the undeformed length of wire between the two adjacent straightened bends.

## 13. Workmanship

13.1 Chain-link fence fabric shall be produced by methods recognized as good commercial practices. The zinc coating on galvanized-after-weaving fabric shall be applied in a continuous process and shall not be applied to the fabric in roll form.

13.2 Excessive roughness, blisters, sal ammoniac spots, bruises, and flaking shall be noted. These and other defects, if present to any considerable extent, shall provide a basis for rejection.

NOTE 3—On fabric that is zinc-coated before weaving, rust formations on the cut ends of the wire at the fabric selvages are inherent characteristics of this material and do not warrant rejection of the fabric.

## 14. Standard Length of Rolls

14.1 The standard length of roll shall be 50 ft [15.24 m]  $\pm$  1 % except as otherwise agreed upon at the time of purchase.

14.2 The length of roll shall be determined by unrolling a roll of fabric on a flat surface and exerting tension by appropriate means to remove all slack. The tension applied shall not reduce the actual height of the fabric by more than  $\frac{1}{16}$  in./ft [5.3 mm/m] of height or by more than  $\frac{1}{2}$  in. [12.7 mm], whichever is less.

## 15. Sampling and Number of Tests

15.1 One roll from every 50 rolls or fraction thereof in a lot shall be taken at random as a sample for test purposes. In no case shall less than two samples be tested, except when the lot is less than 10 rolls, only one roll shall be selected for the sample.

15.2 Sample rolls selected shall be inspected for weave (Section 6), size of mesh (Section 7), diamond count (6.2), wire size (Section 8), height of fabric (Section 9), selvage (Section 10) and length (Section 14).

15.3 On galvanized-after-weaving fabric, test specimens taken from the outside end of the sample rolls shall be tested for breaking strength (Section 12) and weight of zinc coating (Section 11).

15.4 If any specimen tested fails to meet the requirements of this specification, the roll represented by the specimen shall be rejected and two additional rolls shall be tested, both of which shall meet the requirements in every respect; otherwise, the lot represented by the samples may be rejected.

## 16. Inspection

16.1 Unless otherwise specified in the purchase order or contract, the manufacturer is responsible for the performance of all inspection and test requirements specified in this specification. Except as otherwise specified in the purchase order or contract, the manufacturer may use his own or any other suitable facilities for the performance of the inspection and test requirements unless disapproved by the purchaser at the time the order is placed. The purchaser shall have the right to perform any of the inspection and tests set forth in this specification when such inspections and tests are deemed necessary to assure that the material conforms to prescribed requirements.

## 17. Certification and Reports

17.1 When requested by the purchaser in the contract or order, a producer's or supplier's certification that the material was manufactured, sampled, tested, and inspected in accordance with this specification and has been found to meet the requirements. When specified in the purchase order or contract, a report of the tests results shall be furnished.

## 18. Packaging, Marking, and Loading

18.1 Each length of chain-link fence fabric shall be tightly rolled and firmly tied. Each roll shall carry a tag showing the class of coating, the specified wire size, the mesh size, the specified length and height of fabric in the roll, ASTM Designation A 392 and the name or mark of the manufacturer.

18.2 Unless otherwise specified, packaging, marking, and loading for shipment shall be in accordance with Practices A 700.

18.3 When specified in the contract or order, and for direct procurement by or direct shipment to the U.S. government, when Level A is specified, preservation, packaging, and packing shall be in accordance with Level A requirements of MIL-STD-163.

18.4 When specified in the contract or order and for direct procurement by or direct shipment to the U.S. government, marking for shipment, in addition to the requirements specified in the contract or order, shall be in accordance with MIL-STD-129 for U.S. military agencies and in accordance with Fed. Std. No. 123 for civil agencies.

## 19. Keywords

19.1 chain link fence; steel; coatings; zinc (galvanized); fence/fencing materials; chain link; zinc coated (galvanized) iron and steel articles; zinc coated (galvanized) steel chain link fence fabric

**APPENDIX**
**(Nonmandatory Information)**
**X1.**
**TABLE X1.1 Approximate Metric Equivalents for Tables 1 and 2**

Sizes of Wire and Mesh		Height of Fence Fabric	
in.	mm	in.	mm
0.192	4.88	36	910
0.148	3.76	42	1070
0.120	3.05	48	1220
0.113	2.87	60	1520
1	25	72	1830
1 <sup>3</sup> / <sub>4</sub>	44	84	2130
2	50	96	2440
2 <sup>1</sup> / <sub>8</sub>	54	108	2740
		120	3050
		144	3660

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# Standard Specification for Zinc-Coated (Galvanized) Low-Carbon Steel Armor Wire<sup>1</sup>

This standard is issued under the fixed designation A 411; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon ( $\epsilon$ ) indicates an editorial change since the last revision or reapproval.

## 1. Scope\*

1.1 This specification covers zinc-coated low-carbon steel wire for use in armoring for protection against damage of submarine and underground cables used for communication, control, or power purposes.

1.2 The values stated in inch-pound units are to be regarded as the standard.

## 2. Referenced Documents

### 2.1 *ASTM Standards:*<sup>2</sup>

- A 90/A 90M Test Method for Weight [Mass] of Coating on Iron and Steel Articles with Zinc or Zinc-Alloy Coatings
- A 938 Test Method for Torsion Testing of Wire
- B 6 Specification for Zinc (Slab Zinc)
- E 8 Test Methods of Tension Testing of Metallic Materials

## 3. Ordering Information

3.1 It shall be the responsibility of the purchaser to specify all requirements that are necessary for material under this specification. Such requirements may include, but are not limited to, the following information:

- 3.1.1 Quantity of each size,
- 3.1.2 Wire size, diameter in inches or [millimetres] (Section 12), and
- 3.1.3 Weight [Mass], inside diameter, and method of banding of coils.

## 4. Zinc for Coating

4.1 The slab zinc used for the coating shall be any grade of zinc conforming to Specification B 6.

## 5. Base Metal

5.1 The base metal shall be open-hearth, basic-oxygen, or electric-furnace steel, ingot or continuous cast, and of such

quality that, when processed and zinc-coated, the finished wire shall have the properties prescribed in this specification.

## 6. Joints

6.1 The wire shall be furnished in coils of one continuous length. Welds made prior to final wire drawing shall be permitted.

## 7. Tensile Strength

7.1 The zinc-coated wire shall have a tensile strength of not less than 50 000 psi [345 MPa], nor more than 70 000 psi [483 MPa]. The tensile strength of the zinc-coated wire shall be determined in accordance with Test Methods E 8. The diameter of the wire shall be measured over the zinc coating for the purpose of calculating the tensile strength.

## 8. Elongation

8.1 The zinc-coated wire shall have an elongation of not less than 10 % in 10 in. [254 mm] for nominal sizes 0.284 in. [7.21 mm] and smaller. Nominal sizes larger than 0.284 in. shall have an elongation of not less than 9 % in 10 in. The elongation shall be determined as the permanent increase in length after failure of a marked section of the wire originally 10 in. in length.

## 9. Torsion Test

9.1 The zinc-coated wire shall withstand without fracture the minimum number of turns specified in Table 1. This test shall be done in accordance with Test Method A 938 and the number of turns to failure shall meet the requirements of Table 1.

## 10. Weight of Coating

10.1 The weight of zinc coating, in ounces per square foot or [grams per square metre] of uncoated wire surface, shall be not less than that specified in Table 2.

10.2 *Weight of Coating Test*—The zinc coating shall be tested for weight by a stripping test in accordance with Test Methods A 90/A 90M.

## 11. Adherence of Coating

11.1 The zinc coating shall remain adherent when the wire is wrapped at a rate of not more than 15 turns per minute in a close helix of at least 2 turns around a cylindrical mandrel of

<sup>1</sup> This specification is under the jurisdiction of ASTM Committee A05 on Metallic Coated Iron and Steel Products and is the direct responsibility of Subcommittee A05.12 on Wire Specifications.

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<sup>2</sup> For referenced ASTM standards, visit the ASTM website, [www.astm.org](http://www.astm.org), or contact ASTM Customer Service at [service@astm.org](mailto:service@astm.org). For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

\*A Summary of Changes section appears at the end of this standard.

**TABLE 1 Minimum Number of Turns**

Nominal Wire Diameter, in. [mm]	Minimum Turns (8 in. gage length)
0.239 [6.07] and over	7
0.238 to 0.166 [6.05 to 4.22]	9
0.165 to 0.110 [4.19 to 2.79]	13
0.109 to 0.065 [2.77 to 1.65]	19

**TABLE 2 Minimum Weights of Zinc Coating**

Nominal Diameter of Coated Wire, in. [mm]	Minimum Weight of Zinc Coating oz/ft <sup>2</sup> [g/m <sup>2</sup> ] of Uncoated Wire Surface
0.340 [8.64]	1.00 [300]
0.300 [7.62]	1.00 [300]
0.284 [7.21]	1.00 [300]
0.259 [6.58]	1.00 [300]
0.238 [6.05]	1.00 [300]
0.220 [5.59]	1.00 [300]
0.203 [5.16]	1.00 [300]
0.165 [4.19]	0.90 [270]
0.134 [3.40]	0.80 [240]
0.109 [2.77]	0.80 [240]
0.083 [2.11]	0.60 [180]
0.065 [1.65]	0.50 [150]

the diameter specified in Table 3. The zinc coating shall be considered as meeting this requirement if, when the wire is wrapped about the specified mandrel, the coating does not flake and none of it can be removed from the wire by rubbing with fingers. Loosening or detachment during the adhesion test of superficial, small particles of zinc formed by mechanical polishing of the surface of zinc-coated wire shall not be considered cause for rejection.

## 12. Size and Permissible Variations

12.1 *Size*—The size of the zinc-coated wires shall be expressed as the diameter of the wire in decimal fractions of an inch or [millimetres].

12.2 *Permissible Variations*—The permissible variations of the zinc-coated wire from the nominal diameter shall be as specified in Table 4.

## 13. Workmanship, Finish and Appearance

13.1 The surface of the wire shall be free from injurious scale, flaws, splits, and other imperfections not consistent with good commercial practice. The coating shall be continuous and reasonably uniform.

## 14. Sampling

14.1 The inspector shall select at random one sample coil from every 10 coils in the first 100 coils of the lot, and one

**TABLE 3 Mandrel Diameter for Adherence of Coating Tests**

Wire Diameters, in. [mm]	Mandrel Size
0.259 [6.58] and over	5×
0.258 to 0.134 [6.55 to 3.40]	3×
0.133 [3.38] and under	2×

**TABLE 4 Permissible Variations in Diameter of Zinc-Coated Wire**

NOTE 1—It is recognized that the surfaces of zinc coatings, particularly those produced by hot-dip galvanizing, are not perfectly smooth and devoid of irregularities. If the tolerances shown are rigidly applied to such irregularities that are inherent to the product, unjustified rejections of wire that would actually be satisfactory for use could occur. Therefore, it is intended that these tolerances be used in gaging the uniform areas of the galvanized wire.

Nominal Diameter of Coated Wire, in. [mm]	Permissible Variations, plus or minus, in. [mm]
0.340 to 0.260 [8.64 to 6.60]	0.006 [0.15]
0.259 to 0.166 [6.58 to 4.22]	0.005 [0.13]
0.165 to 0.109 [4.19 to 2.77]	0.004 [0.10]
0.108 to 0.065 [2.74 to 1.65]	0.003 [0.08]

sample for every additional 35 coils but not less than 3 coils from the entire lot. From each coil of zinc-coated wire thus selected, a sample of suitable length shall be taken for the weight of coating and mechanical tests as specified in Sections 7-11, inclusive.

## 15. Inspection

15.1 Unless otherwise specified in the contract or purchase order, the manufacturer is responsible for the performance of all inspection and test requirements specified in this standard. Except as otherwise specified in the contract or purchase order, the manufacturer may use his own or any other suitable facility for the performance of the inspection and test requirements unless disapproved by the purchaser at the time the order is placed. The purchaser shall have the right to perform any of the inspections and tests set forth in this standard when such inspections and tests are deemed necessary to assure that the material conforms to prescribed requirements.

## 16. Rejection

16.1 Failure of any of the test specimens to comply with the requirements of this specification shall constitute grounds for rejection of the lot represented by the specimen. The lot may be re-submitted for inspection by testing every coil for the characteristics in which the specimen failed, and sorting out the defective coils.

## 17. Packaging

17.1 The finished zinc-coated wire shall be furnished in compact coils reasonably symmetrical in shape. The weight, inside diameter, and method of banding of the coils shall be agreed upon between the manufacturer and the purchaser.

## 18. Marking

18.1 A durable tag shall be attached to each coil showing the nominal size of wire and the name or mark of the manufacturer. The starting end of each coil shall be indicated by a suitable tag.

## 19. Keywords

19.1 armor wire; zinc coated steel armor wire



SUMMARY OF CHANGES

Committee A05 has identified the location of selected changes to this standard since the last issue (A 411 - 98) that may impact the use of this standard.

A 411 - 03:

- (1) Edited paragraph 3.1 for ordering information consistency with all A05 standards.
- (2) Added metric characteristics to paragraphs 3.1.2, 3.1.3, 10.1, and 12.1 since metric values are provided in the tables.
- (3) Added the casting method to the steelmaking method for clarification in Section 5.

- (4) Changed Section 9 for clarity and uniformity between standards.
- (5) Changed Section 15 for clarity.
- (6) Made an editorial change to the first sentence in paragraph 18.1.
- (7) Eliminated Birmingham Wire Gage from Table 2.

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Designation: A 428/A 428M – 9501

# Standard Test Method for Weight [Mass] of Coating on Aluminum-Coated Iron or Steel Articles<sup>1</sup>

This standard is issued under the fixed designation A 428/A 428M; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon ( $\epsilon$ ) indicates an editorial change since the last revision or reapproval.

## 1. Scope

1.1 This test method covers procedures for determining the weight [mass] of coating on aluminum-coated iron or steel sheets and wire, and on other aluminum-coated iron and steel articles.

1.2 The final results determined by this test method shall be expressed in inch-pound units or SI units, depending on the units used in the material specification to which the results are to be compared. Certain portions of the procedure involving determination of specimen weight [mass] have traditionally been performed in SI units, and corresponding inch-pound units are not included.

~~1.3 In this test method, the quantity of material is described in terms of weight [mass]. Weight is the force describing the gravitation attraction of the earth on a quantity of material. In general usage on the surface of the earth, mass of an unknown quantity is determined by comparing with a known quantity (either directly or indirectly and ignoring the buoyancy of the air) as indicated by the attraction of the earth's gravity, thus weight is actually determined. See Appendix X1 of Terminology E-12 for further discussion of weight and mass.~~

~~1.4~~

1.3 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.* For a specific precautionary statement, see Note 1.

## 2. Referenced Documents

2.1 *ASTM Standards:*

<sup>1</sup> This test method is under the jurisdiction of ASTM Committee ~~A-5~~ A05 on Metallic-Coated Iron and Steel Products and is the direct responsibility of Subcommittee A05.07 on Methods of Testing.

Current edition approved ~~Oct. 10, 1995~~, April 10, 1995; 2001. Published ~~December 1995~~, June 2001. Originally published as A 428 – 58 T. Last previous edition ~~A 428 – 89 $\epsilon$ 1~~, A 428 – 95.

D 1193 Specification for Reagent Water<sup>2</sup>

~~E 12 Terminology Relating to Practice for Using Significant Digits in Test Data to Density and Specific Gravity of Solids, Liquids, and Gases Determine Conformance With Specifications<sup>3</sup>~~

~~E 29 Practice for Using Significant Digits in Test Data to Determine Conformance With Specifications<sup>4</sup>~~

E 691 Practice for Conducting an Interlaboratory Study to Determine the Precision of Test Methods<sup>4</sup>

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<sup>2</sup> *Annual Book of ASTM Standards*, Vol 11.01.

<sup>3</sup> *Annual Book of ASTM Standards*, Vols ~~02.03~~ and ~~15.05~~<sup>2</sup>.

<sup>4</sup> *Annual Book of ASTM Standards*, ~~Vols 02.03 and 14.02~~, Vol 14.02.

### 3. Significance and Use

3.1 This test method provides a standard method of determining the weight [mass] of coating for comparison with specification requirements. A coating of aluminum on iron or steel articles provides protection against corrosion by forming a relatively inert barrier. Specifications for aluminum-coated articles occasionally provide for different classes (weights) [masses] of coating so that the purchaser can select the coating weight [mass] most suited to his needs. The heavier coating will provide greater protection against mechanical damage which may break the coating.

### 4. Reagents

4.1 *Purity of Reagents*—Reagent grade chemicals shall be used in all tests. Unless otherwise indicated, it is intended that all reagents shall conform to the specifications of the Committee on Analytical Reagents of the American Chemical Society, where such specifications are available.<sup>5</sup> Other grades may be used, provided it is first ascertained that the reagent is of sufficiently high purity to permit its use without lessening the accuracy of the determination.

4.2 *Purity of Water*—Water used in preparation of reagent solutions shall conform to Specification D 1193, Type IV or better.

4.3 *Antimony Trichloride Solution*—Dissolve 200 g of antimony trichloride ( $\text{SbCl}_3$ ) in 1000 mL of concentrated hydrochloric acid (HCl, sp gr 1.19) without heating.

4.4 *Hydrochloric Acid* (sp gr 1.19) —Concentrated hydrochloric acid (HCl).

4.5 *Sodium Hydroxide Solution* (20 %) —Dissolve 20 parts by weight [mass] of sodium hydroxide (NaOH) in 80 parts of water.

4.6 *Stannous Chloride Solution*—Dissolve 100 g of stannous chloride ( $\text{SnCl}_2 \cdot 2\text{H}_2\text{O}$ ) in 1000 mL of concentrated hydrochloric acid (HCl, sp gr 1.19) without heating. Add a few granules of reagent grade tin.

4.7 *Hydrochloric Acid (1 + 1)*—Mix 500 mL of HCl (sp. gr. 1.19) with 500 mL of reagent water and cool to room temperature.

NOTE 1—**Warning:** Small amounts of the poisonous gas stibine ( $\text{SbH}_3$ ) may be evolved during the stripping process using the hydrochloric acid-antimony trichloride-stannous chloride method. Hydrochloric acid fumes are present, and hydrogen gas is evolved in the stripping process. Therefore, the test should be performed under conditions of adequate ventilation. A fume hood is recommended for large numbers of samples or where the test is to be carried out frequently over extended periods of time.

### 5. Sampling

5.1 *Aluminum-Coated Sheets*—Samples for weight-of-coating [mass-of-coating] determination shall be secured as designated in the appropriate specification. Test specimens shall have a minimum area of 3 in.<sup>2</sup>[2000 mm<sup>2</sup>] of sheet, but preferably approximately 5 in.<sup>2</sup>[3300 mm<sup>2</sup>] of sheet.

NOTE 2—For convenience in calculating test results in inch-pound units, the specimen should have an area of 5.08 in.<sup>2</sup> of sheet (2.25 ± 0.01 in. square or 2.54 ± 0.01 in. in diameter). The weight [mass] of coating in grams on a specimen of that area is numerically equal to the weight [mass] of coating in ounces per square foot of sheet. For results to be reported in SI units, the specimen should have an area of 3330 mm<sup>2</sup> of sheet (57.7 ± 0.1 mm square or 65.1 ± 0.1 mm in diameter).

5.2 *Aluminum-Coated Wire*—Samples shall be secured as designated in the appropriate specification. The specimen of aluminum-coated wire may be of any length over 12 in. (approximately 300 mm), but preferably about 24 in. (approximately 600 mm). Where a continuous length is not available, shorter lengths totaling over 12 in., but preferably about 24 in., shall be used. Since the density of the steel is known (0.283 lb/in. or 7830 kg/m), it is not necessary to use a specific length of specimen.

5.3 *Aluminum-Coated Articles Other Than Sheet or Wire*—Samples for weight [mass] of coating determination shall be secured as designated in the appropriate specification. Except as otherwise provided, the specimens should have a minimum area of 3 in.<sup>2</sup>[1935 mm<sup>2</sup>] of aluminum-coated surface. For very small items, several pieces may have to be stripped to obtain the minimum area.

5.3.1 In the case of threaded articles, such as bolts and screws, the determination shall be made on a portion of the article that does not include any thread.

### 6. Procedure

#### 6.1 Stripping of

6.1 Strip the aluminum coating from the specimens ~~may be done by~~ using one of the following methods— the sodium hydroxide-hydrochloric acid method ~~or (method A)~~, the hydrochloric acid-antimony trichloride-stannous chloride method (method B) or dilute hydrochloric acid method (method C).

NOTE 3—Methods A and B are the most common methods used for sheets.

6.2 Clean the specimens immediately before determining the weight [mass] by washing in petroleum ether or other suitable solvent, and dry thoroughly.

6.3 Determine the weight [mass] of the specimens individually to the nearest 0.01 g.

<sup>5</sup> *Annual Book of Reagent Chemicals, American Chemical Society Specifications*, American Chemical Society, Washington, DC. For suggestions on the testing of ASTM reagents not listed by the American Chemical Society, see *Analar Standards for Laboratory Chemicals*, Vol 14-02, BDH Ltd., Poole, Dorset, U.K., and the *United States Pharmacopeia and National Formulary*, U.S. Pharmaceutical Convention, Inc. (USPC), Rockville, MD.

6.4 *Sodium Hydroxide-Hydrochloric Acid Method (method A)*—Heat the NaOH solution to approximately 90°C (Note-3) 4) and immerse each specimen in the hot solution until the strong reaction ceases. With silicon-free coatings, gas may be evolved for considerable time, but the specimens should not be left in the solution for more than a few minutes. Longer immersion inhibits the removal of coating during subsequent dips. Several specimens may be immersed simultaneously provided all surfaces are freely exposed to the solution. Remove specimens from solution and scrub all surfaces under running tap water with a clean cellulose sponge to remove the loose deposit formed in the NaOH solution. Rather vigorous scrubbing may be necessary for some types of coating, but abrasive materials should not be used to remove the deposit. Blot with a towel to remove most of the water (Note-4) 5) and immerse each specimen singly for not more than 3 s in HCl (sp gr 1.19) at room temperature. Remove, scrub again under running tap water with a sponge, and re-immerses in the hot NaOH solution for not more than a few minutes or until action again ceases. Repeat this cycle until immersion in HCl shows no visible reaction (Note-5): 6). One to three or more cycles may be required, depending on the type and weight of coating. After the final immersion in the NaOH and HCl solutions, scrub as before, dry thoroughly, and determine the weight [mass] of each specimen to the nearest 0.01 g.

NOTE 34—This temperature is not critical, but the solution should be held several degrees below the boiling point (approximately 105°C) to prevent excessive foaming during the first immersion. The beaker used for heating the solution and immersing the specimens should be less than half full of solution to avoid the danger of foaming over when the specimens are immersed.

NOTE 45—Most of the water should be removed to prevent dilution of the HCl, as dilute HCl will attack the base metal to a greater extent than concentrated HCl.

NOTE 56—It is sometimes difficult to determine the point at which all of the alloy layer has been removed, when stripping silicon-free coatings. If in doubt, determine the weight [mass] of the specimen (after scrubbing and drying) and then put it through one additional stripping cycle. Loss in weight [mass] due to the additional cycle will be of the order of 0.005 g on a 2.25-in. [57.2-mm] square sheet specimen, if all the coating had been removed before the extra cycle.

6.5 *Hydrochloric Acid-Antimony Trichloride-Stannous Chloride Method (method B)*—After determining the weight [mass], immerse each specimen singly in a solution made by mixing 100 mL of antimony trichloride solution and 100 mL of stannous chloride solution (Note-6): 7). Allow the specimen to remain immersed until the evolution of hydrogen has ceased. Action will stop after 1 to 4 min, or somewhat longer, depending on the thickness and silicon content of the coating. A fresh solution must be used for each test (Note-7): 8). The temperature of the stripping solution should not exceed 38°C. After stripping, wash the specimen and scrub it with a soft cloth, using a small amount of abrasive cleansing powder if necessary. Rinse, and dry with an absorbent cloth or paper. Again determine the weight [mass] of the specimens to the nearest 0.01 g.

NOTE 67—Mix the antimony trichloride and stannous chloride solutions together as needed.

NOTE 78—Very heavy coatings may show residual coating after all action has stopped. If on examination after stripping, any coating still remains, repeat the immersion step using fresh solution.

6.6 *Sheet Specimens—Determine Dilute Hydrochloric Acid Method (1 + 1) (method C)*—After determining the area of sheet (one surface) weight (mass), immerse each specimen singly in the stripping solution and allow to remain until the nearest 0.01 in.<sup>2</sup> [5 mm<sup>2</sup>]. If specimens were prepared violent evolution of hydrogen has ceased and only a few bubbles are being evolved. Action will stop after 1 to 4 min or somewhat longer depending on the dimensions as provided in Note 2, they shall thickness and silicon content of the coating. The same solution may be presumed to have an area used repeatedly until the time for stripping becomes inconveniently long. The temperature of 5.08 in.<sup>2</sup> [3330 mm<sup>2</sup>]. When it is not possible to determine the area accurately, as in stripping solution shall at no time exceed 100°F (38°C). After stripping, wash the specimens from corrugated sheets, determine by scrubbing them under running water, dip in hot water and wipe or blow dry. Determine the average thickness weight (mass) of the stripped sheets specimens again, to the nearest 0.001 in. [0.01 mm]. same precision as in the initial determination.

6.7 *Sheet Specimens*—Determine the area of sheet (one surface) to the nearest 0.01 in.<sup>2</sup> [5 mm<sup>2</sup>]. If specimens were prepared to the dimensions as provided in Note 2, they shall be presumed to have an area of 5.08 in.<sup>2</sup> [3330 mm<sup>2</sup>]. When it is not possible to determine the area accurately, as in specimens from corrugated sheets, determine the average thickness of the stripped sheets to the nearest 0.001 in. [0.01 mm].

6.8 *Wire Specimens*—Determine the diameter of the stripped wire to the nearest 0.001 in. [0.01 mm] by taking the average of two measurements at right angles to each other.

6.89 *Specimens Other Than Sheet or Wire*— Determine the total coated area of the original specimen to the nearest 0.01 in.<sup>2</sup> [5 mm<sup>2</sup>]. Alternatively, for specimens of uniform thickness of base metal, such as a piece of plate or pipe, determine the average thickness of the stripped specimen to the nearest 0.001 in. [0.01 mm].

## 7. Calculation

### 7.1 Aluminum-Coated Sheet:

#### 7.1.1 Results in Inch-Pound Units :

7.1.1.1 Calculate the weight [mass] of aluminum-coating when the area of sheet is determined as follows:

$$C = [(W_1 - W_2)/A] \times K \quad (1)$$

where:

C = weight [mass] of coating, oz/ft<sup>2</sup> of sheet,

- $W_1$  = original weight [mass] of specimen, g,  
 $W_2$  = weight [mass] of stripped specimen, g,  
 $A$  = area of sheet, in.<sup>2</sup> or mm<sup>2</sup>, and  
 $K$  = a constant = 5.08 when  $A$  is in in.<sup>2</sup> =  $3.28 \times 10^3$  when  $A$  is in mm<sup>2</sup>.

NOTE 89—If the specimen was prepared to the dimensions as provided in Note 2, having an area of 5.08 in.<sup>2</sup>, the loss of weight [mass] in grams is numerically equal to the weight [mass] of coating in ounces per square foot of sheet.

7.1.1.2 When it is not possible to secure a specimen of measurable area, calculate the weight [mass] of coating as follows:

$$C = [(W_1 - W_2)/W_2] \times T \times K \quad (2)$$

where:

- $C$  = weight [mass] of coating, oz/ft<sup>2</sup> of sheet,  
 $W_1$  = original weight [mass] of specimen, g,  
 $W_2$  = weight [mass] of stripped specimen, g,  
 $T$  = thickness of stripped sheet, in. or mm, and  
 $K$  = a constant = 652 if  $T$  is in in. = 25.7 if  $T$  is in mm.

7.1.2 Results in Metric Units:

7.1.2.1 Calculate the weight [mass] of aluminum coating as follows when the area of sheet is determined:

$$C = [(W_1 - W_2)/A] \times K \quad (3)$$

where:

- $C$  = weight [mass] of coating, g/m<sup>2</sup> of sheet,  
 $W_1$  = original weight [mass] of specimen, g,  
 $W_2$  = weight [mass] of stripped specimen, g,  
 $A$  = area of sheet in in.<sup>2</sup> or mm<sup>2</sup>, and  
 $K$  = a constant =  $1.55 \times 10^3$  if  $A$  is in in.<sup>2</sup> =  $1 \times 10^6$  if  $A$  is in mm<sup>2</sup>.

NOTE 910—If the specimen was prepared to the dimensions as provided in Note 2, having an area of 3330 mm<sup>2</sup> of sheet, the factor  $K/A$  is approximately 300, which may be used in the calculation.

7.1.2.2 When it is not possible to obtain a specimen of measurable area, calculate the weight [mass] of the coating as follows:

$$C = [(W_1 - W_2)/W_2] \times T \times K \quad (4)$$

where:

- $C$  = weight [mass] of coating, g/m<sup>2</sup> of sheet,  
 $W_1$  = original weight [mass] of the specimen, g,  
 $W_2$  = weight [mass] of the stripped specimen, g,  
 $T$  = thickness of stripped sheet, in. or mm, and  
 $K$  = a constant =  $1.99 \times 10^5$  if  $T$  is in in. =  $7.83 \times 10^3$  if  $T$  is in mm.

7.2 Aluminum-Coated Wire:

7.2.1 Results in Inch-Pound Units :

7.2.1.1 Calculate the weight [mass] of aluminum coating as follows:

$$C = [(W_1 - W_2)/W_2] \times D \times M \quad (5)$$

where:

- $C$  = weight [mass] of coating, oz/ft<sup>2</sup> of stripped wire surface,  
 $W_1$  = original weight [mass] of specimen, g,  
 $W_2$  = weight [mass] of stripped specimen, g,  
 $D$  = diameter of stripped wire, in. or mm, and  
 $M$  = a constant = 163 if  $D$  is in in. = 6.42 if  $D$  is in mm

7.2.2 Results in Metric Units:

7.2.2.1 Calculate the weight [mass] of aluminum coating as follows:

$$C = [(W_1 - W_2)/W_2] \times D \times M \quad (6)$$

where:

- $C$  = weight [mass] of coating, g/m<sup>2</sup> of stripped wire surface,  
 $W_1$  = original weight [mass] of specimen, g,  
 $W_2$  = weight [mass] of stripped specimen, g,  
 $D$  = diameter of stripped wire, in. or mm, and  
 $M$  = a constant =  $4.97 \times 10^4$  if  $D$  is in in. =  $1.96 \times 10^3$  if  $D$  is in mm.

7.3 Aluminum-Coated Articles Other Than Sheet or Wire:

7.3.1 Results in Inch-Pound Units :

7.3.1.1 Calculate the weight [mass] of aluminum coating as follows:

$$C = [(W_1 - W_2)/A] \times N \quad (7)$$

where:

- $C$  = weight [mass] of coating, oz/ft<sup>2</sup> of surface,
- $W_1$  = original weight [mass] of specimen, g,
- $W_2$  = weight [mass] of stripped specimen, g,
- $A$  = coated area of original specimen, in.<sup>2</sup> or mm<sup>2</sup>, and
- $N$  = a constant = 5.08 if  $A$  is in in.<sup>2</sup> =  $3.28 \times 10^3$  if  $A$  is in mm<sup>2</sup>.

7.3.1.2 If the specimen has a uniform thickness of base metal, the weight [mass] of the aluminum coating may be calculated as follows:

$$C = [(W_1 - W_2)/W_2] \times G \times Z \quad (8)$$

where:

- $C$  = weight [mass] of coating, oz/ft<sup>2</sup> of surface,
- $W_1$  = original weight [mass] of specimen, g,
- $W_2$  = weight [mass] of stripped specimen, g,
- $G$  = thickness of stripped specimen, in. or mm, and
- $Z$  = a constant = 326 if  $G$  is in in. = 12.8 if  $G$  is in mm.

### 7.3.2 Results in Metric Units:

7.3.2.1 Calculate the weight [mass] of aluminum coating as follows:

$$C = [(W_1 - W_2)/A] \times N \quad (9)$$

where:

- $C$  = weight [mass] of coating, g/m<sup>2</sup> of surface,
- $W_1$  = original weight [mass] of specimen, g,
- $W_2$  = weight [mass] of stripped specimen, g,
- $A$  = coated area of original specimen, in.<sup>2</sup> or mm<sup>2</sup>, and
- $N$  = a constant =  $1.55 \times 10^3$  if  $A$  is in in.<sup>2</sup> =  $1 \times 10^6$  if  $A$  is in mm<sup>2</sup>.

7.3.2.2 If the specimen has a uniform thickness of base metal, the weight [mass] of the aluminum coating may be calculated as follows:

$$C = [(W_1 - W_2)/W_2] \times G \times Z \quad (10)$$

where:

- $C$  = weight [mass] of coating, g/m<sup>2</sup>, of surface,
- $W_1$  = original weight [mass] of specimen, g,
- $W_2$  = weight [mass] of stripped specimen, g,
- $G$  = thickness of stripped specimen, in. or mm, and
- $Z$  = a constant =  $9.95 \times 10^4$  if  $G$  is in in. =  $3.92 \times 10^3$  if  $G$  is in mm.

## 8. Report

8.1 Report the following information:

8.1.1 Weight [mass] of coating on aluminum-coated sheet is expressed in weight [mass] per unit area of sheet, which is the sum of the weights [masses] of coating on both surfaces of the sheet. Weights [masses] of coating on each surface of the sheet are not necessarily equal. Coating weights [masses] on all aluminum-coated articles other than sheets are expressed in weight [mass] per unit area of surface.

8.1.2 Report the weight [mass] of aluminum coating to the nearest 0.01 oz/ft<sup>2</sup>—when reporting in inch-pound units.

8.1.3 Report the weight [mass] of aluminum coating to the nearest 1 g/m<sup>2</sup> when reporting in metric (SI) units.

8.1.4 When the weight [mass] of coating of a number of specimens is to be averaged to determine conformance with a specification limit, the average value shall be reported to the precision of 8.1.2 and 8.1.3 in accordance with the rounding method of Practice E 29.

## 9. Precision and Bias <sup>6</sup>

9.1 *Precision*—The precision of this test method for sheet products has been determined according to Practice E 691.

~~Reagent Chemicals, American Chemical Society Specifications~~, American Chemical Society, Washington, DC. For suggestions on the testing of reagents not listed by the American Chemical Society, see *Analar Standards for Laboratory Chemicals*, BDH Ltd., Poole, Dorset, U.K., and the *United States Pharmacopoeia and National Formulary*, U.S. Pharmaceutical Convention, Inc.

9.1.1 The repeatability of the test method was found to be 0.031 oz/ft<sup>2</sup>[9.5 g/m<sup>2</sup>]<sup>2</sup> of sheet and the reproducibility was found to be 0.034 oz/ft<sup>2</sup>[10.4 g/m<sup>2</sup>].<sup>2</sup>

NOTE 1<sup>1</sup>—These precision results are based on testing specimens having an area of 5.08 in.<sup>2</sup>(32.8 cm<sup>2</sup>) of sheet. Other test specimen sizes may yield different precision results.

9.1.2 The precision of this test method for products other than sheet steel has not been determined.

NOTE 1<sup>2</sup>—Repeatability and reproducibility, based on test error alone, are defined as the difference, in absolute value, of two test results obtained in the same laboratory, or between laboratories on the same material, (the difference will be expected to exceed the repeatability or reproducibility only about 5 % of the time).

9.2 *Bias*—Since there is no accepted reference material suitable for determining bias for the procedures in this test method, no statement on bias is being made.

## 10. Keywords

10.1 aluminum coating; coating weight [mass]; steel sheets; steel wire

~~(USPC), Rockville, MD.~~

<sup>6</sup> Research report available from ASTM Headquarters. Request RR: A05-1000.

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## Standard Specification for Zinc-Coated Flat Steel Armoring Tape<sup>1</sup>

This standard is issued under the fixed designation A 459; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon ( $\epsilon$ ) indicates an editorial change since the last revision or reapproval.

### 1. Scope

1.1 This specification covers requirements for zinc-coated flat steel tape in coils for use as interlocking armor and flat armor for electrical cables. The zinc-coated tape is produced with three classes of zinc coating weight.

1.2 The values stated in inch-pound units are to be regarded as the standard. The values in brackets are provided for information only.

### 2. Referenced Documents

#### 2.1 ASTM Standards:

A 90/A 90M Test Method for Weight [Mass] of Coating on Iron and Steel Articles with Zinc or Zinc-Alloy Coatings<sup>2</sup>

A 902 Terminology Relating to Metallic Coated Steel Products<sup>2</sup>

B 6 Specification for Zinc<sup>3</sup>

### 3. Terminology

3.1 *Definitions*—See Terminology A 902 for definitions of general terminology relating to metallic-coated steel products.

### 4. Ordering Information

4.1 Orders for material under this specification shall include the following information:

4.1.1 Quantity of each size,

4.1.2 Width and thickness (see 13),

4.1.3 Copper-bearing steel base metal, when required (see 5),

4.1.4 Class of coating (see 11), and

4.1.5 Packaging requirements (see 17).

### 5. Materials and Manufacture

5.1 The base metal shall be steel made by the open-hearth, basic-oxygen, or electric-furnace process and of such quality that when processed and coated with zinc, the finished tape shall have the properties and characteristics prescribed in this specification.

5.2 The uncoated tape shall have a mill finish and may have either a mill or slit edge. If the uncoated tape is manufactured by slitting or shearing, slitting burrs shall be kept to a minimum consistent with good commercial practice.

5.3 The zinc shall be applied by either the hot-dip or the electrogalvanizing process by a final operation so that all surfaces including edges are coated.

5.4 The slab zinc when used shall conform to any grade of zinc described in Specification B 6.

### 6. Joints

6.1 The zinc-coated tape shall be furnished in coils of one continuous length, with not more than an average of one weld/50 lb [23 kg]. Only welds made prior to the zinc coating operation shall be permitted and the area of such welds shall conform to the standard tolerance for thickness. The welds shall be smooth and free of sharp projections.

### 7. Sampling

7.1 During the visual inspection specified in Section 16, the inspector shall select at random, 1 sample coil from every 10 coils in the first 100 coils of the lot and 1 sample coil for every additional 35 coils, but not less than 3 coils from the entire lot.

7.2 From each coil of zinc-coated tape thus selected, a sample of suitable length shall be taken for the weight of coating and the mechanical tests as specified in Sections 8 to 12.

7.3 Any sample that indicates the presence of a weld shall be discarded and another sample shall be taken from the coil for testing.

### 8. Tensile Strength

8.1 The zinc-coated tape shall have a tensile strength of 70 ksi [483 MPa], maximum. The tensile strength shall be determined on longitudinal specimens consisting of the full width of the tape when practical, or a straight specimen cut or sheared from the center of the tape.

### 9. Elongation

9.1 The zinc-coated tape shall have an elongation of not less than 10 % in 10 in. [254 mm]. The elongation shall be determined as the permanent increase in length, after failure of a marked section of the tape specimen originally 10 in. in length.

<sup>1</sup> This specification is under the jurisdiction of ASTM Committee A05 on Metallic Coated Iron and Steel Products and is the direct responsibility of Subcommittee A05.11 on Sheet Specifications.

Current edition approved April 10, 2003. Published June 2003. Originally approved in 1961. Last previous edition approved in 1997 as A 459 – 97.

<sup>2</sup> *Annual Book of ASTM Standards*, Vol 01.06.

<sup>3</sup> *Annual Book of ASTM Standards*, Vol 02.04.



## 10. Ductility

10.1 The tape shall be capable of being bent flat on itself, either lengthwise or crosswise, without indication of failure. There shall be no base metal cracks along any bend visible to the naked eye. Cracks at sheared edges and coarse grains on the bends of any specimens may be disregarded. Flaking or cracking of the galvanized finish shall not be interpreted as a failure of the material.

## 11. Weight of Coating

11.1 The weight of zinc coating shall not be less than that prescribed for the class specified, as follows:

Class	Weight of Zinc Coating, oz/ft <sup>2</sup> [g/m <sup>2</sup> ] (Total of Both Surfaces and Both Edges)
Class I	0.35 [110]
Class II	0.70 [210]
Class III	1.00 [300]

11.2 The weight of zinc coating specified is the total amount on both surfaces and both edges of the tape in ounces per square foot [grams per square metre]. The weight of zinc coating shall be calculated in accordance with the section on zinc-coated articles other than sheet or wire of Test Method A 90/A 90M, using the following equation:

$$C = [(W_1 - W_2)/A] \times N$$

11.3 The weight of coating shall be determined by the Hydrochloric Acid-Antimony Chloride Method prescribed in Test Method A 90.

## 12. Adherence of Coating

12.1 The zinc coating shall remain adherent without flaking or spalling when the tape is subjected to a 180° bend over a mandrel of the following diameter:

Class	Diameter of Mandrel, in. [mm]
Classes I and II	1/8 [3.18]
Class III	5/8 [15.88]

12.2 The zinc coating shall be considered as meeting this requirement if, when the tape is bent around the specified mandrel, the coating does not flake and none of it can be removed from the tape by rubbing with the fingers. Loosening or detachment during the adherence test of superficial small particles of zinc formed by mechanical polishing of the surface of the zinc-coated tape shall not constitute failure in this test.

## 13. Permissible Variations in Dimensions

13.1 *Width and Thickness*—The width and thickness of the finished tape shall be expressed in decimal fractions of an inch. The variations in the width and thickness of zinc-coated armoring tape shall be within the limits specified in Table 1.

13.2 *Camber*—The permissible camber for zinc-coated tape shall not exceed the amounts specified in Table 2.

## 14. Workmanship and Finish

14.1 The surface of the tape shall be free of injurious scale, flaws, seams and splits, and other imperfections not consistent with good commercial practice. The zinc coating shall be smooth and continuous.

## 15. Inspection

15.1 The manufacturer shall afford the inspector representing the purchaser all reasonable facilities, without charge, to satisfy him that the material is being furnished in accordance with this specification. All tests and inspections shall be made at the place of manufacture prior to shipment, unless otherwise agreed upon at the time of the purchase, and shall be so conducted as not to interfere unnecessarily with the operation of the works.

## 16. Rejection

16.1 The inspector shall visually examine the entire shipment or lot of coils for surface imperfections. The purchaser may reject the entire lot if after visual examination, more than 3 % of the coils in the entire lot are found defective, or if more than 3 % of the samples selected in accordance with Section 6 fail to pass any of the tests specified in Sections 8 to 13. If not more than 3 % of the samples fail, a second set of samples, consisting of two specimens from each of the coils from which the original nonconforming samples were taken, shall be cut and tested for the nonconforming properties. If any of these samples fail, the purchaser may reject the entire lot.

## 17. Packaging

17.1 The finished zinc-coated tape shall be furnished in compact coils reasonably symmetrical in shape. The weight, inside diameter, and method of banding of the coils shall be agreed upon between the manufacturer and the purchaser.

**TABLE 1 Permissible Variations in Dimensions of Zinc-Coated Tape**

Nominal Ordered Width, in. [mm]	Width Tolerance, in. [mm]	Nominal Ordered Thickness, in. [mm]	Thickness Tolerance, in. [mm]
0 to 1.500 [0 to 38.100], incl	±0.008 [±0.20]	0.020 to 0.025 [0.51 to 0.635]	+0.002 [+0.05] -0.001 [-0.03]
		0.0251 to 0.035 [0.64 to 0.889]	+0.0025 [+0.06] -0.0015 [-0.04]
		0.0351 to 0.045 [0.892 to 1.143]	+0.003 [+0.08] -0.002 [-0.05]
		0.0451 to 0.063 [1.15 to 1.600]	+0.0035 [+0.09] -0.0025 [-0.06]
		0.0631 to 0.089 [1.603 to 2.264]	+0.004 [+0.10] -0.003 [-0.08]
1.5001 to 3.000 [38.103 to 76.20], incl	±0.010 [±0.25]	0.020 to 0.025 [0.51 to 0.635]	+0.002 [+0.05] -0.002 [-0.05]
		0.0251 to 0.035 [0.64 to 0.889]	+0.003 [+0.08] -0.002 [-0.02]
		0.0351 to 0.045 [0.892 to 1.143]	+0.003 [+0.08] +0.004 [+0.01]
		0.0451 to 0.063 [1.15 to 1.600]	+0.004 [+0.01] -0.003 [-0.08]
		0.0631 to 0.089 [1.603 to 2.264]	+0.004 [+0.01] -0.003 [-0.08]

**TABLE 2 Permissible Camber of Zinc-Coated Tape**

Nominal Ordered Width, in. [mm]	Permissible Camber, in. in 8 ft
0 to 1.500 [0 to 38.100], incl	0.50
1.501 to 3.000 [38.103 to 76.20], incl	0.25

**18. Marking**

18.1 A durable tag showing the nominal size of tape and the name or mark of the manufacturer shall be securely attached to one coil on each pallet. The starting end of each coil shall be indicated by a suitable tag.

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## Standard Specification for Copper-Clad Steel Wire Strand<sup>1</sup>

This standard is issued under the fixed designation A 460; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon ( $\epsilon$ ) indicates an editorial change since the last revision or reapproval.

### 1. Scope

1.1 This specification covers copper-clad steel wire strand composed of a number of round steel, copper-clad wires, for use as guys, messengers, span wires, and for similar purposes where electrical conductance is not a requirement.

1.2 The values stated in inch-pound units are to be regarded as the standard. The values given in parentheses are for information only.

### 2. Referenced Documents

#### 2.1 ASTM Standards:

A 902 Terminology Relating to Metallic Coated Steel Products<sup>2</sup>

### 3. Terminology

3.1 *Definitions:* For definitions of terms used in this specification see Terminology A 902.

### 4. Classification

4.1 The strand is classified by the minimum breaking strength and number of wires in the strand as stated in Table 1.

### 5. Ordering Information

5.1 Orders for material under this specification shall include the following information:

5.1.1 Quantity of strand in feet.

5.1.2 Breaking strength and number of wires in strand (4.1 and Table 1).

5.1.3 Package size of coils or reels from Table 2.

5.1.4 ASTM designation and year of issue.

### 6. Materials and Manufacture

6.1 Each wire in the strand shall be composed of a steel core made from steel produced by the open-hearth, basic-oxygen, or electric-furnace process with a substantially uniform and continuous copper cladding thoroughly bonded to it throughout. The thickness and adherence of the copper cladding on the finished wire shall comply with the requirements prescribed in this specification.

6.2 Each wire in the strand shall be of such quality that, when drawn to the size specified in Table 1 and when fabricated into strand, the finished copper-clad steel wire strand shall have the properties and characteristics prescribed in this specification.

### 7. Stranding

7.1 The strand shall consist of either 3 or 7 wires and, unless otherwise specified, shall have a left lay with a uniform pitch. In 3-wire strand, the pitch shall be not less than 12 nor more than 20 times the nominal diameter of the strand. In 7-wire strand, the pitch shall be not less than 10 nor more than 16 times the nominal diameter of the strand. A left lay is defined as a counter-clockwise twist away from the observer looking along the axis of the strand. All wires shall be stranded with uniform tension.

7.2 All wires in the strand shall lie naturally in their true positions in the completed strand, and when the strand is cut, the ends shall remain in position or be readily replaced by hand and then remain in position. This may be accomplished by any means or process, such as preforming, post forming, or form setting.

### 8. Joints and Splices

8.1 Joints or splices may be made prior to final wire drawing in individual finished wires composing the strand, provided that such joints or splices have protection from corrosion equivalent to that of the copper-clad wire itself and that they do not decrease the strength of the finished strand below the minimum breaking strength shown in Table 1. A joint or splice shall be not closer than 50 ft (15.2 m) to any other wire joint or splice in the strand.

8.2 The finished strand shall not be joined or spliced as a unit, unless specifically permitted by the purchaser.

### 9. Thickness of Copper Cladding

9.1 The minimum thickness of the copper cladding on wires taken from the finished strand shall be not less than that specified in Table 3.

9.2 The copper thickness shall be determined by either of the following:

9.2.1 By direct measurements of cross sections of the wires, the ends of the specimens having been ground smooth, polished, and etched before being measured microscopically, or

<sup>1</sup> This specification is under the jurisdiction of ASTM Committee A-5 on Metallic Coated Iron and Steel Products and is the direct responsibility of subcommittee A05.12 on Wire Specifications.

Current edition approved Feb. 15, 1994. Published April 1994. Originally published as A 460 – 61. Last previous edition A 460 – 68 (1991) $\epsilon$ <sup>1</sup>.

<sup>2</sup> *Annual Book of ASTM Standards*, Vol 01.06.

TABLE 1 Physical Properties of Copper-Clad Steel Wire Strands

Minimum Breaking Strength of Strand, lbf (N)	Number of Wires in Strand	Nominal Diameter of Strand, in. (mm) <sup>A</sup>	Nominal Diameter of Wires, in. (mm)	Approximate Weight of Strand, lb/1000 ft (kg/km)
2 200 (9 790)	3	0.164 (4.2)	0.076 (1.93)	49 (73)
4 000 (17 800)	3	0.209 (5.3)	0.097 (2.46)	79 (118)
6 000 (26 700)	3	0.258 (6.6)	0.120 (3.0)	121 (180)
6 000 (26 700)	7	0.237 (6.0)	0.079 (2.01)	122 (182)
8 000 (35 600)	7	0.276 (7.0)	0.092 (2.34)	166 (247)
10 000 (44 500)	7	0.303 (7.7)	0.101 (2.6)	200 (298)
12 500 (55 600)	7	0.345 (8.8)	0.115 (2.9)	259 (385)
14 000 (62 300)	7	0.360 (9.1)	0.120 (3.0)	283 (421)
16 000 (71 200)	7	0.386 (9.8)	0.128 (3.3)	324 (482)
18 000 (80 100)	7	0.414 (10.5)	0.138 (3.5)	374 (557)
20 000 (89 000)	7	0.438 (11.1)	0.146 (3.7)	418 (662)

<sup>A</sup> This diameter is given for the purpose of information and as a guide for the size of fittings, hardware, etc.

TABLE 2 Lengths of Strand in Coils and on Reels

Minimum Breaking Strength of Strand, lbf (N)	Approximate Length of Strand	
	In Coil, ft (m)	On Reel, ft (m)
2 200 (9790)	1000 (305)	10 000 (3050)
4 000 (17 800)	500 (152)	10 000 (3050)
6 000 to 10 000, incl (26 700 to 44 500, incl)	500 (152)	5 000 (1520)
12 500 to 20 000, incl (55 600 to 89 000, incl)	250 (76)	5 000 (1520)
12 500 to 20 000, incl (55 600 to 89 000, incl)	500 (152)	... (..)

TABLE 3 Minimum Thickness of Copper Cladding

Nominal Diameter of Clad Wires in the Strand, in. (mm)	Thickness of Copper Cladding, min, in. (mm)
0.060 to 0.099 (1.52 to 2.52)	0.004 (0.102)
0.100 to 0.119 (2.540 to 3.023)	0.005 (0.127)
0.120 to 0.139 (3.048 to 3.531)	0.006 (0.152)
0.140 to 0.149 (3.556 to 3.785)	0.007 (0.178)

9.2.2 By means of a suitable electrical indicating instrument operating on the permeameter principle.

## 10. Sampling

10.1 For the purpose of inspecting the strand, tests shall be made on representative samples. For lots of 10 000 lb (4536 kg) or less, two samples shall be taken from separate reels or coils in the lot, except that only one sample shall be required where the total length of the strand is 5000 ft (1524 m) or less. For lots over 10 000 lb (4536 kg) one sample from each 10 000 lb (4536 kg) or fraction thereof shall be taken, but the minimum number of samples shall be three.

## 11. Breaking Strength

11.1 The breaking strength of the finished strand shall be not less than that specified in Table 1.

11.2 When the breaking strength is below the minimum specified, the cause of which may have been due to slipping of the specimen in the jaws of the testing machine, breaking within the jaws or within 1 in. (25.4 mm) of the jaws, or the improper socketing of a specimen, the results of the test shall be disregarded and another sample from the same coil or reel shall be tested.

## 12. Elongation

12.1 The elongation shall be not less than 1.5 % and shall be measured on a gage length of not less than 24 in. (610 mm) of

finished strand which does not contain wire joints or splices. Elongation shall be determined by measurements made between the jaws of the testing machine or by an extensometer at the option of the manufacturer, unless otherwise agreed upon at the time of purchase.

12.2 When the elongation is so determined, the gage length shall be the distance between the jaws of the testing machine when a load equal to 10 % of the minimum breaking strength shall have been applied, and the final length shall be the distance between the jaws at the time of fracture of any wire. The fracture shall be between the jaws of the testing machine and not closer than 1 in. (25.4 mm) to either jaw, otherwise the test shall be disregarded.

12.3 When used, the extensometer shall be attached to the test specimen at a tension load equal to 10 % of minimum breaking strength. The elongation shall be observed while applying a tension load to the specimen, and the reading when fracture occurs shall be taken as the elongation of the specimen. Tests in which the extensometer reading is less than 1.5 %, but in which the fracture does not occur between the two attachments of the extensometer to the specimen, shall be disregarded.

12.4 Additional samples shall be taken from the same coil or reel when the previous tests are to be disregarded as stated in 12.2 and 12.3.

## 13. Torsion Test

13.1 Specimens of finished wires taken before stranding shall withstand without fracture not less than 20 twists in a length equivalent to 100 times the nominal diameter of the specimen. The rate of applying the twists shall be approximately 15 turns per minute, all twists to be made in the same direction.

13.2 Wire specimens shall be twisted to destruction and shall not reveal any seams, pits, slivers, or surface imperfections such that performance of the strand would be impaired. Examination of the wire at the break shall show no separation of the copper from the steel visible to the naked eye (normal eyeglasses excepted).

## 14. Wrap Test

14.1 When agreed upon at the time of purchase, samples of individual wires taken from the finished strand shall withstand without fracture, eight complete turns wrapped on itself in a close helix or on a mandrel whose diameter shall be equal to the nominal diameter of the wire.

## 15. Dimensions, Weight, and Permissible Variations

15.1 The size of the component wires in the strand shall be expressed in decimals of an inch (or millimetres) as prescribed in Table 1.

15.2 The diameters of the component wires in the strand shall not vary from the nominal wire diameters by more than  $\pm 0.002$  in. (0.05 mm).

15.3 Nominal diameter of strand and approximate weight of strand are indicated in Table 1.

## 16. Workmanship and Finish

16.1 The finished strand shall be tight, smooth, and free of imperfections not consistent with good commercial practice.

16.2 The diameter of the finished strand shall be uniform, except for a minor increase in diameter due to a wire joint or splice.

## 17. Inspection

17.1 The inspector representing the purchaser shall have free entry at all times to those parts of the plant concerned while work on the contract of the purchaser is being performed. The manufacturer shall afford the inspector all reasonable facilities to satisfy him that the material is being furnished in accordance with this specification. All tests and inspection shall be made prior to shipment at the place of manufacture of the strand, unless otherwise specified and agreed upon at the time of purchase, and shall be so conducted as not to interfere unnecessarily with the operation of the works. Such inspection and sampling shall be made in conjunction with and to the extent of the manufacturer's regular inspection operations. The purchaser may make the tests which govern the acceptance or rejection of the materials in his own laboratories or elsewhere.

## 18. Rejection

18.1 If the wire or strand fails in the first test to meet any requirement of this specification, two additional tests shall be made on samples of wire or strand from the same coil or reel. If failure occurs in either of these tests the lot of wire or strand shall be rejected.

## 19. Packaging, Marking, and Shipping

19.1 Strand shall be furnished in standard lengths in compact coils described in Table 2, unless otherwise agreed upon at the time of purchase. Reels shall be furnished only when so specified by the purchaser.

19.2 Only one length of strand shall be furnished in each coil or on each reel.

19.3 Each coil or reel shall have a weatherproof tag securely fastened to it showing the minimum breaking strength, number of wires and length of strand, ASTM designation, and the name or mark of the manufacturer. If additional information is required on the tag, it shall be so specified at the time of purchase.

19.4 The strand shall be protected against damage in ordinary handling and shipping. Coils shall be thoroughly wrapped with strong paper and properly tied. Reels shall be lagged when specified by the purchaser at the time of purchase.

19.5 The diameter of the coils and reels shall be that generally supplied by the manufacturer, unless otherwise agreed upon at the time of purchase.

## 20. Keywords

20.1 coatings—metallic; copper clad materials; steel wire—copper clad; steel wire strand

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Designation: A 463/A 463M – 02a

## Standard Specification for Steel Sheet, Aluminum-Coated, by the Hot-Dip Process<sup>1</sup>

This standard is issued under the fixed designation A 463/A 463M; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon ( $\epsilon$ ) indicates an editorial change since the last revision or reapproval.

*This standard has been approved for use by agencies of the Department of Defense.*

<sup>1</sup> This specification is under the jurisdiction of ASTM Committee A05 on Metallic Coated Iron and Steel Products and is the direct responsibility of Subcommittee A05.11 on Sheet Specifications.

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### 1. Scope

1.1 This specification covers aluminum-coated steel sheet in coils and cut lengths available with two types of aluminum coating applied by the hot-dip process, with several coating weights [masses].

1.2 Product furnished under this specification shall conform to the applicable requirements of the latest issue of Specification A 924/A 924M, unless otherwise provided herein.

1.3 This specification is applicable to orders in either inch-pound units (as A 463) or SI units [as A 463M]. Values in inch-pound and SI units are not necessarily equivalent. Within the text, SI units are shown in brackets. Each system shall be used independently of the other.

1.4 Unless the order specifies the “M” designation (SI units), the product shall be furnished to inch-pound units.

1.5 The text of this standard references notes and footnotes which provide explanatory material. These notes and footnotes (excluding those in tables and figures) shall not be considered as requirements of the standard.

1.6 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

### 2. Referenced Documents

#### 2.1 ASTM Standards:

A 428/A 428M Test Method for Weight Mass of Coating on Aluminum-Coated Iron or Steel Articles<sup>2</sup>

A 480/A 480M Specification for General Requirements for Flat-Rolled Stainless and Heat-Resisting Steel Plate, Sheet, and Strip<sup>3</sup>

A 902 Terminology Relating to Metallic Coated Steel Products<sup>2</sup>

A 924/A 924M Specification for General Requirements for Steel Sheet, Metallic-Coated by the Hot-Dip Process<sup>2</sup>

E 517 Test Method for Plastic Strain Ratio  $r$  for Sheet Metal<sup>4</sup>

E 646 Test Method for Tensile Strain-Hardening Exponents ( $n$  values) of Metallic Sheet Materials<sup>4</sup>

#### 2.2 ISO Standard:

ISO 5000 Continuous Hot-Dip Aluminum-Silicon-Coated Cold-Reduced Carbon Steel of Commercial and Drawing Qualities<sup>5</sup>

### 3. Terminology

3.1 *Definitions*—See Terminology A 902 for definitions of general terminology relating to metallic-coated steel products.

### 4. Classification

4.1 The steel sheet is available in several designations, as follows:

4.1.1 Commercial Steel (CS Types A, B, and C),

4.1.2 Forming Steel (FS),

4.1.3 Deep Drawing Steel (DDS),

<sup>2</sup> Annual Book of ASTM Standards, Vol 01.06.

<sup>3</sup> Annual Book of ASTM Standards, Vol 01.03.

<sup>4</sup> Annual Book of ASTM Standards, Vol 03.01.

<sup>5</sup> Available from International Organization for Standardization (ISO), 1 rue de Varembe, Case postale 56, CH-1211, Geneva 20, Switzerland.

- 4.1.4 Extra Deep Drawing Steel (EDDS),
- 4.1.5 Structural Steel (SS),
- 4.1.6 High Strength-Low Alloy Steel (HSLAS Type A),
- 4.1.7 High Strength-Low Alloy Steel (HSLAS Type B),
- 4.1.8 Ferritic Stainless Steel (FSS Type 409), and
- 4.1.9 Ferritic Stainless Steel (FSS Type 439).

4.2 Structural Steel (SS) and High Strength-Low Alloy Steels (HSLAS Types A and B) are available in several grades and classes.

4.3 The aluminum coating is available in two types with several coating weights [masses] with coating designations as shown in Table 1.

4.3.1 *Coating Type 1* is manufactured using a coating bath of aluminum–silicon alloy containing 5 to 11 % silicon to promote better adherence. It is intended principally for heat-resisting applications and also for uses where corrosion resistance and heat are involved. It is available as a coating on each of the designations of steel sheet listed in 4.1.

4.3.2 *Coating Type 2* is a commercially pure aluminum. It is intended principally for use in applications requiring corrosion resistance and is available only as a coating on Commercial Steel, Forming Steel, Structural Steel, and High Strength-Low Alloy Steel.

## 5. Ordering Information

5.1 Product under this specification shall be ordered to decimal thickness only, and dimensional tolerances of Specification A 924/A 924M shall apply. Specification A 480/A 480M shall apply to FSS (Types 409 and 439) for thickness tolerances only. The following, as required, shall be used to adequately describe the product required.

5.1.1 Name of product (steel sheet, aluminum-coated Type 1 or 2),

5.1.2 Designation of sheet (CS (Types A, B, and C), FS, DDS, EDDS, SS, HSLAS (Type A or B); and FSS (Types 409 and 439)).

5.1.2.1 When a CS type is not specified, Type B will be furnished.

5.1.2.2 When a SS or HSLAS designation is specified, state the type, grade, or class, or combination thereof.

5.1.3 ASTM designation number and year of issue,

5.1.4 Coating designation,

5.1.5 Specify whether oiled or dry or chemically treated, oiled or dry,

**TABLE 1 Weight [Mass] of Coating Requirements<sup>A,B</sup>**

NOTE 1—Tables X2.1 and X2.2 provide an estimate of coating thickness based on coating weight [mass].

Coating Designation	Minimum Requirement	
	Triple-Spot Test, Total Both Sides	Single-Spot Test, Total Both Sides
	Inch-Pound Units	
	oz/ft <sup>2</sup>	oz/ft <sup>2</sup>
T1-13	0.13	0.10
T1-25	0.25	0.20
T1-40	0.40	0.30
T1-100	1.00	0.90
T2-LC	no minimum	no minimum
T2-65	0.65	0.60
T2-100	1.00	0.90
	SI Units	
	g/m <sup>2</sup>	g/m <sup>2</sup>
T1M 40	40	30
T1M 75	75	60
T1M 120	120	90
T1M 300	300	270
T2M LC	no minimum	no minimum
T2M 200	200	180
T2M 300	300	270

<sup>A</sup> The coating designation number is the term by which this product is specified. Because of the many variables and changing conditions that are characteristic of continuous hot-dip coating lines, the weight [mass] of coating is not always evenly divided between the two surfaces of a sheet, nor is the coating evenly distributed from edge to edge. However, normally not less than 40 % of the single-spot test limit will be found on either surface.

<sup>B</sup> No minimum means that there are no established minimum requirements for triple- and single-spot tests, but aluminum coating shall be present.

5.1.6 Dimensions (show thickness, minimum or nominal; width; and length, if cut lengths). The purchaser shall specify the appropriate table of thickness tolerances in Specification A 924/A 924M that applies to the order, that is, the table of thickness tolerances for 3/8-in. [10-mm] edge distance, or the table of thickness tolerances for 1-in. [25-mm] edge distance. A 480/A 480M shall apply to FSS (Types 409 and 439) for thickness tolerances only.

5.1.7 Coil size requirements (specify maximum outside diameter (OD), acceptable inside diameter (ID), and maximum coil weight),

5.1.8 Application (show part identification and description),

5.1.9 Certification, if required, and heat analysis and mechanical property report, and

5.1.10 Special requirements (if required).

NOTE 1—Typical ordering descriptions are as follows: Steel sheet, aluminum-coated, Forming Steel (FS), ASTM A 463 – \_\_, Coating Designation T1 40, chemically treated dry, minimum 0.040 in. by 34 in. by coil, 48-in. maximum outside diameter, 20-in. inside diameter, 20 000-lb maximum coil weight, for muffler ends.

Steel Sheet, aluminum-coated, Commercial Steel (CS Type A), ASTM A 463M – \_\_, Coating Designation T1M 120, chemically treated dry, minimum 1.00 mm by 920 mm by coil, 1200-mm maximum outside diameter, 500-mm inside diameter, 10 000-kg maximum coil weight, for range heat shield.

NOTE 2—The purchaser should be aware that there are variations in manufacturing practices among the producers and therefore is advised to establish the producer’s standard (or default) procedures for thickness tolerances.

## 6. Chemical Composition

### 6.1 Base Metal:

6.1.1 The heat analysis of the base metal shall conform to the requirements shown in Table 2 for CS (Types A, B, and C), FS, DDS, EDDS, and FSS (Types 409 and 439), Table 3 for SS and HSLAS.

6.1.2 When the amount of copper, nickel, chromium, or molybdenum is less than 0.02 %, report the analysis either as <0.02 % or the actual determined value. When the amount of vanadium, titanium, or columbium is less than 0.008 %, report the analysis as either <0.008 % or the actual determined value.

6.1.3 See Specification A 924/A 924M for chemical analysis procedures and product analysis tolerances.

6.1.4 The heat analysis of the base metal for FSS (Types 409 and 439) shall conform to the requirements shown in Table 2.

6.1.5 See Specification A 480/A 480M for chemical analysis procedures and product analysis tolerances for FSS (Types 409 and 439).

### 6.2 Coating Bath Composition:

6.2.1 The bath metal used for Type 1 shall contain an aluminum-silicon alloy containing 5 to 11 % silicon, the balance aluminum.

6.2.2 The bath metal used for Type 2 shall contain commercially pure aluminum.

## 7. Mechanical Properties

7.1 Structural steel and high strength low alloy steel shall conform to the mechanical property requirements of Table 4 for the type, grade, or class, or combination thereof, specified.

7.2 The typical mechanical properties for CS (Types A, B, and C), FS, DDS, EDDS and FSS (Types 409 and 439), steel sheet designations are listed in Table 5. These mechanical property values are nonmandatory. They are solely to provide the purchaser

**TABLE 2 Chemical Requirements<sup>A</sup>**

Designation	Composition, %—Heat Analysis												
	Element, max (unless otherwise shown)												
	C	Mn	P	S	Al	Cu	Ni	Cr	Mo	V	Cb	Ti <sup>B</sup>	N
CS Type A <sup>C,D,E</sup>	0.10	0.60	0.030	0.035	...	0.20	0.20	0.15	0.06	0.008	0.008	0.025	...
CS Type B <sup>F,C</sup>	0.02 to 0.15	0.60	0.030	0.035	...	0.20	0.20	0.15	0.06	0.008	0.008	0.025	...
CS Type C <sup>C,D,E</sup>	0.08	0.60	0.10	0.035	...	0.20	0.20	0.15	0.06	0.008	0.008	0.025	...
FS <sup>C,G</sup>	0.02 to 0.10	0.50	0.020	0.030	...	0.20	0.20	0.15	0.06	0.008	0.008	0.025	...
DDS <sup>D,E</sup>	0.06	0.50	0.020	0.025	0.01, min	0.20	0.20	0.15	0.06	0.008	0.008	0.025	...
EDDS <sup>H</sup>	0.02	0.40	0.020	0.020	0.01, min	0.20	0.20	0.15	0.06	0.10	0.10	0.15	...
FSS Type 409 <sup>I</sup>	0.030	1.00	0.040	0.020	...	0.50	0.50	10.5 to	0.60	...	...	See	...
								11.7				Footnote <sup>J</sup>	
FSS Type 439 <sup>J</sup>	0.07	1.00	0.040	0.030	0.15	0.50	0.50	17.0 to	0.06	...	...	See	...
								19.0				Footnote <sup>J</sup>	

<sup>A</sup>Where an ellipsis ( . . . ) appears in the table, there is no requirement, but the analysis result shall be reported.

<sup>B</sup>For CS, FS, and DDS steels containing more than 0.02% carbon, titanium is permitted to 0.025% provided the ratio of % titanium to % nitrogen does not exceed 3.4.

<sup>C</sup>When a deoxidized steel is required for the application, the purchaser has the option to order CS and FS to a minimum of 0.01 % total aluminum.

<sup>D</sup>Steel is permitted to be furnished as a vacuum degassed or chemically stabilized steel, or both, at the producer’s option.

<sup>E</sup>For carbon levels less than or equal to 0.02%, vanadium, columbium, or titanium, or combinations thereof are permitted to be used as stabilizing elements at the producer’s option. In such cases, the applicable limit for vanadium and columbium shall be 0.10% max, and the limit for titanium shall be 0.15% max.

<sup>F</sup>For CS, specify Type B to avoid carbon levels below 0.02 %.

<sup>G</sup>Shall not be furnished as a stabilized steel.

<sup>H</sup>Shall be furnished as a stabilized steel.

<sup>I</sup>Shall contain silicon 1.00 % maximum, nitrogen 0.030 % maximum, and titanium [6 × (carbon + nitrogen)] minimum to 0.50 % maximum.

<sup>J</sup>Shall contain silicon 1.00 % maximum, nitrogen 0.04 % maximum, titanium + columbium [0.20 + 4 × (carbon + nitrogen)] minimum to 1.10 % maximum.



**TABLE 3 Chemical Requirements<sup>A</sup>**

Composition, %—Heat Analysis Element, max (unless otherwise shown)

Designation	C	Mn	P	S	Cu	Ni	Cr	Mo	V	Cb	Ti <sup>B</sup>	N
<b>SS</b>												
Grade 33 [230]	0.20	...	0.04	0.04	0.20	0.20	0.15	0.06	0.008	0.008	0.025	...
Grade 37 [255]	0.20	...	0.10	0.04	0.20	0.20	0.15	0.06	0.008	0.008	0.025	...
Grade 40 [275]	0.25	...	0.10	0.04	0.20	0.20	0.15	0.06	0.008	0.008	0.025	...
Grade 50 [340](Classes 1 and 2)	0.25	...	0.20	0.04	0.20	0.20	0.15	0.06	0.008	0.008	0.025	...
Grade 50 [340](Class 3)	0.25	...	0.04	0.04	0.20	0.20	0.15	0.06	0.008	0.008	0.025	...
Grade 80 [550]	0.20	...	0.04	0.04	0.20	0.20	0.15	0.06	0.008	0.008	0.025	...
<b>HSLAS Type A<sup>C</sup></b>												
<del>Grade 50 [340]</del>	<del>0.20</del>	<del>4.20</del>	<del>...</del>	<del>0.035</del>	<del>0.20</del>	<del>0.20</del>	<del>0.15</del>	<del>0.16</del>	<del>0.01</del>	<del>0.005</del>	<del>0.01</del>	<del>...</del>
<u>Grade 50 [340]</u>	<u>0.20</u>	<u>1.20</u>	<u>...</u>	<u>0.035</u>	<u>0.20</u>	<u>0.20</u>	<u>0.15</u>	<u>0.16</u>	<u>0.01</u>	<u>0.005</u>	<u>0.01</u>	<u>...</u>
<del>Grade 60 [410]</del>	<del>0.20</del>	<del>4.35</del>	<del>...</del>	<del>0.035</del>	<del>0.20</del>	<del>0.20</del>	<del>0.15</del>	<del>0.16</del>	<del>0.01</del>	<del>0.005</del>	<del>0.01</del>	<del>...</del>
<u>Grade 60 [410]</u>	<u>0.20</u>	<u>1.35</u>	<u>...</u>	<u>0.035</u>	<u>0.20</u>	<u>0.20</u>	<u>0.15</u>	<u>0.16</u>	<u>0.01</u>	<u>0.005</u>	<u>0.01</u>	<u>...</u>
<del>Grade 70 [480]</del>	<del>0.20</del>	<del>4.65</del>	<del>...</del>	<del>0.035</del>	<del>0.20</del>	<del>0.20</del>	<del>0.15</del>	<del>0.16</del>	<del>0.01</del>	<del>0.005</del>	<del>0.01</del>	<del>...</del>
<u>Grade 70 [480]</u>	<u>0.20</u>	<u>1.65</u>	<u>...</u>	<u>0.035</u>	<u>0.20</u>	<u>0.20</u>	<u>0.15</u>	<u>0.16</u>	<u>0.01</u>	<u>0.005</u>	<u>0.01</u>	<u>...</u>
<del>Grade 80 [550]</del>	<del>0.20</del>	<del>4.65</del>	<del>...</del>	<del>0.035</del>	<del>0.20</del>	<del>0.20</del>	<del>0.15</del>	<del>0.16</del>	<del>0.01</del>	<del>0.005</del>	<del>0.01</del>	<del>...</del>
<u>Grade 80 [550]</u>	<u>0.20</u>	<u>1.65</u>	<u>...</u>	<u>0.035</u>	<u>0.20</u>	<u>0.20</u>	<u>0.15</u>	<u>0.16</u>	<u>0.01</u>	<u>0.005</u>	<u>0.01</u>	<u>...</u>
<b>HSLAS Type B<sup>C,D</sup></b>												
<del>Grade 50 [340]</del>	<del>0.15</del>	<del>4.20</del>	<del>...</del>	<del>0.035</del>	<del>0.20</del>	<del>0.20</del>	<del>0.15</del>	<del>0.16</del>	<del>0.01</del>	<del>0.005</del>	<del>0.01</del>	<del>...</del>
<u>Grade 50 [340]</u>	<u>0.15</u>	<u>1.20</u>	<u>...</u>	<u>0.035</u>	<u>0.20</u>	<u>0.20</u>	<u>0.15</u>	<u>0.16</u>	<u>0.01</u>	<u>0.005</u>	<u>0.01</u>	<u>...</u>
<del>Grade 60 [410]</del>	<del>0.15</del>	<del>4.20</del>	<del>...</del>	<del>0.035</del>	<del>0.20</del>	<del>0.20</del>	<del>0.15</del>	<del>0.16</del>	<del>0.01</del>	<del>0.005</del>	<del>0.01</del>	<del>...</del>
<u>Grade 60 [410]</u>	<u>0.15</u>	<u>1.20</u>	<u>...</u>	<u>0.035</u>	<u>0.20</u>	<u>0.20</u>	<u>0.15</u>	<u>0.16</u>	<u>0.01</u>	<u>0.005</u>	<u>0.01</u>	<u>...</u>
<del>Grade 70 [480]</del>	<del>0.15</del>	<del>4.65</del>	<del>...</del>	<del>0.035</del>	<del>0.20</del>	<del>0.20</del>	<del>0.15</del>	<del>0.16</del>	<del>0.01</del>	<del>0.005</del>	<del>0.01</del>	<del>...</del>
<u>Grade 70 [480]</u>	<u>0.15</u>	<u>1.65</u>	<u>...</u>	<u>0.035</u>	<u>0.20</u>	<u>0.20</u>	<u>0.15</u>	<u>0.16</u>	<u>0.01</u>	<u>0.005</u>	<u>0.01</u>	<u>...</u>
<del>Grade 80 [550]</del>	<del>0.15</del>	<del>4.65</del>	<del>...</del>	<del>0.035</del>	<del>0.20</del>	<del>0.20</del>	<del>0.15</del>	<del>0.16</del>	<del>0.01</del>	<del>0.005</del>	<del>0.01</del>	<del>...</del>
<u>Grade 80 [550]</u>	<u>0.15</u>	<u>1.65</u>	<u>...</u>	<u>0.035</u>	<u>0.20</u>	<u>0.20</u>	<u>0.15</u>	<u>0.16</u>	<u>0.01</u>	<u>0.005</u>	<u>0.01</u>	<u>...</u>

<sup>A</sup>Where an ellipsis (. . .) appears in the table, there is no requirement, but the analysis result shall be reported.

<sup>B</sup>Titanium is permitted for SS steels to 0.025% provided the ratio of % titanium to % nitrogen does not exceed 3.4.

<sup>C</sup>HSLAS and HSLAS-F steels commonly contain the strengthening elements columbium, vanadium, and titanium added singly or in combination. The minimum requirements only apply to the microalloy elements selected for strengthening of the steel.

<sup>D</sup>The producer has the option to treat HSLAS Type B steels by means of small alloy additions to effect sulfide inclusion control.

with as much information as possible to make an informed decision on the steel to be specified. Values outside these ranges are to be expected.

7.3 When base metal mechanical properties are required, all tests shall be conducted in accordance with the methods specified in Specification A 924/A 924M.

#### 7.4 Bending Properties:

7.4.1 *Minimum Cold Bending Radii*—Structural steel sheet is commonly fabricated by cold bending. There are many interrelated factors that affect the ability of a steel to cold form over a given radius under shop conditions. These factors include: thickness, strength level, degree of restraint, relationship to rolling direction, chemistry, and base metal microstructure. Appendix X1 lists the suggested minimum inside radius for 90° cold bending for these steel sheets. They presuppose “hard way” bending (bend axis parallel to rolling direction) and reasonably good shop forming practices. Where possible, the use of larger radii or “easy way” bends are recommended for improved performance.

7.4.2 Fabricators should be aware that cracks may initiate upon bending a sheared edge. This is not considered to be a fault of the steel but is rather a function of the induced cold-work.

### 8. Coating Properties

8.1 *Coating Weight [Mass]*—Coating weight [mass] shall conform to the requirements as shown in Table 1 for the specific coating designation.

#### 8.2 Coating Weight [Mass] Tests:

**TABLE 4 Mechanical Requirements, Base Metal (Longitudinal)**

Inch-Pound Units				
Designation	Grade	Yield Strength, min, ksi	Tensile Strength, min, ksi <sup>A</sup>	Elongation in 2 in., min, % <sup>A</sup>
SS	33	33	45	20
	37	37	52	18
	40	40	55	16
	50 (Class 1)	50	65	12
	50 (Class 2)	50	...	12
	50 (Class 3)	50	70	12
	80 <sup>B</sup>	80 <sup>C</sup>	82	...
HSLAS Type A	50	50	60 <sup>D</sup>	20
	60	60	70 <sup>D</sup>	16
	70	70	80 <sup>D</sup>	12
	80	80	90 <sup>D</sup>	10
HSLAS Type B	50	50	60 <sup>D</sup>	22
	60	60	70 <sup>D</sup>	18
	70	70	80 <sup>D</sup>	14
	80	80	90 <sup>D</sup>	12

SI Units				
Designation	Grade	Yield Strength, min, MPa	Tensile Strength, min, MPa <sup>A</sup>	Elongation in 50 mm, min, % <sup>A</sup>
SS	230	230	310	20
	255	255	360	18
	275	275	380	16
	340 (Class 1)	340	450	12
	340 (Class 2)	340	...	12
	340 (Class 3)	340	480	12
	550 <sup>B</sup>	550 <sup>C</sup>	570	...
HSLAS Type A	340	340	410 <sup>D</sup>	20
	410	410	480 <sup>D</sup>	16
	480	480	550 <sup>D</sup>	12
	550	550	620 <sup>D</sup>	10
HSLAS Type B	340	340	410 <sup>D</sup>	22
	410	410	480 <sup>D</sup>	18
	480	480	550 <sup>D</sup>	14
	550	550	620 <sup>D</sup>	12

<sup>A</sup> Where an ellipsis ( . . . ) appears, there is no requirement.

<sup>B</sup> If the hardness result is 85 HRB or higher, no tension test is required.

<sup>C</sup> As there is no discontinuous yield curve, the yield strength should be taken as the stress at 0.5 % elongation under load or 0.2 % offset.

<sup>D</sup> If a higher tensile strength is required, the user should consult the producer.

**TABLE 5 Typical Ranges of Mechanical Properties (Nonmandatory) (Longitudinal Direction)<sup>A,B</sup>**

Designation	Yield Strength		Elongation, %	$r_m$ Value <sup>C</sup>	$n$ Value <sup>D</sup>
	ksi	[MPa]			
CS Type A	25/50	[170/345]	≥20	<i>E</i>	<i>E</i>
CS Type B	30/50	[205/345]	≥20	<i>E</i>	<i>E</i>
CS Type C	25/55	[170/380]	≥15	<i>E</i>	<i>E</i>
FS	25/45	[170/310]	≥26	1.0/1.4	0.17/0.21
DDS <sup>F</sup>	20/35	[140/240]	≥32	1.2/1.7	0.19/0.24
EDDS <sup>F</sup>	18/30	[125/205]	≥38	1.5/2.0	0.21/0.26
FSS Type 409	25/50	[170/345]	≥20	<i>E</i>	<i>E</i>
FSS Type 439	30/60	[205/415]	≥22	<i>E</i>	<i>E</i>

<sup>A</sup> The typical mechanical property values presented here are nonmandatory. They are intended solely to provide the purchaser with as much information as possible to make an informed decision on the steel to be specified. Values outside of these ranges are to be expected. The purchaser may negotiate with the supplier if a specific range or a more restrictive range is required for the application.

<sup>B</sup> These typical mechanical properties apply to the full range of steel sheet thicknesses. The yield strength tends to increase and some of the formability values tend to decrease as the sheet thickness decreases.

<sup>C</sup>  $r_m$  Value—Average plastic strain ratio as determined by the method in Test Method E 517.

<sup>D</sup>  $n$  Value—Strain-hardening exponent as determined by the method in Test Method E 646.

<sup>E</sup> No typical mechanical properties have been established.

<sup>F</sup> DDS and EDDS are available only as Coating Type 1 steel sheet.

8.2.1 Coating weight [mass] tests shall be performed in accordance with the requirements stated in Specification A 924/A 924M.

8.2.2 The referee method to be used shall be Test Method A 428.

### 8.3 Coating Bend Test:

8.3.1 The bend test specimens of coated sheet shall be capable of being bent through 180° in any direction without flaking of

the coating on the outside of the bend only. For all designations the coating bend test inside diameter shall be equal to twice the thickness of the specimen. Flaking of the coating within 0.25 in. [6 mm] of the edge of the bend specimen shall not be cause for rejection.

8.3.2 Coating bend test specimens shall be taken in accordance with Specification A 924/A 924M.

## 9. Dimensions and Permissible Variations

9.1 All dimensions and permissible variations shall comply with the requirements of Specification A 924/A 924M.

## 10. Keywords

10.1 aluminum-coated steel; coatings—aluminum; metallic coatings; steel sheet—aluminum coated

## APPENDIXES

### (Nonmandatory Information)

#### X1. BENDING PROPERTIES

X1.1 Table X1.1 shows suggested minimum inside radii for cold bending.

#### X2. RELATIONSHIP BETWEEN COATING WEIGHT [MASS] AND THICKNESS

X2.1 *Aluminum Type 1 Coatings*—Table X2.1 provides factors for converting between coating weight [mass] and thickness, and between values in inch-pound units and SI units.

X2.2 *Aluminum Type 2 Coatings*—Table X2.2 provides factors for converting between coating weight [mass] and thickness, and between values in inch-pound units and SI units.

**TABLE X1.1 Suggested Minimum Inside Radii for Cold Bending<sup>A</sup>**

NOTE 1— $t$  = radius equivalent to the steel thickness.

NOTE 2—The suggested radii should be used as minimums for 90° bends in actual shop practice.

Designation	Minimum Inside Radius for Cold Bending
CS, FS, DDS, EDDS, and FSS	0 $t$
SS	1½ $t$

<sup>A</sup> Material that does not perform satisfactorily when fabricated in accordance with the requirements of Table X1.1 may be subject to rejection pending negotiation with the steel supplier.

**TABLE X2.1 Conversion Factors Between Coating Weight [Mass] and Thickness<sup>A</sup>**

Coating Weight [Mass]		Coating Thickness	
oz/ft <sup>2</sup>	g/m <sup>2</sup>	mils	µm
1.0	305.15 <sup>B</sup>	3.98	101.09 <sup>B</sup>
0.00328 <sup>B</sup>	1.0	0.01304 <sup>B</sup>	0.33128 <sup>B</sup>
0.25126 <sup>B</sup>	76.672 <sup>B</sup>	1.0	25.4 <sup>B</sup>
0.00989 <sup>B</sup>	3.0186 <sup>B</sup>	0.03937 <sup>B</sup>	1.0

<sup>A</sup> One ounce of Type 1 aluminum coating per square foot of surface corresponds to an average coating thickness of 0.00398 in., based on a density of 0.109 lb/in.<sup>3</sup>. All other values in Table X2.1 are based on this relationship and on standard inch-pound to SI conversions.

<sup>B</sup> Weight [mass] to thickness conversions are reliable to only two significant figures. Inch-pound to SI conversions are reliable to five significant figures. A greater number of digits are shown in Table X2.1 to reduce errors due to rounding when calculating equivalencies for coating weight [mass] or thickness greater than unity.

**TABLE X2.2 Conversion Factors Between Coating Weight [Mass] and Thickness<sup>A</sup>**

Coating Weight [Mass]		Coating Thickness	
oz/ft <sup>2</sup>	g/m <sup>2</sup>	mils	µm
1.0	305.15 <sup>B</sup>	3.74	94.996 <sup>B</sup>
0.00328 <sup>B</sup>	1.0	0.012256 <sup>B</sup>	0.31131 <sup>B</sup>
0.26738 <sup>B</sup>	81.591 <sup>B</sup>	1.0	25.4 <sup>B</sup>
0.010527 <sup>B</sup>	3.2122 <sup>B</sup>	0.03937 <sup>B</sup>	1.0

<sup>A</sup> One ounce of Type 2 aluminum coating per square foot of surface corresponds to an average coating thickness of 0.00374 in., based on a density of 0.116 lb/in.<sup>3</sup>. All other values in Table X2.2 are based on this relationship and on standard inch-pound to SI conversions.

<sup>B</sup> Weight [mass] to thickness conversions are reliable to only two significant figures. Inch-pound to SI conversions are reliable to five significant figures. A greater number of digits are shown in Table X2.2 to reduce errors due to rounding when calculating equivalencies for coating weight [mass] or thickness greater than unity.

### X3. RATIONALE FOR CHANGES IN PRODUCT DESIGNATIONS

X3.1 Subcommittee A05.11 has revised the designations used to classify the various products available in each hot-dip coated specification. The previous “Quality” designations (Commercial Quality (CQ), Drawing Quality (DQ), etc.) have been replaced with designations and descriptions more closely related with product characteristics. Many of the former “Quality” specifications described the steel only in terms of limited chemical composition, which in some cases was identical for two or more qualities. The former designations also did not reflect the availability of new steels that are the result of the use of new technologies, such as vacuum degassing and steel ladle treatments.

X3.1.1 The former “Quality” designators, defined in very broad qualitative terms, did not provide the user with all of the information needed to select the appropriate steel for an application. The new designations are defined with technical information, such as specific chemical composition limits and typical nonmandatory mechanical properties. These steel characteristics are important to users concerned with the weldability and formability of the coated steel products. The typical mechanical properties included in the new designation system are those indicated by the tension test. These properties are more predictive of steel formability than other tests, such as the hardness test, which may not compensate adequately for product variables such as substrate thickness and coating weight.

X3.1.2 The new designations also provide the user with the flexibility to restrict the steels applied on any order. For example, a user can restrict the application of ultra-low carbon steels through the selection of an appropriate “type” designator.

X3.1.3 There is a limited relationship between the former and current system of designation. Some of the reasons for this limited relationship are the following: the addition of steels not previously described in ASTM specifications; restrictions placed on ranges of chemical composition; the addition of typical mechanical properties; and the enhanced capability of steel producers to combine chemical composition and processing methods to achieve properties tailored to specific applications.

X3.1.4 The changes in designation are significant, which may create transition issues that will have to be resolved. Continuing dialogue between users and producers will have to be maintained to assist in the transition to the new designation system. A user with concerns about the appropriate coated steel to order for a specific application should consult with a steel supplier or producer.

**X4. RELATIONSHIP BETWEEN SPECIFICATIONS THAT DESCRIBE REQUIREMENTS FOR A COMMON PRODUCT**

X4.1 Standard ISO 5000 may be reviewed for comparison with this standard. The relationship between the standards may only be approximate; therefore, the respective documents should be consulted for actual requirements. Those who use these documents must determine which specifications address their needs.

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*This standard is subject to revision at any time by the responsible technical committee and must be reviewed every five years and if not revised, either reapproved or withdrawn. Your comments are invited either for revision of this standard or for additional standards and should be addressed to ASTM International Headquarters. Your comments will receive careful consideration at a meeting of the responsible technical committee, which you may attend. If you feel that your comments have not received a fair hearing you should make your views known to the ASTM Committee on Standards, at the address shown below.*

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# Standard Specification for Aluminum-Coated Steel Wire Strand<sup>1</sup>

This standard is issued under the fixed designation A 474; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon ( $\epsilon$ ) indicates an editorial change since the last revision or reapproval.

## 1. Scope

1.1 This specification covers five grades of aluminum-coated, steel wire strand, composed of a number of round, steel wires, with aluminum coatings, for use as guys, messengers, span wires, and for similar purposes.

1.2 The five grades covered are as follows:

- 1.2.1 Utilities,
- 1.2.2 Common,
- 1.2.3 Siemens-Martin,
- 1.2.4 High-Strength, and
- 1.2.5 Extra High-Strength.

1.3 Minimum breaking strengths of strand for each grade are specified in Table 1.

1.4 The values stated in inch-pound units are to be regarded as the standard.

## 2. Referenced Documents

2.1 *ASTM Standards:*

A 428 Test Method for Weight of Coating on Aluminum-Coated Iron or Steel Articles<sup>2</sup>

## 3. Description of Strand

3.1 The designation of the finished strand shall be expressed as the nominal diameter of the strand, the number of the wires in the strand, and the grade of the strand as prescribed in Table 1.

## 4. Ordering Information

4.1 Orders for material under this specification shall include the following information:

- 4.1.1 Quantity of strand in feet.
- 4.1.2 Nominal strand diameter (size), number of wires, grade, and minimum breaking strength of strand (Section 8 and Table 1).
- 4.1.3 Length of strand in coils or on reels (Section 19).

## 5. Material and Manufacture

5.1 The base metal shall be steel made any commercially accepted steel making process and of such quality and purity that, when drawn to the size of wire specified and coated with aluminum, the finished strand and the individual wires shall be of uniform quality and have the properties and characteristics as prescribed in this specification.

5.2 The ingot or pig aluminum used for coating shall conform to the following impurity limits: copper, maximum, %, 0.10, and iron, maximum, %, 0.50.

## 6. Stranding

6.1 Unless otherwise specified, 3-wire strand shall have a left lay with a uniform pitch of not less than 10 nor more than 16 times the nominal diameter of the strand. Seven-wire strand shall have a left lay with a uniform pitch of not more than 16 times the nominal diameter of the strand. A left lay is defined as a counter-clockwise twist away from the observer. All wires shall be stranded with uniform tension. Stranding shall be sufficiently close to ensure no appreciable reduction in diameter when stressed to 10% of the specified strength.

6.2 All wires in the strand shall lie naturally in their true positions in the completed strand, and when the strand is cut, the ends shall remain in position or be readily replaced by hand and then remain in position. This may be accomplished by any means or process, such as preforming, post forming, or form setting.

## 7. Joints and Splices

7.1 There shall be no strand joints or strand splices in any length of the completed strand unless specifically permitted by the purchaser.

7.2 In 3-wire strand, there shall be no joints in individual wires. In 7-wire strand, joints in individual wires shall be acceptable provided there is not more than one joint in any 150-ft [46-m] section of the completed strand and the location of each wire joint is marked on the strand with paint or some other distinguishing mark.

7.3 Joints in the wires composing the strand shall be of the electric-butt-welded type. Care shall be taken to prevent injury to the wire during electric-butt-welding. All joints shall be well

<sup>1</sup> This specification is under the jurisdiction of ASTM Committee A05 on Metallic Coated Iron and Steel Products and is the direct responsibility of Subcommittee A05.12 on Wire Specifications.

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<sup>2</sup> *Annual Book of ASTM Standards*, Vol 01.06.

**TABLE 1 Physical Properties of Aluminum-Coated Steel Wire Strand**

Nominal Diameter of Strand, in. [mm]	Number of Wires in Strand	Nominal Diameter of Coated Wires in Strand, in. [mm]	Approximate Weight of Strand, lb/1000 ft [kg/m]	Minimum Breaking Strength of Strand, lbf [kN]										
				Utilities Grade <sup>A</sup>		Common Grade		Siemens-Martin Grade		High-Strength Grade		Extra-High-Strength Grade		
3/16 [4.76]	7	0.062 [1.57]	73 [0.108]	...	...	1 150 [5.1]	1 900 [8.5]	2 850 [12.7]	...	...	...	...	...	...
3/16 [4.76]	7	0.065 [1.65]	80 [0.118]	2 400 [10.7]	(1) <sup>B</sup>	...	...	...	...	...	...	...	...	...
1/4 [6.35]	3	0.120 [3.05]	117 [0.173]	3 150 [14.0]	(2)	...	...	...	...	...	...	...	...	...
1/4 [6.35]	3	0.120 [3.05]	117 [0.173]	4 500 [20.0]	(3)	...	...	...	...	...	...	...	...	...
1/4 [6.35]	7	0.080 [2.03]	121 [0.179]	...	...	1 900 [8.5]	3 150 [14.0]	4 750 [21.1]	6 650 [29.6]	...	...	...	...	...
9/32 [7.14]	7	0.093 [2.36]	164 [0.243]	4 600 [20.5]	(1)	...	...	...	...	...	...	...	...	...
5/16 [7.94]	3	0.145 [3.68]	171 [0.253]	6 500 [28.9]	(3)	...	...	...	...	...	...	...	...	...
5/16 [7.94]	7	0.104 [2.64]	205 [0.303]	...	...	3 200 [14.2]	5 350 [23.8]	8 000 [35.6]	11 200 [49.8]	...	...	...	...	...
5/16 [7.94]	7	0.109 [2.77]	225 [0.333]	6 000 [26.7]	(1)	...	...	...	...	...	...	...	...	...
3/8 [9.52]	3	0.165 [4.19]	220 [0.326]	8 500 [37.8]	(3)	...	...	...	...	...	...	...	...	...
3/8 [9.52]	7	0.120 [3.05]	273 [0.404]	11 500 [51.2]	(4)	4 250 [18.9]	6 950 [30.9]	10 800 [48.0]	15 400 [68.5]	...	...	...	...	...
7/16 [11.11]	7	0.145 [3.68]	399 [0.591]	18 000 [80.1]	(4)	5 700 [25.4]	9 350 [41.6]	14 500 [64.5]	20 800 [92.5]	...	...	...	...	...
1/2 [12.7]	7	0.165 [4.19]	517 [0.765]	25 000 [111.2]	(4)	7 400 [32.9]	12 100 [53.8]	18 800 [83.6]	26 900 [119.7]	...	...	...	...	...

<sup>A</sup>The utilities grade is used principally by communication and power and light industries.  
<sup>B</sup>The last numbers in parentheses refer to elongation requirements specified in Section 9%.

made and shall have protection from corrosion equivalent to that of the aluminum-coated wire itself.

**8. Breaking Strength and Weight**

8.1 The minimum breaking strength of the finished strand shall be as specified in Table 1 and the approximate weight per 1000 ft or 305 m of strand shall be as indicated in Table 1.

8.2 A test in which the breaking strength is below the minimum specified and which may have been caused by the slipping of the specimen in the jaws of the testing machine, by breaking within the jaws or within 1 in. [25 mm] of the jaws, or by the improper socketing of a specimen shall be disregarded and another sample from the same coil or reel shall be tested. Tests shall be made on lengths of strand that do not contain wire joints or splices.

**9. Elongation**

9.1 The elongation of the strand in 24 in. [610 mm] shall be not less than that specified in Table 2.

9.2 The elongation shall be determined as the percent increase in separation between the jaws of the testing machine from the position after application of the initial load to the position at the initial failure in the test specimen. The separation of the jaws of the testing machine shall be approximately 2 ft [0.61 m] when under an initial load equal to 10 % of the required minimum breaking strength of the strand. The elongation values shall be recorded only for specimens that break over 1 in. from the jaws of the testing machine. Additional

samples shall be taken from the same coil or reel when the previous tests are to be disregarded.

9.3 Elongation tests shall be made on lengths of strand that do not contain wire joints or splices.

**10. Dimensions and Permissible Variations of Wires**

10.1 The diameter of the aluminum-coated wire forming the strand specified in Table 1 shall be within the limits prescribed in Table 3.

**11. Sampling**

11.1 Perform sampling for determination of compliance to this specification on each lot of material. A lot shall consist of all the strand of one size and one grade in each shipment. The number of samples to be taken shall be as follows:

	Number of Samples
5000 ft [1525 m] or less	1
Over 5000 to 30 000 ft [1525 to 9145 m]	2
Over 30 000 to 150 000 ft [9145 to 45 720 m]	3
Over 150 000 ft [45 720 m]	4

11.2 Each sample taken shall be subjected to all tests prescribed in this specification.

**12. Weight of Coating**

12.1 The weight of aluminum coating, in ounces per square foot or kilograms per square metre, of uncoated wire surface,

**TABLE 2 Elongation Requirements for Grades of Strand**

Grade of Strand	Elongation in 24 in. or 610 mm, min, %
Utilities (1) <sup>A</sup> and common strand	10
Utilities (2) <sup>A</sup> and Siemens-Martin	8
Utilities (3) <sup>A</sup> and high-strength	5
Utilities (4) <sup>A</sup> and extra-high-strength	4

<sup>A</sup>See Table 1, Footnote B.

**TABLE 3 Permissible Variations in Diameter of Aluminum-Coated Wires<sup>A</sup>**

Nominal Diameter of Coated Wires in the Strand, in. [mm]	Permissible Variations, plus and minus, in. [mm]
0.061 to 0.090 [1.55 to 2.29]	0.003 [0.08]
0.091 to 0.120 [2.31 to 3.05]	0.004 [0.10]
0.121 and over [3.07 and over]	0.005 [0.13]

<sup>A</sup>It is recognized that the surface of aluminum coatings, particularly those produced by hot dipping, is not perfectly smooth and devoid of irregularities. If the tolerances shown in this table are rigidly applied to such irregularities that are inherent to the product, unjustified rejections of wire that would actually be satisfactory for use could occur. Therefore, it is intended that these tolerances be used in gaging the uniform areas of the aluminum-coated wire.

on any individual wire of the completed strand shall be not less than that specified in Table 4.

### 13. Tests of Coating

13.1 Determine the weight of the aluminum coating in accordance with Test Method A 428.

### 14. Adherence of Coating

14.1 The aluminum-coated wire shall be capable of being wrapped at a rate not exceeding 15 turns per minute in a close helix of at least two turns around a cylindrical mandrel equal to three times the nominal diameter of the wire under test, without cracking or flaking the aluminum coating to such an extent that any aluminum can be removed by rubbing with the bare fingers. Loosening or detachment during the adhesion test of superficial, small particles of aluminum formed by mechanical polishing of the surface of aluminum-coated wire shall not be considered cause for rejection.

### 15. Ductility of Steel

15.1 The individual wires of the completed strand shall not fracture when wrapped at a rate not exceeding 15 turns per minute in a close helix of at least two turns around a cylindrical mandrel. The mandrel diameter for testing common- and Siemens-Martin-grade strand shall be equal to the nominal diameter of the individual wires of the strand. The mandrel diameter for utilities, high-strength, and extra-high-strength grade strand, shall be equal to three times the nominal diameter of the individual wires of the strand.

**TABLE 4 Nominal Diameters and Minimum Weights of Coating for Aluminum-Coated Steel Wires**

Nominal Diameter of Coated Wire in the Strand, in. [mm]	Minimum Weight of Aluminum Coating, oz/ft <sup>2</sup> [g/m <sup>2</sup> ] of Uncoated Wire Surface
0.062 [1.57]	0.30 [92]
0.065 [1.65]	0.30 [92]
0.080 [2.03]	0.30 [92]
0.093 [2.36]	0.32 [98]
0.104 [2.64]	0.32 [98]
0.109 [2.77]	0.35 [107]
0.120 [3.05]	0.35 [107]
0.145 [3.68]	0.35 [107]
0.165 [4.19]	0.40 [122]

### 16. Finish

16.1 The aluminum-coated wire shall be free of imperfections not consistent with good commercial practice. The coating shall be continuous and reasonably uniform.

### 17. Inspection

17.1 The manufacturer shall afford the inspector representing the purchaser all reasonable facilities, without charge, to satisfy him that the material is being furnished in accordance with this specification. All tests and inspection shall be made at the place of manufacture prior to shipment, unless otherwise specified, and shall be so conducted as not to interfere unnecessarily with the operation of the works.

### 18. Rejection

18.1 If the wire or strand fails in the first test to meet any requirement of this specification, two additional tests shall be made on samples of wire or strand from the same coil or reel. If failure occurs in either of these tests, the lot of wire or strand shall be rejected.

### 19. Packaging and Marking

19.1 Wire strand shall be furnished in standard lengths, (19.1.1) and in compact coils or on reels (19.1.2) as specified by the purchaser; otherwise lengths shall be as agreed upon at the time of purchase. Only one length of strand shall be furnished in each coil or on each reel. Lengths of strand may vary between the standard (nominal) length and 10 % over the standard (nominal) length, unless otherwise specified by the purchaser.

19.1.1 Standard lengths of strand are as follows: 250, 500, 1000, 2500, and 5000 ft [75, 150, 305, 760, and 1525 m].

19.1.2 Standard practice is to furnish all strand 7/16 in. [11.11 mm] and over in diameter on reels in lengths of 1000 ft and over. Strand lengths of less than 1000 ft are regularly furnished in coils.

19.2 Each coil or reel shall have a strong weather-resistant tag securely fastened to it showing the length, nominal diameter, number of wires, grade of the strand, ASTM designation A 474, and the name or mark of the manufacturer. If additional information is required on the tag, it shall be so specified at the time of purchase.

### 20. Keywords

20.1 aluminum-coated steel wire strand; wire strand

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# Standard Specification for Zinc-Coated Steel Wire Strand<sup>1</sup>

This standard is issued under the fixed designation A 475; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last approval. A superscript epsilon ( $\epsilon$ ) indicates an editorial change since the last revision or reapproval.

*This standard has been approved for use by agencies of the Department of Defense.*

## 1. Scope\*

1.1 This specification covers five grades of zinc-coated, steel wire strand, composed of a number of round, steel wires, with four weights of zinc coatings, suitable for use as guys, messengers, span wires, and for similar purposes.

1.2 The five grades covered are as follows:

1.2.1 Utilities,

1.2.2 Common,

1.2.3 Siemens-Martin,

1.2.4 High-Strength, and

1.2.5 Extra High-Strength.

1.2.6 Minimum breaking strengths of strand for each grade are described in Section 7.

1.3 The four weights of zinc coatings are: Class 1 and Classes A, B, and C. Minimum weights of zinc coatings are described in Section 10.

1.4 The values stated in inch-pound units are to be regarded as the standard. The values given in brackets are for information only.

## 2. Referenced Documents

2.1 *ASTM Standards:*<sup>2</sup>

A 90/A 90M Test Method for Weight [Mass] of Coating on Iron and Steel Articles with Zinc or Zinc-Alloy Coatings  
A 902 Terminology Relating to Metallic Coated Steel Products  
B 6 Specification for Zinc

## 3. Terminology

3.1 Definitions—For definitions of terms used in this standard, refer to Terminology A 902.

3.2 *Definitions of Terms Specific to This Standard:*

3.2.1 *strand*—the designation of the finished strand shall be expressed as the nominal diameter of the strand, the number of

the wires in the strand, the minimum breaking strength of the strand (see Section 7), and the class of coating (see Section 10).

## 4. Ordering Information

4.1 Orders for material under this specification shall include the following information:

4.1.1 Quantity of strand in feet,

4.1.2 Nominal strand diameter, number of wires, grade, and minimum breaking strength of strand (Section 7 and Table 1),

4.1.3 Weight (class) of zinc coating (Section 10 and Table 2),

4.1.4 Length of strand in coils or on reels (Section 18), and

4.1.5 ASTM designation and year of issue.

## 5. Materials and Manufacture

5.1 The base metal shall be steel made by any commercially accepted steel making process and of such quality and purity that, when drawn to the size of wire specified and coated with zinc, the finished strand and the individual wires shall be of uniform quality and have the properties and characteristics as prescribed in this specification.

5.2 The slab zinc, when used for the coating, shall be any grade of zinc conforming to Specification B 6.

## 6. Stranding

6.1 Unless otherwise specified, strand shall have a left lay. A left lay is defined as a counter-clockwise twist away from the observer. All wires shall be stranded with uniform tension. Stranding shall be sufficiently close to ensure no appreciable reduction in diameter when stressed to 10 % of the minimum breaking strength.

6.2 The 3-wire strand shall consist of three wires concentrically twisted with a uniform pitch of not less than 14 nor more than 20 $\times$  the specified nominal diameter of the strand.

6.3 The 7-wire strand shall consist of a center wire with a 6-wire layer concentrically twisted over it with a uniform pitch of not more than 16 $\times$  the specified nominal diameter of the strand.

6.4 The 19-wire strand shall consist of a center wire with a 6-wire layer concentrically twisted over it, having a right lay and a uniform pitch of not more than 16 $\times$  the nominal diameter of this 7-wire core. The nominal diameter of this 7-wire core shall be considered to be 3 $\times$  the nominal diameter

<sup>1</sup> This specification is under the jurisdiction of ASTM Committee A05 on Metallic Coated Iron and Steel Products and is the direct responsibility of Subcommittee A05.12 on Wire Specifications.

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<sup>2</sup> For referenced ASTM standards, visit the ASTM website, [www.astm.org](http://www.astm.org), or contact ASTM Customer Service at [service@astm.org](mailto:service@astm.org). For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

\*A Summary of Changes section appears at the end of this standard.

**TABLE 1 Physical Properties of Zinc-Coated Steel Wire Strand**

NOTE 1—The numbers in boldface type indicate sizes and grades most commonly used and readily available.

Nominal Diameter of Strand, in. [mm]	Number of Wires in Strand	Nominal Diameter of Coated Wires in Strand, in. [mm]	Approximate Weight of Strand, lb/1000 ft [kg/km]	Minimum Breaking Strength of Strand, lbf [kN]				
				Utilities Grade <sup>A</sup>	Common Grade	Siemens-Martin Grade	High-Strength Grade	Extra High-Strength Grade
1/8 [3.18]	7	0.041 [1.04]	32 [48]	...	<b>540 [2.402]</b>	910 [4.048]	1 330 [5.916]	1 830 [8.140]
5/32 [3.97]	7	0.052 [1.32]	51 [76]	...	<b>870 [3.870]</b>	1 470 [6.539]	2 140 [9.519]	2 940 [13.078]
3/16 [4.76]	7	0.062 [1.57]	73 [109]	...	<b>1 150 [5.115]</b>	1 900 [8.452]	2 850 [12.677]	3 990 [17.748]
3/16 [4.76]	7	0.065 [1.65]	80 [119]	<b>2 400 [10.676] (1)<sup>B</sup></b>	...	...	...	...
7/32 [5.56]	3	0.104 [2.64]	88 [131]	...	1 400 [6.228]	2 340 [10.409]	3 500 [15.569]	4 900 [21.796]
7/32 [5.56]	7	0.072 [1.83]	98 [146]	...	1 540 [6.850]	2 560 [11.387]	3 850 [17.126]	5 400 [24.020]
1/4 [6.35]	3	0.120 [3.05]	117 [174]	<b>3 150 [14.012] (2)<sup>B</sup></b>	1 860 [8.274]	3 040 [13.523]	4 730 [21.040]	6 740 [29.981]
1/4 [6.35]	3	0.120 [3.05]	117 [174]	<b>4 500 [20.017] (3)<sup>B</sup></b>	...	...	...	...
1/4 [6.35]	7	0.080 [2.03]	121 [180]	...	<b>1 900 [8.452]</b>	<b>3 150 [14.012]</b>	4 750 [21.129]	6 650 [29.581]
9/32 [7.14]	3	0.130 [3.30]	137 [204]	...	2 080 [9.252]	3 380 [15.035]	5 260 [23.398]	7 500 [33.362]
9/32 [7.14]	7	0.093 [2.36]	164 [244]	<b>4 600 [20.462] (1)<sup>B</sup></b>	2 570 [11.432]	4 250 [18.905]	6 400 [28.469]	8 950 [39.812]
5/16 [7.94]	3	0.145 [3.68]	171 [255]	<b>6 500 [28.913] (3)<sup>B</sup></b>	2 490 [11.076]	4 090 [18.193]	6 350 [28.246]	9 100 [40.479]
5/16 [7.94]	7	0.104 [2.64]	205 [305]	...	<b>3 200 [14.234]</b>	5 350 [23.798]	<b>8 000 [35.586]</b>	11 200 [49.820]
5/16 [7.94]	7	0.109 [2.77]	225 [335]	<b>6 000 [26.689] (1)<sup>B</sup></b>	...	...	...	...
3/8 [9.52]	3	0.165 [4.19]	220 [328]	<b>8 500 [37.810] (3)<sup>B</sup></b>	3 330 [14.813]	5 560 [24.732]	8 360 [37.187]	11 800 [52.489]
3/8 [9.52]	7	0.120 [3.05]	273 [407]	<b>11 500 [51.155] (4)<sup>B</sup></b>	<b>4 250 [18.905]</b>	<b>6 950 [30.915]</b>	10 800 [48.040]	15 400 [68.503]
7/16 [11.11]	7	0.145 [3.68]	399 [595]	<b>18 000 [80.068] (4)<sup>B</sup></b>	<b>5 700 [25.355]</b>	<b>9 350 [41.591]</b>	<b>14 500 [64.499]</b>	20 800 [92.523]
1/2 [12.70]	7	0.165 [4.19]	517 [770]	<b>25 000 [111.206] (4)<sup>B</sup></b>	<b>7 400 [32.917]</b>	<b>12 100 [53.823]</b>	<b>18 800 [83.627]</b>	26 900 [119.657]
1/2 [12.70]	19	0.100 [2.54]	504 [751]	...	7 620 [33.895]	12 700 [56.492]	19 100 [84.961]	26 700 [118.768]
9/16 [14.29]	7	0.188 [4.78]	671 [1000]	...	9 600 [42.703]	15 700 [69.837]	24 500 [108.981]	35 000 [155.688]
9/16 [14.29]	19	0.113 [2.87]	637 [949]	...	9 640 [42.881]	16 100 [71.616]	24 100 [107.202]	33 700 [149.905]
5/8 [15.88]	7	0.207 [5.26]	813 [1211]	...	11 600 [51.599]	19 100 [84.961]	29 600 [131.667]	42 400 [188.605]
5/8 [15.88]	19	0.125 [3.18]	796 [1186]	...	11 000 [48.930]	18 100 [80.513]	28 100 [124.995]	40 200 [178.819]
3/4 [19.05]	19	0.150 [3.81]	1 155 [1721]	...	16 000 [71.172]	26 200 [116.543]	40 800 [181.487]	58 300 [259.331]
7/8 [22.22]	19	0.177 [4.50]	1 581 [2356]	...	21 900 [97.416]	35 900 [159.691]	55 800 [248.211]	79 700 [354.523]
1 [25.40]	19	0.200 [5.08]	2 073 [3089]	...	28 700 [127.664]	47 000 [209.066]	73 200 [325.610]	104 500 [464.839]
1 [25.40]	37	0.143 [3.63]	2 057 [3065]	...	28 300 [125.885]	46 200 [205.508]	71 900 [319.827]	102 700 [456.832]
1 1/8 [28.58]	37	0.161 [4.09]	2 691 [4010]	...	36 000 [160.136]	58 900 [262.000]	91 600 [407.457]	130 800 [581.827]
1 1/4 [31.75]	37	0.179 [4.55]	3 248 [4840]	...	44 600 [198.391]	73 000 [324.720]	113 600 [505.318]	162 200 [721.502]

<sup>A</sup> The utilities grade is used principally by communication and power and light industries.

<sup>B</sup> Refer to elongation requirements specified in Section 8.

**TABLE 2 Nominal Diameters and Minimum Weights of Coating for Zinc-Coated Steel Wires<sup>A</sup>**

Nominal Diameter of Coated Wire in the Strand, in. [mm]	Minimum Weight of Coating, oz/ft <sup>2</sup> [g/m <sup>2</sup> ] of Uncoated Wire Surface			
	Class 1 <sup>B</sup>	Class A <sup>C</sup>	Class B <sup>D</sup>	Class C <sup>D</sup>
0.041 [1.04]	0.15 [46]	0.40 [122]	0.80 [244]	1.20 [366]
0.052 [1.32]	0.15 [46]	0.40 [122]	0.80 [244]	1.20 [366]
0.062 [1.57]	0.15 [46]	0.50 [153]	1.00 [305]	1.50 [458]
0.065 [1.65]	0.15 [46]	0.50 [153]	1.00 [305]	1.50 [458]
0.072 [1.83]	0.15 [46]	0.50 [153]	1.00 [305]	1.50 [458]
0.080 [2.03]	0.30 [92]	0.60 [183]	1.20 [366]	1.80 [549]
0.093 [2.36]	0.30 [92]	0.70 [214]	1.40 [427]	2.10 [641]
0.100 [2.54]	0.30 [92]	0.70 [214]	1.40 [427]	2.10 [641]
0.104 [2.64]	0.30 [92]	0.80 [244]	1.60 [488]	2.40 [732]
0.109 [2.77]	0.30 [92]	0.80 [244]	1.60 [488]	2.40 [732]
0.113 [2.87]	0.30 [92]	0.80 [244]	1.60 [488]	2.40 [732]
0.120 [3.05]	0.30 [92]	0.85 [259]	1.70 [519]	2.55 [778]
0.125 [3.18]	0.30 [92]	0.85 [259]	1.70 [519]	2.55 [778]
0.130 [3.30]	0.30 [92]	0.85 [259]	1.70 [519]	2.55 [778]
0.143 [3.63]	0.40 [122]	0.90 [275]	1.80 [549]	2.70 [824]
0.145 [3.68]	0.40 [122]	0.90 [275]	1.80 [549]	2.70 [824]
0.150 [3.81]	0.40 [122]	0.90 [275]	1.80 [549]	2.70 [824]
0.161 [4.09]	0.40 [122]	0.90 [275]	1.80 [549]	2.70 [824]
0.165 [4.19]	0.40 [122]	0.90 [275]	1.80 [549]	2.70 [824]
0.177 [4.50]	0.40 [122]	0.90 [275]	1.80 [549]	2.70 [824]
0.179 [4.55]	0.40 [122]	0.90 [275]	1.80 [549]	2.70 [824]
0.188 [4.78]	0.40 [122]	1.00 [305]	2.00 [610]	3.00 [915]
0.200 [5.08]	0.40 [122]	1.00 [305]	2.00 [610]	3.00 [915]
0.207 [5.26]	0.40 [122]	1.00 [305]	2.00 [610]	3.00 [915]

<sup>A</sup> For intermediate sizes of wire in the strand, the weight designations are the same as for the next finer size shown in this table.

<sup>B</sup> Class 1 (formerly "galvanized") coating applies to common grade of strand only.

<sup>C</sup> Class A, "extra galvanized" and "double galvanized" are equivalent terms.

<sup>D</sup> Class A, Class B, and Class C coatings apply to all grades of strand.

of the wires. A 12-wire outer layer, having a left lay shall be concentrically twisted over the 7-wire core and shall have a uniform pitch of not more than 16× the specified nominal diameter of the strand.

6.5 The 37-wire strand shall consist of a center wire with a 6-wire layer concentrically twisted over it, having a left lay and a uniform pitch of not more than 16× the nominal diameter of this 7-wire inner core. The nominal diameter of this 7-wire inner core shall be considered to be 3× the nominal diameter of the wire. An intermediate layer of 12 wires having a right lay shall be concentrically twisted over this 7-wire core and shall have a uniform pitch of not more than 16× the nominal diameter of this 19-wire core. The nominal diameter of this 19-wire core shall be considered as 5× the nominal diameter of the wires. An 18-wire outer layer, having a left lay shall be concentrically twisted over the 19-wire core and shall have a uniform pitch of not more than 16× the specified nominal diameter of the strand.

6.6 All wires in the strand shall lie naturally in their true positions in the completed strand and, when the strand is cut, the ends shall remain in position or be readily replaced by hand and then remain in position. This may be accomplished by any means or process, such as preforming, post forming, or form setting.

## 7. Breaking Strength and Weight

7.1 The approximate weight per unit length of strand and the minimum breaking strength of the finished strand shall be as specified in Table 1.

7.2 A test in which the breaking strength is below the minimum specified and which may have been caused by the slipping of the specimen in the jaws of the testing machine, by breaking within the jaws or within 1 in. [25.4 mm] of the jaws, or by the improper socketing of a specimen shall be disregarded and another sample from the same coil or reel shall be tested. Tests shall be made on lengths of strand that do not contain wire joints or splices.

## 8. Elongation

8.1 The elongation of the strand in 24 in. [610 mm] shall be not less than that specified in Table 3.

8.2 The elongation shall be determined as the percent increase in separation between the jaws of the testing machine from the position after application of the initial load to the position at the initial failure in the test specimen. The separation of the jaws of the testing machine shall be approximately 2 ft when under an initial load equal to 10 % of the required minimum breaking strength of the strand. The elongation values shall be recorded only for specimens which break over 1 in. from the jaws of the testing machine. Additional samples shall be taken from the same coil or reel when the previous tests are to be disregarded.

8.3 Elongation tests shall be made on lengths of strand which do not contain wire joints or splices.

## 9. Ductility of Steel

9.1 The zinc-coated wire shall not fracture when wrapped at a rate not exceeding 15 turns/min in a close helix of at least 2 turns around a cylindrical mandrel. The mandrel diameter for testing common and Siemens-Martin grade strand shall be equal to the nominal diameter of the individual wires of the strand. The mandrel diameter for utilities, high-strength, and extra high-strength grade strand, shall be equal to 3× the nominal diameter of the individual wires of the strand.

## 10. Weight of Coating

10.1 The weight of zinc coating shall not be less than that specified in Table 2.

10.2 The weight of the zinc coating shall be determined by a stripping test in accordance with Test Method A 90/A 90M.

## 11. Adherence of Coating

11.1 The zinc-coated wire shall be capable of being wrapped at a rate not exceeding 15 turns/min in a close helix

**TABLE 3 Elongation Requirements for Grades of Strand**

Grade of Strand	Elongation in 24 in. [610 mm], min, %
Utilities Grade (1) <sup>A</sup> and Common Strand	10
Utilities Grade (2) <sup>A</sup> and Siemens-Martin	8
Utilities Grade (3) <sup>A</sup> and High-Strength	5
Utilities Grade (4) <sup>A</sup> and Extra High-Strength	4

<sup>A</sup> See Table 1, Footnote B.

of at least two turns around a cylindrical mandrel equal to 3× the nominal diameter of the wire under test, without cracking or delaminating the zinc coating to such an extent that any zinc can be removed by rubbing with the bare fingers. Loosening or detachment during the adhesion test of superficial small particles of zinc formed by mechanical polishing of the surface of zinc-coated wire shall not be considered cause for rejection.

**12. Joints and Splices**

12.1 Electric-welded butt joints made prior to the start of cold drawing of the wire are permitted; however, no electric-welded butt joints shall be made during the cold drawing operation. Electric-welded butt joints of the wire shall be permitted only as specified in 12.2.

12.2 In 3-wire strand, there shall be no joints made in the individual finished wire. In 7-wire strand, joints made in individual finished wires shall be acceptable provided there is not more than one joint in any 150-ft [45.7-m] section of the completed strand and the location of each joint is marked on the strand with paint or some other distinguishing mark. Factory joints made in the individual finished wires of 19 and 37-wire strand shall be kept well spaced and at a minimum in number.

12.3 Joints in the wires composing the strand shall be either the brazed-lap type or electric-butt-welded type. When the brazed type of joint is used, the length of the lap shall be not less than 3× the diameter of the wire and the overlapping faces shall be smooth, clean, properly fluxed, and completely covered by the brazing metal. When the electric-welded type of joint is used, care shall be taken to prevent injury to the wire during electric-butt welding. All joints shall be well made and shall be coated with zinc after completion so that the joints shall have protection from corrosion equivalent to that of the zinc-coated wire itself.

12.4 There shall be no strand joints or strand splices in any length of the completed strand unless specifically permitted by the purchaser.

**13. Permissible Variations in Size**

13.1 The diameter of the zinc-coated wire forming the strand specified in Table 1 shall be within the limits prescribed in Table 4.

**14. Workmanship**

14.1 The zinc-coated wire shall be free of imperfections not consistent with good commercial practice. The coating shall be continuous and reasonably uniform.

**TABLE 4 Permissible Variations in Diameter of Individual Zinc-Coated Wires<sup>A</sup>**

Nominal Diameter of Coated Wires in the Strand, in. [mm]	Permissible Variations, ±in. [mm]
0.041 to 0.060 [1.04 to 1.52]	0.002 [0.05]
0.061 to 0.090 [1.55 to 2.29]	0.003 [0.08]
0.091 to 0.120 [2.31 to 3.05]	0.004 [0.10]
0.121 and over [3.07 and over]	0.005 [0.13]

<sup>A</sup> It is recognized that the surfaces of heavy zinc coatings, particularly those produced by hot galvanizing, are not perfectly smooth and devoid of irregularities. If the tolerances shown in Table 4 are rigidly applied to such irregularities that are inherent to the product, unjustified rejections of wire that would actually be satisfactory for use could occur. Therefore, it is intended that these tolerances be used in gaging the uniform areas of the galvanized wire.

**15. Sampling**

15.1 Sampling for determination of compliance to this specification shall be performed on each lot of material. A lot shall consist of all the strand of one size and one grade in each shipment. The number of samples to be taken shall be as follows:

	Number of Samples
5000 ft [1524 m] or less	1
Over 5000 to 30 000 ft [1524 to 9144 m]	2
Over 30 000 to 150 000 ft [9144 to 45 720 m]	3
Over 150 000 ft [45 720 m]	4

15.2 Each sample taken shall be subjected to all tests prescribed in Sections 6, 7, and 8.

15.3 In addition to the strand testing in 15.2, the individual wires shall be tested. The number of individual wires to be selected from each sample of strand and tested to determine compliance with Sections 9, 10, 11, and 13 shall be as follows:

- 3-wire strand—3 wires
- 7-wire strand—4 wires
- 19-wire strand—3 wires from each layer (total of 6 wires)
- 37-wire strand—3 wires from each layer (total of 9 wires)

15.3.1 Individual wire samples selected for compliance to Section 13 shall be discarded if any distortion of the wire occurred during the stranding operation.

15.4 Instead of testing the wires from the completed strand in accordance with 15.3, the producer may elect to establish compliance with Sections 9, 10, 11, and 13 of this specification by tests made on the wires prior to stranding, unless otherwise stipulated by the purchaser. However, if the producer makes this election, the purchaser still reserves the right to test wires from the completed strand for compliance.

**16. Inspection**

16.1 The manufacturer shall afford the inspector representing the purchaser all reasonable facilities to satisfy him that the material is being furnished in accordance with this specification. All tests and inspection shall be made at the place of manufacture prior to shipment, unless otherwise specified, and shall be so conducted as not to interfere unnecessarily with the operation of the works.

**17. Rejection**

17.1 If the wire or strand fails in the first test to meet any requirement of this specification, two additional tests shall be made on samples of wire or strand from the same coil or reel. If failure occurs in either of these tests, the lot of wire or strand shall be rejected.

**18. Packaging and Package Marking**

18.1 Wire strand shall be furnished in standard lengths (see 18.1.1) and in compact coils or on reels (see 18.1.2) as specified by the purchaser; otherwise lengths shall be as agreed upon at the time of purchase. Only one length of strand shall be furnished in each coil or on each reel. Lengths of strand may vary between the standard (nominal) length and 10 % over the standard (nominal) length, unless otherwise specified by the purchaser.

18.1.1 Standard lengths of strand are as follows: 250, 500, 1000, 2500, and 5000 ft [76, 152, 304, 760, and 1520 m].

18.1.2 Standard practice is to furnish all strand  $\frac{7}{16}$  in. [11.11 mm] and over in diameter on reels in lengths of 1000 ft [304 m] and over. Strand lengths of less than 1000 ft are regularly furnished in coils.

18.2 Each coil or reel shall have a strong weather-resistant tag securely fastened to it showing the length, nominal diam-

eter, number of wires, grade of the strand, class of coating, ASTM Specification A 475, and the name or mark of the manufacturer. If additional information is required on the tag, it shall be so specified at the time of purchase.

## 19. Keywords

19.1 steel wire strand; wire; zinc-coated steel wire strand

## SUMMARY OF CHANGES

Committee A05 has identified the location of selected changes to this standard since the last issue (A 475 - 98) that may impact the use of this standard.

### A 475 - 03:

- (1) Renumbered sections to meet Form and Style requirements.
- (2) Editorial changes were made in paragraphs 2.1, 3.2.1, 4.1.3, 7.1, 8.3, 10.1, 10.2, 11.1, 18.2, Section 17, and Table 1.
- (3) Changed Type 1 to Class 1 in paragraph 1.3 and Table 2
- (4) Added paragraph 4.1.5.
- (5) Changed “base metal” in paragraph 5.1 to “any commer-

cially accepted steel making process.”

- (6) Incorporated Note 1 into paragraph 15.3.1.
- (7) Incorporated Note 2 into paragraph 11.1.
- (8) Changed Section 14 from “Finish” to “Workmanship.”
- (9) Changed “kg/304.8m” to “kg/km” in Column 4 heading and changed the metric values in Column 4 in Table 1.
- (10) Added Summary of Changes section.

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# Standard Specification for Aluminum-Coated Steel Chain-Link Fence Fabric<sup>1</sup>

This standard is issued under the fixed designation A 491; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon ( $\epsilon$ ) indicates an editorial change since the last revision or reapproval.

## 1. Scope

1.1 This specification covers aluminum-coated steel chain-link fence fabric, aluminum-coated before weaving.

1.2 The values stated in inch-pound units are to be regarded as the standard. The values given in parentheses are for information only.

## 2. Referenced Documents

### 2.1 ASTM Standards:

A 370 Test Methods and Definitions for Mechanical Testing of Steel Products<sup>2</sup>

A 700 Practices for Packaging, Marking, and Loading Methods for Steel Products for Domestic Shipment<sup>3</sup>

A 817 Specification for Metallic-Coated Steel Wire for Chain Link Fence Fabric<sup>4</sup>

### 2.2 Federal Standard:

Fed. Std. No. 123 Marking for Shipment, Civil Agencies<sup>5</sup>

### 2.3 Military Standards:

MIL-STD-129 Marking for Shipment and Storage<sup>5</sup>

MIL-STD-163 Steel Mill Products, Preparation for Shipment and Storage<sup>5</sup>

## 3. Terminology

### 3.1 Definitions of Terms Specific to This Standard:

3.1.1 *chain link fence fabric*—a fencing material made from steel wire helically wound and interwoven in such a manner as to provide a continuous mesh without knots or ties except in the form of knuckling or of twisting the ends of the wires to form the selvage of the fabric.

3.1.2 *diamond count*—the number of diamond openings from one edge of the fabric to the other. The diamond count of a given fabric shall begin at the first completed diamond at one edge and continue to the unfinished ( $\frac{1}{2}$ ) or full opening at the other edge.

3.1.3 *knuckling*—a term used to describe the type of selvage obtained by interlocking adjacent pairs of wire ends and then bending the wire ends back into a loop. The loop shall be closed or nearly closed to a measurement less than the diameter of the wire.

3.1.4 *twisting*—a term used to describe the type of selvage obtained by twisting adjacent pairs of wire ends together in a close helix of  $1\frac{1}{2}$  machine turns, which is equivalent to 3 full twists, and cutting the wire ends at an angle. The wire ends beyond the twist shall be at least  $\frac{1}{4}$  in. [6.4 mm] long. This type of selvage is not used on fabric with a mesh size of less than 2 in. [50.8 mm].

## 4. Ordering Information

4.1 Orders for chain-link fence fabric purchased to this specification shall include the following information:

4.1.1 Quantity (Section 14),

4.1.2 Size of mesh (Section 7),

4.1.3 Size of wire (Section 8),

4.1.4 Height of fabric (Section 9),

4.1.5 Diamond count, if specified (Section 6),

4.1.6 Type of selvage (Section 10),

4.1.7 Certification if required (Section 17), and

4.1.8 ASTM designation and year of issue.

4.2 All rolls of fencing accepted by the purchaser shall be billed on the basis of the original footage of the rolls before sampling, unless changed by contractual arrangement.

NOTE 1—A typical ordering description is as follows: 25 rolls, 50 ft each, chain-link fence fabric, aluminum-coated, 2 in. mesh. 0.148 in. wire, 60 in. high, knuckled both selvages, to ASTM A 491-XX.

## 5. Materials

5.1 The wire from which the fabric is woven shall conform to all requirements of Specification A 817 for Type I coating.

<sup>1</sup> This specification is under the jurisdiction of ASTM Committee F14 on Fences and is the direct responsibility of Subcommittee F14.40 on Chain Link Fabric and Wire Accessories.

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<sup>2</sup> Annual Book of ASTM Standards, Vol 01.03.

<sup>3</sup> Annual Book of ASTM Standards, Vol 01.05.

<sup>4</sup> Annual Book of ASTM Standards, Vol 01.06.

<sup>5</sup> Available from Standardization Documents Order Desk, Bldg. 4 Section D, 700 Robbins Ave., Philadelphia, PA 19111-5094, Attn: NPODS.

## 6. Weave

6.1 The wire shall be woven throughout in the form of approximately uniform square mesh, having parallel sides and horizontal and vertical diagonals of approximately uniform dimensions. The top and bottom of the fabric shall be knuckled or twisted as specified in Section 10.

6.2 Typical diamond count for each standard height is shown in Table 1. Other diamond counts are permissible provided that they are consistent within a lot. The purchaser has the option to specify the diamond count (4.1.5).

## 7. Size of Mesh

7.1 The size of mesh shall be as indicated in Table 2 (see Fig. 1).

7.2 The permissible variation from the specified size of mesh shall be  $\pm 1/8$  in. [ $\pm 3.2$  mm] for all mesh sizes over 1 in. [25 mm], and  $\pm 1/16$  in. [ $\pm 1.6$  mm] for all mesh sizes 1 in. [25.4 mm] and under.

7.3 The size of mesh shall be determined by measuring the minimum clear distance between the wires forming the parallel sides of the mesh, and determined as the average of two readings taken at right angles to each other.

## 8. Size of Wire

8.1 Chain-link fabric shall be fabricated from wire diameters as listed in Specification A 817, with a permissible variation from the specified diameter of the coated wire of  $\pm 0.005$  in. [ $\pm 0.13$  mm].

## 9. Height of Fabric

9.1 Chain-link fabric shall be furnished in the standard heights shown in Table 2. Custom order fabric is available in heights to and including 20 ft. [6.56 m]. The height of fabric shall be the overall dimension from ends of twists or knuckles. The permissible variation from the specified height shall be  $\pm 1$  in. [ $\pm 25$  mm] for standard selvage on fabric with mesh sizes 1 in. [25 mm] and over and  $\pm 1/2$  in. [ $\pm 13$  mm] for all fabric with mesh sizes less than 1 in. [25 mm].

## 10. Selvage

10.1 Unless otherwise specified by the purchaser, fabrics with 2- or 2 1/8-in. [50- or 54-mm] mesh, in heights 60 in. [1520 mm] and under shall be knuckled at both selvages. Fabric 72

in. [1830 mm] high and over shall be knuckled at one selvage and twisted at the other.

10.2 The selvages of fabrics with meshes of less than 2 in. [50 mm] shall be knuckled.

NOTE 2—**Caution:** Twisted selvages for fence fabric under 72 in. [1830 mm] in height are not recommended because of consumer safety considerations.

## 11. Weight of Aluminum Coating

11.1 The weight of aluminum coating on the wire in the fabric shall be as specified in Specification A 817, for the wire diameter used (see Table 3).

## 12. Breaking Strength

12.1 Wire constituting the fabric shall meet the minimum breaking strength listed in the Breaking Strength Table of Specification A 817 (see Table 4) when tested in accordance with Test Methods and Definitions A 370. Specimens used to establish conformance with this requirement shall consist of individual pickets from a section of the fence fabric. The specimen shall be of sufficient length so as to be firmly gripped in the testing machine after straightening. The actual gage length (distance between jaws) of the specimen shall be limited to the undeformed length of wire between two adjacent straightened bends.

## 13. Workmanship, Finish, and Appearance

13.1 Chain-link fence fabric shall be produced by methods recognized as good commercial practices.

13.2 Excessive roughness, blisters, and flaking shall be noted. These and other defects, if present to any considerable extent, shall provide a basis for rejection.

NOTE 3—Rust formations on the cut ends of the wire at the fabric selvages are inherent characteristics of this material and do not warrant rejection of the fabric.

## 14. Standard Length of Rolls

14.1 The standard length of roll shall be 50 ft [15.24 m]  $\pm 1$  % except as otherwise agreed upon at the time of purchase.

14.2 The length of roll shall be determined by unrolling a roll of fabric on a flat surface and exerting tension by appropriate means to remove all slack. The tension applied

**TABLE 1 Typical Diamond Count<sup>A</sup>**

NOTE 1—Other diamond counts are permitted (see 6.2).

NOTE 2— For fabric heights over 144 in., see Section 9.

Nominal Diameter Coated Wire, in.	Size of Mesh, in.	Height of Fence Fabric, in.										
		36	42	48	60	72	84	96	108	120	144	
0.192	2	10½	12½	13½	17½	20½	24½	27½	31½	34½	41½	
0.148	2	10½	12½	13½	17½	20½	24½	27½	31½	34½	41½	
0.148	1	20	23	27	33	39	45	53	61	67	79	
0.135	2	10½	12½	13½	17½	20½	24½	27½	31½	34½	41½	
0.120	2	10½	12½	14½	17½	20½	24½	...	...	...	...	
0.120	1¾	...	...	...	...	...	...	31½	35½	39½	47½	
0.120	1	20	23	27	33	39	45	53	61	67	79	
0.113	2½	9½	11½	13½	16½	19½	...	...	...	...	...	

<sup>A</sup>See Appendix X1 for metric equivalents.

**TABLE 2 Sizes of Wire and Mesh<sup>A</sup>**

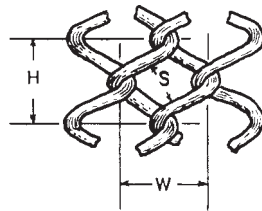
NOTE— For fabric heights over 144 in., see 9.1.

Specified Diameter of Coated Wire, in.	Size, Coated Wire Gage	Size of Mesh, in. <sup>B</sup>	Height of Fence Fabric, in.
0.192	6	2	36, 42, 48, 60, 72, 84, 96, 108, 120, 144
0.148	9	2	36, 42, 48, 60, 72, 84, 96, 108, 120, 144
0.148	9	1	36, 42, 48, 60, 72, 84, 96, 108, 120, 144
0.135	10	2	36, 42, 48, 60, 72, 84, 96, 108, 120, 144
0.120	11	2	36, 42, 48, 60, 72, 84
0.120	11	1¾	96, 108, 120, 144
0.120	11	1	36, 42, 48, 60, 72, 84, 96, 108, 120, 144
0.120	11	5/8 <sup>C</sup>	36, 42, 48, 60, 72, 84, 96, 108, 120, 144
0.120	11	1/2 <sup>C</sup>	36, 42, 48, 60, 72, 84, 96, 108, 120, 144
0.120	11	3/8 <sup>C</sup>	36, 42, 48, 60, 72, 84, 96, 108, 120, 144
0.113	11½	2½	36, 42, 48, 60, 72

<sup>A</sup>See Appendix X1 for metric equivalents.

<sup>B</sup>See Fig. 1 for mesh dimensions for 5/8 in., 1/2 in., and 3/8 in. fence fabric.

<sup>C</sup>These sizes are designed for security purposes.



Selvage, S	Height, H, in.	Width, W, in.
3/8 in. mesh	¾	¾
1/2 in. mesh	15/16	15/16
5/8 in. mesh	1 1/8	1 1/8

**FIG. 1 Mesh Dimensions for 3/8 in., 1/2 in., and 5/8 in. Fence Fabric**

**TABLE 3 Minimum Weight of Aluminum Coating for Type I**

Specified Diameter of Coated Wire, in. [mm]	Minimum Weight of Coating, oz/ft <sup>2</sup> [g/m <sup>2</sup> ] of uncoated wire surface
0.192 [4.88]	0.40 [122]
0.148 [3.76]	0.40 [122]
0.135 [3.43]	0.40 [122]
0.120 [3.05]	0.35 [107]
0.113 [2.87]	0.30 [92]

**TABLE 4 Breaking Strength**

Specified Diameter of Coated Wire, in. [mm]	Breaking Strength, min, lbf [N]
0.192 [4.88]	2170 [9650]
0.148 [3.76]	1290 [5740]
0.135 [3.43]	1290 [5740]
0.120 [3.05]	850 [3780]
0.113 [2.87]	750 [3340]

shall not reduce the actual height of the fabric by more than 1/16 in./ft [5.3 mm/m] of height or by more than 1/2 in. [12.7 mm], whichever is less.

**15. Sampling and Number of Tests**

15.1 One roll from every 50 rolls or fraction thereof in a lot shall be taken at random as a sample for test purposes. In no

case shall less than two samples be tested except when the lot is less than 10 rolls only one roll shall be selected for the sample.

15.2 Sample rolls selected shall be inspected for weave (Section 6), size of mesh (Section 7), diamond count (6.2), wire size (Section 8), height of fabric (Section 9), selvage (Section 10) and length (Section 14).

15.3 If any specimen tested fails to meet the requirements of this specification, the roll represented by the specimen shall be rejected and two additional rolls shall be inspected, both of which shall meet the requirements in every respect; otherwise, the lot represented by the samples may be rejected.

**16. Inspection**

16.1 Unless otherwise specified in the purchase order or contract, the manufacturer is responsible for the performance of all inspection and test requirements specified in this specification. Except as otherwise specified in the purchase order or contract, the manufacturer may use his own or any other suitable facilities for the performance of the inspection and test requirements unless disapproved by the purchaser at the time the order is placed. The purchaser shall have the right to perform any of the inspection and tests set forth in this specification when such inspections and tests are deemed necessary to assure that the material conforms to prescribed requirements.



**17. Certification**

17.1 When specified in the purchase order or contract, a producer's or supplier's certification shall be furnished to the purchaser that the material was manufactured, sampled, tested, and inspected in accordance with this specification and has been found to meet the requirements. When specified in the purchase order or contract, a report of the test results shall be furnished.

**18. Packaging, Marking, and Loading**

18.1 Each length of chain-link fence fabric shall be tightly rolled and firmly tied. Each roll shall carry a tag showing the type of coating, the specified wire size, mesh size, the specified length and height of fabric in the roll, ASTM Designation A 491, and the name or mark of the manufacturer.

18.2 Unless otherwise specified, packaging, marking and loading for shipment shall be in accordance with Practices A 700.

18.3 When specified in the contract or order, and for direct procurement by or direct shipment to the U.S. government, when Level A is specified, preservation, packaging, and packing shall be in accordance with Level A requirements of MIL-STD-163.

18.4 When specified in the contract or order, and for direct procurement by or direct shipment to the U.S. government, marking for shipment, in addition to the requirements specified in the contract or order, shall be in accordance with MIL-STD-129 for U.S. military agencies and in accordance with Fed. Std. No. 123 for civil agencies.

**19. Keywords**

19.1 aluminum coated (aluminized) iron and steel articles; aluminum coated (aluminized) steel chain link fence fabric; chain link fence; steel; coatings; aluminum (aluminized); fence/fencing materials; chain link

**APPENDIX**

**(Nonmandatory Information)**

**X1. Approximate Metric Equivalents for Table 1 and Table 2**

**TABLE X1.1 Approximate Metric Equivalents for Table 1 and Table 2**

Sizes of Wire and Mesh		Height of Fence Fabric	
in.	mm	in.	mm
0.192	4.88	36	910
0.148	3.76	42	1070
0.135	3.43	48	1220
0.120	3.05	60	1520
0.113	2.87	72	1830
1	25	84	2130
1 $\frac{3}{4}$	44	96	2440
2	50	108	2740
2 $\frac{1}{8}$	54	120	3050
		144	3660

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# Standard Specification for Zinc-Coated Parallel and Helical Steel Wire Structural Strand and Zinc-Coated Wire for Spun-In-Place Structural Strand<sup>1</sup>

This standard is issued under the fixed designation A 586; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

## 1. Scope

1.1 This specification covers zinc-coated parallel and helical steel wire structural strand, prestretched or nonprestretched, for use where a high-strength, high-modulus prefabricated zinc-coated steel multiple-wire tension member is desired as a component part of a structure.

1.2 The strand is furnished with Class A weight zinc-coated wires throughout. It can be furnished with Class B weight or Class C weight zinc-coated outer wires where additional corrosion protection is required.

1.3 The sections of this specification describing wire (that is, Sections 4, 5, 6, and 10) also cover zinc-coated steel wire used for spun-in-place strands for structural application.

1.4 The values stated in inch-pound units are to be regarded as the standard.

## 2. Referenced Documents

### 2.1 ASTM Standards:

A 90/A 90M Test Method for Weight of Coating on Zinc-Coated (Galvanized) Iron or Steel Articles<sup>2</sup>

B 6 Specification for Zinc (Slab Zinc)<sup>3</sup>

## 3. Ordering Information

3.1 Orders for material under this specification shall include the following information:

3.1.1 Length of strand,

3.1.2 Nominal diameter of strand (Table 1 and Table 2),

3.1.3 Prestretched (see 7.3) or nonprestretched,

3.1.4 Coating weight class on outer wires if other than Class A (Table 3),

3.1.5 Mechanical tests if required (see 7.5 and 9.1),

3.1.6 Special packaging requirements (11.1), and

3.1.7 Inspection (10.1).

NOTE 1—A typical ordering description is as follows: 2500 ft, 1 in., 1 × 19 galvanized helical strand, class A coating, on wooden reels, to ASTM Specification A 586 – \_\_\_\_.

<sup>1</sup> This specification is under the jurisdiction of ASTM Committee A-5 on Metallic-Coated Iron and Steel Products, and is the direct responsibility of Subcommittee A05.12 on Wire Specifications.

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<sup>2</sup> Annual Book of ASTM Standards, Vol 01.06.

<sup>3</sup> Annual Book of ASTM Standards, Vol 02.04.

TABLE 1 Properties of Zinc-Coated Steel Structural Strand

Nominal Diameter, in.	Minimum Breaking Strength in Tons of 2000 lb				
	Class A Coating Throughout	Class A Coating Inner Wires, Class B Coating Outer Wires	Class A Coating Inner Wires, Class C Coating Outer Wires	Approx Gross Metallic Area, in. <sup>2</sup>	Approx Weight, lb/ft
1/2	15.0	14.5	14.2	0.150	0.52
5/16	19.0	18.4	18.0	0.190	0.66
9/16	24.0	23.3	22.8	0.234	0.82
11/16	29.0	28.1	27.5	0.284	0.99
3/4	34.0	33.0	32.3	0.338	1.18
13/16	40.0	38.8	38.0	0.396	1.39
7/8	46.0	44.6	43.7	0.459	1.61
15/16	54.0	52.4	51.3	0.527	1.85
1	61.0	59.2	57.9	0.600	2.10
1 1/16	69.0	66.9	65.5	0.677	2.37
1 1/8	78.0	75.7	74.1	0.759	2.66
1 3/16	86.0	83.4	81.7	0.846	2.96
1 1/4	96.0	94.1	92.2	0.938	3.28
1 5/16	106.0	104.0	102.0	1.03	3.62
1 3/8	116.0	114.0	111.0	1.13	3.97
1 7/16	126.0	123.0	121.0	1.24	4.34
1 1/2	138.0	135.0	132.0	1.35	4.73
1 9/16	150.0	147.0	144.0	1.47	5.13
1 5/8	162.0	159.0	155.0	1.59	5.55
1 11/16	176.0	172.0	169.0	1.71	5.98
1 3/4	188.0	184.0	180.0	1.84	6.43
1 13/16	202.0	198.0	194.0	1.97	6.90
1 7/8	216.0	212.0	207.0	2.11	7.39
1 15/16	230.0	226.0	221.0	2.25	7.89
2	245.0	241.0	238.0	2.40	8.40
2 1/16	261.0	257.0	253.0	2.55	8.94
2 1/8	277.0	273.0	269.0	2.71	9.49
2 3/16	293.0	289.0	284.0	2.87	10.05
2 1/4	310.0	305.0	301.0	3.04	10.64
2 5/16	327.0	322.0	317.0	3.21	11.24
2 3/8	344.0	339.0	334.0	3.38	11.85
2 7/16	360.0	355.0	349.0	3.57	12.48
2 1/2	376.0	370.0	365.0	3.75	13.13
2 9/16	392.0	386.0	380.0	3.94	13.80
2 5/8	417.0	411.0	404.0	4.13	14.47
2 11/16	432.0	425.0	419.0	4.33	15.16
2 3/4	452.0	445.0	438.0	4.54	15.88
2 7/8	494.0	486.0	479.0	4.96	17.36
3	538.0	530.0	522.0	5.40	18.90
3 1/8	584.0	575.0	566.0	5.86	20.51
3 1/4	625.0	616.0	606.0	6.34	22.18
3 5/8	673.0	663.0	653.0	6.83	23.92
3 1/2	724.0	714.0	702.0	7.35	25.73
3 3/8	768.0	757.0	745.0	7.88	27.60
3 3/4	822.0	810.0	797.0	8.43	29.50
3 7/8	878.0	865.0	852.0	9.00	31.50
4	925.0	911.0	897.0	9.60	33.60

**TABLE 2 Properties of Zinc-Coated Steel Structural Strand**

Approx Nominal Diameter, mm	Approximate Minimum Breaking Strength in Metric Tons				
	Class A Coating Through- out	Class A Coating Inner Wires Class B Coating Outer Wires	Class A Coating Inner Wires Class C Coating Outer Wires	Approx Metallic Area, mm <sup>2</sup>	Approx Weight, kg/m
12.7	13.6	13.2	12.9	96.8	0.77
14.3	17.2	16.7	16.3	122.6	0.98
15.9	21.8	21.1	20.7	151.0	1.2
17.5	26.3	25.5	25.0	183.2	1.5
19.1	30.8	29.9	29.3	218.1	1.8
20.6	36.3	35.2	34.5	255.5	2.1
22.2	41.7	40.5	39.6	296.1	2.4
23.8	49.0	47.5	46.5	340.0	2.8
25.4	55.3	53.7	52.5	387.1	3.1
27.0	62.6	60.7	59.4	436.8	3.5
28.6	70.8	68.7	67.2	489.7	4.0
30.2	78.0	75.7	74.1	545.8	4.4
31.8	87.1	85.4	83.6	605.6	4.9
33.3	96.2	94.4	92.5	664.5	5.4
34.9	105.2	103.4	100.7	729.0	5.9
36.5	114.3	111.6	109.8	800.0	6.5
38.1	125.2	122.5	119.8	871.0	7.0
39.7	136.1	133.4	130.6	948.4	7.6
41.3	147.0	144.2	140.6	1025.8	8.3
42.9	159.7	156.0	153.3	1103.2	8.9
44.5	170.6	166.9	163.3	1187.1	9.6
46.0	183.3	179.6	176.0	1271.0	10.3
47.6	196.9	192.3	187.8	1361.3	11.0
49.2	208.7	205.0	200.5	1451.6	11.7
50.8	222.3	218.6	215.9	1548.4	12.5
51.1	236.8	233.2	229.5	1645.2	13.3
54.0	251.3	247.7	244.0	1748.4	14.1
55.6	265.8	262.2	257.6	1851.6	15.0
57.2	281.2	276.7	273.1	1961.3	15.8
58.7	296.7	292.0	287.6	2071.0	16.7
60.3	312.1	307.5	302.0	2180.7	17.6
61.9	326.6	322.1	316.6	2303.2	18.6
63.5	341.1	335.7	331.1	2419.4	19.5
65.1	355.6	350.2	344.7	2541.9	20.5
66.7	378.3	372.9	366.5	2664.5	21.5
68.3	391.9	385.6	380.1	2793.6	22.6
69.9	410.1	403.7	397.4	2929.0	23.6
73.0	448.2	440.9	434.5	3200.0	25.8
76.2	488.1	480.8	473.6	3483.9	28.1
79.4	529.8	521.6	513.5	3780.7	30.5
82.6	567.0	558.8	549.8	4090.3	33.0
85.7	610.5	601.5	592.4	4406.5	35.6
88.9	656.8	647.7	636.8	4742.0	38.3
92.01	696.7	686.7	675.9	5083.9	41.1
95.3	745.7	734.8	723.0	5438.7	43.9
98.4	796.5	784.7	772.9	5806.5	46.9
101.6	839.2	826.5	813.7	6193.6	50.0

#### 4. Material

4.1 *Base Metal*—The base metal shall be carbon steel made by the open-hearth, basic-oxygen, or electric-furnace process and of such quality that the finished strand and the hard-drawn individual zinc-coated wires coated by the hot-dip or electrolytic process shall have the properties and characteristics as prescribed in this specification.

4.2 *Zinc*—The slab zinc when used shall conform to Specification B 6.

#### 5. Physical Requirements

##### 5.1 *Tensile Properties:*

5.1.1 The zinc-coated wire used in the parallel wire strand shall, prior to fabrication, conform to the mechanical properties

in Table 4. In this case the prestretching provision of the test sample of 5.1.2 is not permitted.

5.1.2 The zinc-coated wire used in the helical wire strand shall conform to the mechanical properties in Table 4 prior to fabrication, but the wire test sample may be prestretched to 55 % of the minimum tensile strength specified in Table 4 prior to conducting the tests.

5.1.3 The tensile strength and the stress at 0.7 % extension shall be based on the actual cross-sectional area of the finished wire, including the zinc coating.

5.1.4 *Test Specimens*—The test specimens shall be free of bends or kinks other than the curvature resulting from the usual coiling operation. The hand straightening necessary to permit insertion of the specimen in the jaws of the testing machine shall be performed by drawing between wood blocks or by some other equally satisfactory means.

5.2 *Stress at 0.7 % Extension Under Load*—The value of stress at 0.7 % extension under load shall be determined by one of the following procedures, depending on the type of extensometer used:

5.2.1 *Non-Autographic Extensometer*—When a non-autographic extensometer is used to measure the 0.7 % extension, it shall have a gage length of 10 in. (254 mm), and it shall be so graduated that the smallest division corresponds to a strain not larger than 0.0001 in./in. (0.0001 mm/mm) of gage length. Apply a load corresponding to the tensile stress indicated in Table 5, using the nominal diameter of the specimen. Maintain this load while a 10-in. extensometer is attached and adjusted to the initial setting shown in Table 5. Then increase the load uniformly until the extensometer indicates an extension of 0.07 in. (1.78 mm) or 0.7 % extension. Record the load for this extension. The stress corresponding to this load shall meet the requirements for the stress of 0.7 % extension specified in Table 4, depending on the class of coating under consideration. Hold the specimen at 0.7 % extension under load and remove the extensometer used to measure the stress at 0.7 % extension; then replace it with an elongation extensometer. Continue the application of load until fracture occurs. Record the elongation attained from the elongation extensometer and add to it 0.7 % obtained from the stress at 0.7 % extensometer to get the total elongation.

5.2.2 *Autographic Extensometer*—When an autographic extensometer is used, it shall have a gage length of at least 2 in. (50.8 mm) and the magnification of strain shall not be less than 250. Apply a load, corresponding to the tensile stress indicated in Table 5, using the nominal diameter of the specimen. Maintain this load and attach the extensometer. Then increase the load uniformly until the extension recorded by the extensometer is at least 0.7 %. Determine the load at 0.7 % extension from the load-strain curve. The stress corresponding to this load shall meet the requirements for stress at 0.7 % extension prescribed in Table 4, depending on the class of coating under consideration. Hold the specimen at 0.7 % extension under load and remove the extensometer used to measure the stress at 0.7 % extension; then replace it with an elongation extensometer. Continue the application of load until fracture occurs. Record the elongation attained from the elongation extensometer and add to it 0.7 % obtained from the

**TABLE 3 Minimum Weight of Coating**

Nominal Diameter of Coated Wire		Weight of Zinc Coating, min					
		oz/ft <sup>2</sup> of Uncoated Wire Surface			g/m <sup>2</sup> of Uncoated Wire Surface		
in.	mm	Class A Coating	Class B Coating	Class C Coating	Class A Coating	Class B Coating	Class C Coating
0.040 to 0.061, incl	1.016 to 1.549, incl	0.40	0.80	1.20	122	244	366
0.062 to 0.079, incl	1.575 to 2.007, incl	0.50	1.00	1.50	153	305	458
0.080 to 0.092, incl	2.032 to 2.337, incl	0.60	1.20	1.80	183	366	549
0.093 to 0.103, incl	2.362 to 2.616, incl	0.70	1.40	2.10	214	427	641
0.104 to 0.119, incl	2.642 to 3.023, incl	0.80	1.60	2.40	244	488	732
0.120 to 0.142, incl	3.048 to 3.607, incl	0.85	1.70	2.55	259	519	778
0.143 to 0.187, incl	3.632 to 4.750, incl	0.90	1.80	2.70	275	549	824
0.188 and larger <sup>A</sup>	4.775 and larger <sup>A</sup>	1.00	2.00	3.00	305	610	915

<sup>A</sup>This is not to imply that larger wire will be manufactured to any unlimited diameter. It only implies that the wire sizes chosen by the strand manufacturer must meet the requirements of this specification.

**TABLE 4 Mechanical Requirements**

Zinc Coating Class	Nominal Diameter		Stress at 0.7 % Extension Under Load, min		Tensile Strength, min		Total Elongation in 10 in. or 250 mm, min, %
	in.	mm	psi	MPa	psi	MPa	
A	0.040 to 0.110	1.016 to 2.794	150 000	1030	220 000	1520	2.0
	0.111 and larger <sup>A</sup>	2.820 and larger <sup>A</sup>	160 000	1100	220 000	1520	4.0
B	0.090 and larger <sup>A</sup>	2.286 and larger <sup>A</sup>	150 000	1030	210 000	1450	4.0
C	0.090 and larger <sup>A</sup>	2.286 and larger <sup>A</sup>	140 000	970	200 000	1380	4.0

<sup>A</sup>This is not to imply that larger wire will be manufactured to any unlimited diameter. It only implies that the wire sizes chosen by the strand manufacturer must meet the requirements of this specification.

**TABLE 5 Initial Settings for Determining Stress at 0.7 % Extension**

Nominal Diameter		Initial Stress		Initial Setting of Extensometer, in./in. or mm/mm
in.	mm	ksi	MPa	
0.040 to 0.089, incl	1.070 to 2.26, incl	14	100	0.0005 (0.05 % extension)
0.090 to 0.119, incl	2.29 to 3.02, incl	28	190	0.0010 (0.10 % extension)
0.120 and larger	3.05 and larger <sup>A</sup>	42	290	0.0015 (0.15 % extension)

<sup>A</sup>This is not to imply that larger wire will be manufactured to any unlimited diameter. It only implies that the wire sizes chosen by the strand manufacturer must meet the requirements of this specification.

stress at 0.7 % extensometer to get the total elongation.

**NOTE 2**—The extensometer used for the stress at 0.7 % extension and the elongation extensometer may be the same instrument. Two separate instruments are advisable since the more sensitive stress at 0.7 % extensometer that could be damaged when the wire fractures may be removed following the determination of the 0.7 % extension. The elongation extensometer may be constructed with less sensitive parts or be constructed in such a way that little damage would result if fracture occurs while the extensometer is attached to the specimen.

**5.3 Elongation**—In determining total elongation (elastic plus plastic extension) autographic or extensometer methods may be employed. If fracture takes place outside the middle third of the gage length, the elongation value obtained may not be representative of the material.

**5.4 Tensile Strength**—The tensile strength is determined from the maximum load during the total elongation test.

**5.5 Ductility of Steel**—The zinc-coated wire, prior to fabrication into strand, shall be capable of being wrapped two turns in a close helix at a rate not exceeding 15 turns per minute around a cylindrical steel mandrel equal to three times the nominal diameter of the wire under test without fracture of the wire.

**5.6 Weight of Zinc Coating**—The weight of zinc coating on the individual wires prior to fabrication of strand shall be not less than that specified in Table 3.

**5.7 Adherence of Coating**—The zinc-coated wire, prior to fabrication into strand, shall be capable of being wrapped two turns in a close helix at a rate not exceeding 15 turns per minute around a cylindrical steel mandrel equal to five times the nominal diameter of the wire under test without cracking or flaking the zinc coating to such an extent that any zinc can be removed by rubbing with the bare fingers. Loosening or detachment during the adherence test of superficial small particles of zinc formed by mechanical polishing of the surface of zinc-coated wire shall not be considered cause for rejection.

**5.8** If any sample breaking within the grips or the jaws of the testing machine results in values below the specified limits for tensile strength, stress at 0.7 % extension or elongation, the results shall be considered invalid and retesting shall be required.

**5.8.1** If any test fails to meet the minimum value required, two additional tests shall be made on samples of wire from the same coil or reel and if failure occurs in either of these tests, the coil or reel shall be rejected. If both of these tests pass, the coil or reel shall be accepted.

**5.9 Finish**—The zinc-coated wire surface shall be free of imperfections not consistent with good commercial practice. The coating shall be continuous and reasonably uniform.

**NOTE 3**—It is recognized that the surface of heavy zinc coatings,

particularly those produced by the hot-dip galvanizing process, are not perfectly smooth and not devoid of irregularities.

**6. Test for Coating Weight**

6.1 The weight of the zinc coating shall be determined by a stripping test made on the individual wires prior to fabrication of strand, in accordance with Test Method A 90/A 90M.

**7. Strand**

7.1 The zinc-coated strand shall consist of layers of wire about a center wire. The number of layers and number and size of wires in each layer shall be determined by the manufacturer.

7.2 The minimum breaking strength of helical strand properties are shown in Table 1 and Table 2. Specifically dimensioned strand bigger than 4 in. (101.6 mm) may be employed provided that the breaking strength, gross metallic area, and weight per unit length are defined. The properties of parallel wire strand shall be as agreed upon between the purchaser and the manufacturer.

7.3 When specified, the helical strand shall be prestretched under tension of not more than 55 % of the breaking strength listed in Table 1 and Table 2.

7.4 The modulus of elasticity shall be as shown in Table 6.

7.5 If specified, a test for modulus of elasticity shall be made on each manufactured length of strand. The modulus of elasticity shall be determined from gage length of not less than 100 in. (2.54 m) and shall be computed on the sum of the gross metallic cross-sectional areas of the wire making up the strand, including the zinc coating. Throughout the range from 10 % to 50 % of the breaking strength listed in Table 1 and Table 2, the modulus of elasticity shall not be less than the value shown in Table 6.

**8. Joints and Splices**

8.1 The wires shall be made in such lengths that the helical

strands can be manufactured with no splices or joints in the finished outer wires. Welds made in the outer wires prior to drawing are permitted. Splicing of the inner wires during the stranding operation is permissible. Joints in the wires of strand shall be dispersed sufficiently so as to maintain the minimum breaking strength as listed in Table 1 and Table 2. When joints are necessary in any wires, they shall be made in accordance with best known acceptable practices and shall be recoated in a workmanlike manner with zinc or a lead-zinc compound containing a minimum of 50 % zinc.

**9. Sampling and Testing**

9.1 If specified, a test sample shall be taken from each manufactured length of strand and tested to the minimum breaking strength. If it fails to meet the minimum breaking strength requirement, and has not broken in the cone or grips, two additional samples shall be cut from the same manufactured length and tested. If either additional sample fails the retest for breaking strength, the manufactured length in question shall be rejected. If both of these two samples pass the retest for breaking strength, the manufactured length in question shall be accepted. Any test, however, which fails due to faulty attaching of the sockets shall be disregarded.

**10. Inspection**

10.1 All tests and inspection shall be made at the place of manufacture unless otherwise specified and shall be so conducted as not to interfere unnecessarily with the operations of the works. The manufacturer shall afford the inspector representing the purchaser all reasonable facilities to satisfy him that the material is being furnished in accordance with this specification. When specified, inspection may be waived, and certified copies of test reports furnished.

**11. Packaging**

11.1 Structural strand shall be packaged in coils or on reels at the discretion of the manufacturer unless otherwise specified. Strand shall be packaged in such a manner so that no permanent deformation of wires in the strand will occur.

**12. Keywords**

12.1 structural strand; zinc-coated strand; zinc-coated wire for spun-in-place structural strand

**TABLE 6 Minimum Moduli of Elasticity of Prestretched Structural Strand**

Nominal Diameter Strand		Minimum Modulus—Class A Coating <sup>A</sup>	
in.	mm	ksi	MPa
1/2 to 2 5/16	12.70 to 65.09	24 000	165 500
2 5/8 and larger	66.67 and larger	23 000	158 600

<sup>A</sup>For Class B or Class C weight of zinc-coated outer wires, reduce minimum modulus 1000 ksi or 6900 MPa.

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*This standard is subject to revision at any time by the responsible technical committee and must be reviewed every five years and if not revised, either reapproved or withdrawn. Your comments are invited either for revision of this standard or for additional standards and should be addressed to ASTM Headquarters. Your comments will receive careful consideration at a meeting of the responsible technical committee, which you may attend. If you feel that your comments have not received a fair hearing you should make your views known to the ASTM Committee on Standards, 100 Barr Harbor Drive, West Conshohocken, PA 19428.*



# Standard Specification for Steel Sheet, Electrolytic Zinc-Coated, for Light Coating Weight [Mass] Applications<sup>1</sup>

This standard is issued under the fixed designation A 591/A 591M; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

*This standard has been approved for use by agencies of the Department of Defense.*

## 1. Scope

1.1 This specification covers zinc coatings produced by electro-deposition for light coating weight [mass] applications on steel sheet. This product is available in four zinc-coating designations which are listed in Table 1. For electrolytic zinc-coated steel sheet with coating masses heavier than described in this specification, see Specification A 879.

1.2 This product is intended for applications requiring some degree of corrosion resistance with or without requirements for formability, strength, paintability, or a combination thereof. The coating is used to provide some enhancement in corrosion performance as compared to an uncoated product. It is not intended to withstand outdoor exposure without chemical treating and painting.

1.3 The steel sheet used as the substrate shall be as described in one of the following specifications, as specified in the order: A 366/A 366M, A 569/A 569M, A 570/A 570M, A 606, A 607, A 611, A 620/A 620M, A 622/A 622M, A 659/A 659M, A 715, A 794, A 812/A 812M, A 963/A 963M, and A 969/A 969M.

1.3.1 This coating process has essentially no effect on the base metal mechanical properties and can be used on any grade or quality of hot or cold-rolled steel sheet.

1.4 For purposes of determining conformance with this specification, values shall be rounded to the nearest unit in the right-hand place of figures used in expressing the limiting values in accordance with the rounding method of Practice E 29.

1.5 The values stated in either inch-pound or SI units are to be regarded separately as standard. Within the text, the SI units are shown in brackets. The values stated in each system are not exact equivalents; therefore, each system must be used independently of the other.

## 2. Referenced Documents

### 2.1 ASTM Standards:

A 90/A 90M Test Method for Weight [Mass] of Coating on

<sup>1</sup> This specification is under the jurisdiction of ASTM Committee A-5 on Metallic Coated Iron and Steel Products and is the direct responsibility of Subcommittee A05.11 on Sheet Specifications.

Current edition approved May 10, 1998. Published December 1998. Originally published as A 591 – 68. Last previous edition A 591 – 96.

**TABLE 1 Coating Class and Minimum Coating Limits Coating Minimum Requirements Per Side**

Inch-Pound Units			
Coating Designation	Coating Name	Weight, oz/ft. <sup>2</sup>	Thickness, mils.
10Z	Flash	0.01	0.017
20Z	Intermediate	0.02	0.034
40Z	Full	0.04	0.068
80Z	Double	0.08	0.136
SI Units			
Coating Designation	Coating Name	Mass, g/m <sup>2</sup>	Thickness, μm
03G	Flash	3	0.42
06G	Intermediate	6	0.84
12G	Full	12	1.68
24G	Double	24	3.36

Iron and Steel Articles with Zinc or Zinc-Alloy Coatings<sup>2</sup>  
A 366/A 366M Specification for Commercial Steel (CS) Sheet, Carbon, (0.15 Maximum Percent) Cold-Rolled<sup>3</sup>  
A 568/A 568M Specification for Steel, Sheet, Carbon and High Strength, Low-Alloy, Hot-Rolled and Cold-Rolled, General Requirements for<sup>3</sup>  
A 569/A 569M Specification for Steel, Carbon (0.15 Maximum, Percent), Hot-Rolled Sheet and Strip Commercial<sup>3</sup>  
A 570/A 570M Specification for Steel, Sheet and Strip, Carbon, Hot-Rolled, Structural Steel<sup>3</sup>  
A 606 Specification for Steel, Sheet and Strip, High-Strength, Low-Alloy, Hot-Rolled and Cold-Rolled with Improved Atmospheric Corrosion Resistance<sup>3</sup>  
A 607 Specification for Steel, Sheet and Strip, High-Strength, Low-Alloy, Columbium or Vanadium, or Both, Hot-Rolled and Cold-Rolled<sup>3</sup>  
A 611 Specification for Structural Steel (SS), Sheet, Carbon, Cold-Rolled<sup>3</sup>  
A 620/A 620M Specification for Drawing Steel (DS), Sheet, Carbon, Cold-Rolled<sup>3</sup>  
A 622/A 622M Specification for Drawing Steel (DS), Sheet, and Strip, Carbon, Hot-Rolled<sup>3</sup>  
A 659/A 659M Specification for Commercial Steel (CS), Sheet and Strip, Carbon (0.16 maximum to 0.25 Maximum

<sup>2</sup> Annual Book of ASTM Standards, Vol 01.06.

<sup>3</sup> Annual Book of ASTM Standards, Vol 01.03.

Percent), Hot-Rolled<sup>3</sup>

A 700 Practices for Packaging, Marking, and Loading Methods for Steel Products for Domestic Shipment<sup>4</sup>

A 715 Specification for Steel Sheet and Strip, High-Strength, Low-Alloy, Hot-Rolled, and Steel Sheet, Cold-Rolled, High-Strength, Low-Alloy, with Improved Formability<sup>3</sup>

A 754/A 754M Test Method for Coating Weight [Mass] by X-Ray Fluorescence<sup>2</sup>

A 794 Specification for Commercial Steel (CS), Sheet (Carbon 0.16 % Maximum to 0.25 % Maximum), Cold-Rolled<sup>3</sup>

A 879 Specification for Steel Sheet, Zinc-Coated by the Electrolytic Process for Applications Requiring Designation of Coating Mass on Each Surface<sup>2</sup>

A 902 Terminology Relating to Metallic Coated Steel Products<sup>2</sup>

A 917 Specification for Steel Sheet, Coated by the Electrolytic Process for Applications Requiring Designation of the Coating Mass on Each Surface (General Requirements)<sup>2</sup>

A 963/A 963M Specification for Deep Drawing Steel (DDS), Sheet, Carbon, Cold-Rolled<sup>3</sup>

A 969/A 969M Specification for Extra Deep Drawing (EDDS), Steel, Sheet, Carbon, Cold-Rolled<sup>3</sup>

B 504 Test Method for Measurement of Thickness of Metallic Coatings by the Coulometric Method<sup>5</sup>

E 29 Practice for Using Significant Digits in Test Data to Determine Conformance with Specifications<sup>6</sup>

### 3. Terminology

3.1 *Definitions*—For definitions of general terms used in this standard, refer to Terminology A 902.

3.2 *Definitions of Terms Specific to This Standard:*

3.2.1 *surface treatment, n*—(1) a passivating chemical treatment applied to zinc coated steel sheet to retard corrosion (storage stain) during shipment and storage, or (2) a phosphatized treatment to prepare the zinc coating for post painting.

3.2.1.1 *Discussion*—The inhibiting characteristics of the passivating chemical treatment are limited; if a lot becomes wet in shipment or storage it should be used or dried immediately.

3.2.1.2 *Discussion*—Passivating chemical treatment is sometimes undesirable because it may inhibit further processing such as phosphatizing or painting.

3.2.2 *oiling, n*—a coating applied to zinc-coated steel sheet alone or in addition to chemical treatment for further protection against the onset of storage corrosion; the oil coating is intended as a corrosion inhibitor only and not as a rolling or drawing lubricant.

3.2.2.1 *Discussion*—Electrolytic zinc-coated steel sheet is not normally produced with oiling.

### 4. Classification

4.1 The steel base metal is classified by steel sheet designation as Commercial Steel (CS), Drawing Steel (DS), Deep

Drawing Steel (DDS), Extra Deep Drawing Steel (EDDS), Structural Steel (SS), and High Strength-Low Alloy Steel (HSLAS).

4.2 The zinc coating is classified by thickness, coating designation or coating name.

4.3 *Surface Treatments*—Treatments for the zinc-coated surface, when specified, are passivating chemical treatment, or phosphating treatment, either alone or in combination with oiling.

### 5. Ordering Information

5.1 Material shall be ordered to a decimal thickness for both coils and cut lengths. The thickness is the total of the base metal and the coating.

5.2 Orders for material under this specification shall include the following, as required, to describe the required material:

5.2.1 Name of material (electrolytic zinc-coated steel sheet),

5.2.2 ASTM designation and year of issue (A 591— \_\_\_ for inch-pound units [A 591M— \_\_\_ for SI units]),

5.2.3 ASTM designation of the specification for the steel sheet substrate to which the zinc coating is applied, including all necessary ordering information enumerated in that specification, including the steel designation,

5.2.4 Coating class,

5.2.4.1 Type of surface treatment,

5.2.5 Oiled or not oiled,

5.2.6 Dimensions (including thickness, width, and length (if cut lengths),

5.2.7 Coil size requirements (specify maximum outside diameter, acceptable inside diameter, and maximum weight),

5.2.8 Packaging requirements,

5.2.9 Certification, if required, and whether heat analysis, mechanical properties, and coating mass report is to be furnished,

5.2.10 Application (show part identification and description), and

5.2.11 Special requirements (if any).

NOTE 1—A typical ordering description in inch-pound units is as follows: Electrolytic zinc-coated steel sheet, to ASTM A 591— \_\_\_; with steel sheet substrate conforming to ASTM A 366, Commercial Steel; zinc coating designation 20Z (Intermediate Coating), not surface treated, not oiled; 0.063 in. by 36 in. by coil; coil requirements — 56 in. max outer diameter, 24 in. inner diameter, 20 000 lb max; for painted school locker panels. A typical ordering description in SI units is as follows: Electrolytic zinc-coated steel sheet to ASTM A 591M— \_\_\_; with steel sheet substrate conforming to ASTM A 366M, Commercial Steel; zinc coating designation 06G (Intermediate Coating), not surface treated, not oiled; 1.00 mm nominal by 900 mm by coil; coil requirements — 1500 mm max outer diameter, 609.6 mm inner diameter, 10 000 kg max; for painted school locker panels.

### 6. Coating Properties

6.1 Coating weight [mass] shall conform to the requirements as given in Table 1. The weight [mass] of the coating is the single spot value on each surface of the sheet in oz/ft<sup>2</sup> [g/m<sup>2</sup>].

6.2 *Coating Mass and Thickness Tests:*

6.2.1 The weigh-strip-weigh method (see Test Method A 90/A 90M) is a destructive test that determines coating mass by measuring the difference in weight [mass] between a coated

<sup>4</sup> Annual Book of ASTM Standards, Vol 01.05.

<sup>5</sup> Annual Book of ASTM Standards, Vol 02.05.

<sup>6</sup> Annual Book of ASTM Standards, Vol 14.02.



and a stripped (uncoated) sample. If one surface is protected suitably during the initial stripping, coating mass can be determined for each surface independently. Conversion of the coating mass to coating thickness is possible only if the density of the coating is known precisely.

6.2.2 Coating thickness measurements by X-ray fluorescence (see Test Method A 754) is a nondestructive test that determines coating mass by converting X-ray fluorescence measurements to coating mass values. This method is readily adaptable to the continuous monitoring of coating mass during coating. Thus modern electroplating facilities are frequently equipped with X-ray fluorescence gages that provide feedback to control the coating mass. These devices are permitted for use as a basis for determining suitability for shipment provided that they have been calibrated properly.

6.2.3 Measurement by Coulometric method (see Test Method B 504) is a destructive test that determines coating mass and or thickness electrochemically. The method is rapid and versatile for light coating mass applications.

6.2.4 The referee method to be used shall be as agreed upon between the producer and the consumer. In the absence of such agreement, Test Method A 90/A 90M shall be used as the referee method.

6.2.5 Estimate the coating thickness from the coating weight [mass] by using the following relationships:

6.2.5.1 *Inch-Pound Units*—1 oz/ft<sup>2</sup> coating weight = 1.7 mils coating thickness; 1 mil coating thickness = 0.59 oz/ft<sup>2</sup> coating weight.

6.2.5.2 *SI Units*—1 g/m<sup>2</sup> coating mass = 0.14 μm coating thickness; 1 μm coating thickness = 7.14 g/m<sup>2</sup> coating mass.

### 6.3 Coating Mass Test:

6.3.1 One test specimen shall be taken from the lift of cut lengths or coils such that no portion of the specimen is closer than 1 in. [25 mm] to the edge of the as-received sheet.

### 6.4 Coating Bend Test:

6.4.1 For all steel sheets other than Structural (physical) and High Strength Low-Alloy, the coated sheet shall be capable of being bent 180° flat on itself (Ot) in any direction without flaking of the coating on the outside of the bend only. Flaking of the coating within ¼ in. [6 mm] of the edge of the bend specimen shall not be a cause for rejection.

6.4.2 For Structural Steel sheets, the bend test specimens shall be capable of being bent through 180° in any direction without flaking of the coating on the outside of the bend only. Flaking of coating within ¼ in. [6 mm] of the edge of the bend specimen shall not be cause for rejection. The ratio of the bend diameter to the thickness of the specimen for Structural steel shall be as outlined in the Bend Test Requirements table of Specification A 611.

6.4.3 For High Strength Low-Alloy Steel sheets, the bend test specimens shall be capable of being bent according to the provisions of Appendix X1 of Specification A 607 without flaking of the coating on the outside of the bend only. Flaking of coating within ¼ in. [6 mm] of the edge of the bend specimen shall not be cause for rejection.

6.4.4 Coating bend test specimens shall be 2 to 4 in. [50 to 100-mm] wide. The specimen shall be cut not less than 2 in. [50 mm] from the edge of the test sheet.

6.4.5 Electrolytic zinc coatings are usually tightly adherent even when used for difficult forming operations; however, powdering or flaking can occur if the material is severely formed or “coined” during fabrication.

## 7. Dimensions and Permissible Variations

7.1 Material furnished under this specification shall meet all applicable requirements of the current edition of Specification A 568/A 568M for the steel designation specified, unless otherwise specified herein.

## 8. Certification

8.1 When required by the purchase order, a certificate of compliance or a test report, or both, shall be furnished to the purchaser.

8.1.1 The certificate of compliance shall include a certification that the product has been manufactured and tested in accordance with the requirements of the product specification, and that the test results conform to the requirements of that specification.

8.1.2 The test report shall show the heat analysis and the results of all tests required by the product specification and the order.

8.1.3 These documents shall provide information necessary to identify the product represented; for example, the manufacturer’s name or brand, ASTM specification, coating designation, grade (when required), ordered thickness, width, length (if cut length), and unit identification (heat number, coil number, etc...).

8.1.4 A signature is not required. However, the certification documents shall clearly identify the organization submitting the information. Notwithstanding the absence of a signature, the organization submitting the documents is responsible for the accuracy of the information.

8.2 The furnishing of a certificate of compliance or test report, or both, shall not restrict the right of the purchaser to sample and test the product furnished.

## 9. Packaging and Package Marking


9.1 It is common practice to use the methods of packaging as listed in the latest revision of Practices A 700.

9.1.1 Purchaser shall specify the packaging methods, if other than as described in 9.1.

9.2 As a minimum requirement, the material shall be identified by having the manufacturer’s name, ASTM designation, weight, purchaser’s order number, and material identification legibly shown on a tag attached to each coil or shipped unit.

## 10. Keywords

10.1 coatings, metallic; coating zinc; steel products, electrodeposited coatings; steel sheet, zinc coated (electrolytic process); corrosion, steel; zinc coatings

 **A 591/A 591M**

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# Standard Specification for Tin Mill Products, Electrolytic Tin-Coated, Cold-Rolled Sheet<sup>1</sup>

This standard is issued under the fixed designation A 599/A 599M; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

## 1. Scope

1.1 This specification covers cold-rolled steel sheet in coils or in cut lengths, tin-coated by electrodeposition. The product is commonly known as electrolytic tin-coated sheet, and is for applications that need good solderability, good surface appearance, and a degree of corrosion resistance. Tin-coated sheet is produced to various designations of tin coating, as outlined in Table 1.

1.1.1 Electrolytic tin-coated sheet is customarily available as commercial steel (CS); drawing steel (DS); deep drawing steel (DDS); extra deep drawing steel (EDDS), and structural steel (SS). The tin coating is available as unmelted or melted.

1.2 *Limitations*—This specification is applicable to orders in either inch-pound units (as A 599), which is supplied in thicknesses from 0.015 in. to 0.033 in., or SI units [as A 599M], which is supplied in thicknesses from 0.38 mm to 0.84 mm. For thicknesses lighter than 0.015 in. [0.38 mm], refer to A 624 [A 624M].

1.3 Unless the order shows the “M” designation [SI units], the product shall be furnished to inch-pound units. The values stated in either inch-pound or SI units are to be regarded as standard. Within the text, the SI units are shown in brackets. The values stated in each system are not exact equivalents; therefore, each system must be used independently of the other. Combining values from the two systems may result in nonconformance with this specification.

## 2. Referenced Documents

### 2.1 ASTM Standards:

A 568/A 568M Specification for Steel, Sheet, Carbon, and High-Strength, Low-Alloy, Hot-Rolled and Cold-Rolled, General Requirements for<sup>2</sup>

A 623 Specification for Tin Mill Products, General Requirements<sup>3</sup>

A 623M Specification for Tin Mill Products, General Requirements (Metric)<sup>3</sup>

<sup>1</sup> This specification is under the jurisdiction of ASTM Committee A01 on Steel, Stainless Steel, and Related Alloys and is the direct responsibility of Subcommittee A01.20 on Tin Mill Products.

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<sup>2</sup> Annual Book of ASTM Standards, Vol 01.03.

<sup>3</sup> Annual Book of ASTM Standards, Vol 01.06.

**TABLE 1 Electrolytic Tin-Coated Sheets Coating Weight [Mass]**

NOTE 1—Listed below are the commonly produced coating weights [mass] upon agreement between the producer and the purchaser. Other combinations of coatings may be specified and the appropriate minimum average test values<sup>A</sup> apply.

Designation No.	Nominal Tin Coating Weight [Mass] (Each Surface) lb/base box (g/m <sup>2</sup> ) <sup>B</sup>	Minimum Average Coating Weight [Mass] (Each Surface Test Value) lb/base box (g/m <sup>2</sup> ) <sup>B,C</sup>
5 (0.6/0.6)	0.025/0.025 (0.6/0.6)	0.02/0.02 (0.5/0.5)
10 (1.1/1.1)	0.05/0.05 (1.1/1.1)	0.04/0.04 (0.9/0.9)
15 (1.7/1.7)	0.075/0.075 (1.7/1.7)	0.06/0.06 (1.4/1.4)
20 (2.2/2.2)	0.10/0.10 (2.2/2.2)	0.08/0.08 (1.8/1.8)
25 (2.8/2.8)	0.125/0.125 (2.8/2.8)	0.11/0.11 (2.5/2.5)
50 (5.6/5.6)	0.25/0.25 (5.6/5.6)	0.23/0.23 (5.2/5.2)
75 (8.4/8.4)	0.375/0.375 (8.4/8.4)	0.35/0.35 (7.8/7.8)
100 (11.2/11.2)	0.50/0.50 (11.2/11.2)	0.45/0.45 (10.1/10.1)

<sup>A</sup>Refer to Specifications A 623 and A 623M.

<sup>B</sup>A base box is defined as a unit of area equivalent to 112 sheets 14 in. by 20 in. or 31 360 in.<sup>2</sup> (refer to Specification A 623).

<sup>C</sup>The minimum single spot value shall not be less than 80 % of the minimum average tin coating weight [mass] (see 8.1 and 8.2).

A 624/A 624M Specification for Tin Mill Products, Electrolytic Tinplate, Single-Reduced<sup>3</sup>

A 630 Test Methods for Determination of Tin Coating Weights for Hot-Dip and Electrolytic Tin Plate<sup>3</sup>

A 700 Practices for Packaging, Marking, and Loading Methods for Steel Products for Domestic Shipment<sup>4</sup>

A 1008/A 1008M Specification for Steel, Sheet, Cold-Rolled, Carbon, Structural, High-Strength Low-Alloy and High-Strength Low-Alloy with Improved Formability<sup>2</sup>

## 3. Terminology

### 3.1 Definitions of Terms Specific to This Standard:

3.1.1 *chemical treatment*—a passivating chemical treatment, normally applied to the tinned surface to stabilize the surface to control tin oxide formation and growth. Sodium dichromate is most commonly used. Without such treatment, severe tin oxide growth, and its resultant discoloration, is a hazard. Excessive oxide growth may also cause poor solderability and poor adhesion of organic coatings. If a special surface treatment is required, it should be negotiated with the supplier.

<sup>4</sup> Annual Book of ASTM Standards, Vol 01.05.

### 3.2 Finishes:

3.2.1 *No. 5 Finish*—a shot-blasted roll base metal finish usually employed on unmelted tin-coated sheet.

3.2.2 *No. 7 Finish*—a ground-roll base metal finish usually employed on melted tin-coated sheet.

3.2.2.1 *Discussion*—It is possible to produce either No. 5 or No. 7 Finish as unmelted or melted; however, end application is important and should be negotiated with the producer.

3.3 *melted tin coating*—tin coated by electrodeposition on a base steel normally having a ground-roll finish (see 3.2), and then melted to reflow the tin. The resultant coating has a brighter appearance than unmelted tin. An iron-tin alloy layer is developed during the melting operation, thus reducing the amount of free tin available. Due to the limitations of the reflow section of the plating lines, certain thicknesses may not be available with a melted finish.

3.4 *oil*—an extremely thin oil film furnished on both surfaces of tinned sheet to minimize abrasion in shearing, coiling or uncoiling, shipping, and handling. Usually dioctyl sebecate (DOS) or acetyl tributyl citrate (ATBC) is used. Surface active agents such as glycerol mono-oleate may be incorporated into the lubricant for application on tinned sheet. Oil film other than normal should be negotiated with the producer. The oil film is not a drawing lubricant.

3.5 *unmelted tin coating*—tin-coated by electrodeposition on a base steel normally having a dull, blasted-roll surface texture (see 3.2). The deposited tin also has a dull gray appearance.

## 4. Ordering Information

4.1 Orders for material under this specification shall include the following, as required, to adequately describe the required material.

4.1.1 Name of material (electrolytic tin-coated sheet) and quality.

4.1.2 Coating designation (melted or unmelted).

4.1.3 *Base Metal Finish*—Specify either No. 5 (blasted roll) or No. 7 (ground roll) base metal finish. If a special finish is required, it should be negotiated with the supplier.

4.1.4 Dimensions (show thickness, width, and length, if cut lengths).

4.1.5 *Coil Size Requirements*—Specify maximum outside diameter (OD), acceptable inside diameter (ID), and maximum coil weight [mass]; specify whether welds are acceptable or not.

4.1.6 Application (show part identification and description).

4.1.7 ASTM designation number and year of issue.

4.1.8 Special requirements, if required.

NOTE 1—A typical ordering description is as follows: Electrolytic Tin-Coated Sheet—Deep Drawing Steel (DDS), Coating Designation 25, Unmelted, No. 5 Finish, 0.018 by 26<sup>3</sup>/<sub>16</sub> in. by coil, 60 in. max OD, 16 in. ID, 18 000 lb max, coil for oil-filter shells. ASTM A 599—\_\_\_\_. [Tin-Coated Sheet—Deep Drawing Steel (DDS), Coating Designation 2.8/2.8, Unmelted, No. 5 Finish, 0.50 mm by 668 mm by coil, 1530 mm max OD, 408 mm ID, 8.2 metric tons max, coil for oil-filter shells. ASTM A 599M—\_\_\_\_.]

## 5. Manufacture

5.1 *Base Metal*—The base metal is produced in conformance to that described for cold-rolled sheet in Specification A 568/A 568M.

5.2 *Coil Preparation*—Normal coil inside diameter is 16 in. [400 mm]; any other should be negotiated. Requirements as to the maximum outside diameter and to the maximum weight should be indicated. The leading ends of lap welds shall not exceed 1 in. [25 mm].

## 6. Chemical Requirements

6.1 The chemical composition of base metal furnished in accordance with this specification shall conform to the requirements of the applicable quality designations of Specification A 1008/A 1008M.

## 7. Mechanical Requirements

7.1 Structural steel (SS) sheet, high-strength low-alloy steel (HSLAS) sheet and high-strength low-alloy steel with improved formability (HSLAS-F) are approved to tensile property values as specified in Table 4 of Specification A 1008/A 1008M.

7.2 Commercial steel (CS) sheet, drawing steel (DS) sheet, deep drawing steel (DDS) sheet, and extra deep drawing steel (EDDS) sheet are produced to typical nonmandatory mechanical properties found in Table 3 of Specification A 1008/A 1008M.

## 8. Weight [Mass] of Coating

8.1 The weight [mass] of coating shall conform to the requirements prescribed in Table 1 for the coating designation. The weight of coating is the total amount on both sides of a sheet, expressed in pounds per base box [or in grams per square metre].

8.2 *Determination of Tin Coating Weights*—Typical methods for determination of tin coating weights are described in Test Methods A 630. In cases of dispute, Method D, referee method, shall be used.

## 9. Weight [Mass] of Coating Tests

9.1 When the purchaser wishes to make tests to ascertain compliance of this specification for tin coating weight on a lot of any specific item of electrolytic tin-coated sheet, the procedure to be employed shall be that described in Test Methods A 630.

## 10. Dimensions and Tolerances

10.1 Except for thickness and width tolerances shown in Tables 2 and 3, material furnished to this specification shall conform to the applicable requirements of the latest edition of Specification A 568/A 568M. It is noted that tin-coated sheet does not carry the width overrun associated with lighter gage tin mill products.

## 11. Workmanship and Quality Level Requirements

11.1 The production of coils does not afford the same opportunity for inspection, grading, and sorting as does the production of cut lengths. Accordingly, appropriate processing



**TABLE 2 Thickness Tolerances for Electrolytic Tin-Coated Steel Sheet**

NOTE 1—Thickness is measured at any point across the width not less than 3/8 in. (9.5 mm) from a side edge.

Specified Width, in. [mm]	Thickness Tolerance, Over and Under, in. [mm]	
	Specified Thickness, in. [mm]	
	Over 0.020 to 0.036 [0.51 to 0.91]	Over 0.015 to 0.020 [0.38 to 0.51], incl
Over 12 to 36 [300 to 900], incl	0.003 [0.08]	0.002 [0.05]

**TABLE 3 Width Tolerance for Electrolytic Tin-Coated Sheet**

Specified Width, in. [mm]	Tolerance over Specified Width, in. [mm] (No Tolerance Under)
Over 12 to 30 [300 to 600]	1/8 [3]
Over 30 to 48 [600 to 1200]	3/16 [5]

and quality control procedures are required by the purchaser to obtain optimum utilization of the product. The hazard of abrasion on coils is greater than on cut lengths and may occur during coiling, shipping, or uncoiling.

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**12. General Requirements for Delivery**

12.1 Material furnished under this specification shall conform to the applicable requirements of the latest edition of Specification A 568/A 568M unless otherwise specified herein.

12.2 Tin-coated steel sheet shall be ordered to a base metal decimal thickness for both coils and cut lengths, exclusive of the coating thickness.

**13. Rejection and Rehearing**

13.1 Rejection and rehearing are subject to the same procedure as described in Specification A 568/A 568M.

**14. Marking**

14.1 Marking shall be in accordance with the requirements of Specification A 568/A 568M.

**15. Packaging and Loading**

15.1 It is normal to ship coils with the eye vertical. Experience has shown that transit abrasion is minimized by shipping with the eye of the coil vertical.

15.2 It is common practice to use the methods shown in the latest edition of Practices A 700.



# Standard Specification for Zinc-Coated Steel Structural Wire Rope<sup>1</sup>

This standard is issued under the fixed designation A 603; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon ( $\epsilon$ ) indicates an editorial change since the last revision or reapproval.

## 1. Scope

1.1 This specification covers zinc-coated steel structural wire rope, prestretched or nonprestretched for use where a high-strength, relatively flexible prefabricated zinc-coated multiple-wire tension member is desired as a component part of a structure.

1.2 The wire rope is furnished with Class A weight zinc-coated wires throughout. It can be furnished with Class B weight or Class C weight zinc-coated outer wires or Class B weight or Class C weight zinc-coated wires throughout where additional corrosion protection is required.

1.3 The values stated in inch-pound units are to be regarded as the standard. The values given in brackets are for information only.

## 2. Referenced Documents

### 2.1 ASTM Standards:

A 90/A 90M Test Method for Weight (Mass) of Coating on Iron or Steel Articles with Zinc or Zinc-Alloy Coatings<sup>2</sup>

A 902 Terminology Relating to Metallic Coated Steel Products<sup>2</sup>

B 6 Specification for Zinc (Slab Zinc)<sup>3</sup>

## 3. Terminology

3.1 *Definitions*—For definitions of terms used in this specification, see Terminology A 902.

## 4. Ordering Information

4.1 Orders for material under this specification shall include the following information:

4.1.1 Length of wire rope,

4.1.2 Nominal diameter of wire rope (Tables 1-4),

4.1.3 Prestretched (see 8.3) or nonprestretched,

4.1.4 Coating-weight class if other than Class A (Table 5),

4.1.5 Mechanical tests if required (see 10.1),

4.1.6 Special packaging requirements (Section 13), and

4.1.7 Inspection (Section 12).

## 5. Materials and Manufacture

5.1 *Base Metal*—The base metal shall be carbon steel made by the open-hearth, basic-oxygen, or electric-furnace process and of such quality that the finished wire rope and the hard-drawn individual zinc-coated wires coated by the hot-dip or electrolytic process shall have the properties and characteristics as prescribed in this specification.

5.2 *Zinc*—The slab zinc when used shall conform to Specification B 6 or better.

## 6. Physical Properties

### 6.1 Tensile Properties:

6.1.1 The zinc-coated wire used in the wire rope shall conform to the mechanical properties in Table 6 prior to fabrication, but the wire test sample may be prestretched to 55 % of the minimum tensile strength specified in Table 6 prior to conducting the tests.

6.1.2 The tensile strength and the stress at 0.7 % extension shall be based on the actual cross-sectional area of the finished wire, including the zinc coating.

6.1.3 *Test Specimens*—The test specimens shall be free of bends or kinks other than the curvature resulting from the usual coiling operation. The hand straightening necessary to permit insertion of the specimen in the jaws of the testing machine shall be performed by drawing between wood blocks or by some other equally satisfactory means.

6.2 *Stress at 0.7 % Extension Under Load*—The value of stress at 0.7 % extension under load shall be determined by one of the following procedures, depending on the type of extensometer used:

6.2.1 *Non-Autographic Extensometer*—When a non-autographic extensometer is used to measure the 0.7 % extension, it shall have a gage length of 10 in. [254 mm], and it shall be so graduated that the smallest division corresponds to a strain not larger than 0.0001 in./in. [0.0001 mm/mm] of gage length. Apply a load corresponding to the tensile stress indicated in Table 5, using the nominal diameter of the specimen. Maintain this load while a 10-in. extensometer is attached and adjusted to the initial setting shown in Table 5. Then increase the load uniformly until the extensometer

<sup>1</sup> This specification is under the jurisdiction of ASTM Committee A05 on Metallic-Coated Iron and Steel Products and is the direct responsibility of Subcommittee A05.12 on Wire Specifications.

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<sup>2</sup> *Annual Book of ASTM Standards*, Vol 01.06.

<sup>3</sup> *Annual Book of ASTM Standards*, Vol 02.04.

**TABLE 1 Properties of Single-Class Zinc-Coated Steel Structural Wire Rope (Inch-Pound Units)**

Nominal Diameter, in.	Minimum Breaking Strength in Tons of 2000 lb			Approximate Gross Metallic Area, in. <sup>2</sup>	Approximate Weight/ft, lb
	Class A Coating Throughout	Class B Coating Throughout	Class C Coating Throughout		
3/8	6.5	6.2	5.9	0.065	0.24
7/16	8.8	8.4	8.0	0.091	0.32
1/2	11.5	11.0	10.5	0.119	0.42
9/16	14.5	13.8	13.2	0.147	0.53
5/8	18.0	17.2	16.4	0.182	0.65
11/16	21.5	20.5	19.5	0.221	0.79
3/4	26.0	24.8	23.6	0.268	0.95
13/16	30.0	28.6	27.3	0.311	1.10
7/8	35.0	33.4	31.8	0.361	1.28
15/16	40.0	38.2	36.4	0.414	1.47
1	45.7	43.6	41.5	0.471	1.67
1 1/8	57.8	55.1	52.5	0.596	2.11
1 1/4	72.2	68.9	65.6	0.745	2.64
1 3/8	87.8	83.8	79.8	0.906	3.21
1 1/2	104.0	99.2	94.5	1.076	3.82
1 5/8	123.0	117.0	112.0	1.270	4.51
1 3/4	143.0	136.0	130.0	1.470	5.24
1 7/8	164.0	156.0	149.0	1.690	6.03
2	186.0	177.0	169.0	1.920	6.85
2 1/8	210.0	200.0	191.0	2.170	7.73
2 1/4	235.0	224.0	214.0	2.420	8.66
2 3/8	261.0	249.0	237.0	2.690	9.61
2 1/2	288.0	275.0	262.0	2.970	10.60
2 5/8	317.0	302.0	288.0	3.270	11.62
2 3/4	347.0	331.0	315.0	3.580	12.74
2 7/8	379.0	362.0	344.0	3.910	13.90
3	412.0	393.0	374.0	4.250	15.11
3 1/4	475.0	453.0	432.0	5.040	18.00
3 1/2	555.0	529.0	504.0	5.830	21.00
3 3/4	640.0	611.0	582.0	6.670	24.00
4	730.0	696.0	664.0	7.590	27.00

indicates an extension of 0.07 in. [1.78 mm] or 0.7 % extension. Record the load for this extension. The stress corresponding to this load shall meet the requirements for the stress of 0.7 % extension specified in Table 6, depending on the class of coating under consideration. Hold the specimen at 0.7 % extension under load and remove the extensometer used to measure the stress at 0.7 % extension; then replace it with an elongation extensometer. Continue the application of load until fracture occurs. Record the elongation attained from the elongation extensometer and add to it 0.7 % obtained from the stress at 0.7 % extensometer to get the total elongation.

**6.2.2 Autographic Extensometer**—When an autographic extensometer is used, it shall have a gage length of at least 2 in. [50.8 mm] and the magnification of strain shall not be less than 250. Apply a load, corresponding to the tensile stress indicated in Table 5, using the nominal diameter of the specimen. Maintain this load and attach the extensometer. Then increase the load uniformly until the extension recorded by the extensometer is at least 0.7 %. Determine the load at 0.7 % extension from the load-strain curve. The stress corresponding to this load shall meet the requirements for stress at 0.7 % extension prescribed in Table 6, depending on the class of coating under consideration. Hold the specimen at 0.7 % extension under load and remove the extensometer used to measure the stress at 0.7 % extension; then replace it with an elongation extensometer. Continue the application of load until fracture occurs. Record the elongation attained from the elongation extensometer and add to it 0.7 % obtained from the stress at 0.7 % extensometer to get the total elongation.

**NOTE 1**—The extensometer used for the stress at 0.7 % extension and the elongation extensometer may be the same instrument. Two separate instruments are advisable in that the more sensitive stress at 0.7 % extensometer which could be damaged when the wire fractures, may be removed following the determination of the 0.7 % extension. The elongation extensometer may be constructed with less sensitive parts or be constructed in such a way that little damage would result if fracture occurs while the extensometer is attached to the specimen.

**6.3 Elongation**—In determining total elongation (elastic plus plastic extension) autographic or extensometer methods may be employed. If fracture takes place outside the middle third of the gage length, the elongation value obtained may not be representative of the material.

**6.4 Tensile Strength**—The tensile strength is determined from the maximum load during the total elongation test.

**6.5 Ductility of Steel**—The zinc-coated wire, prior to fabrication into wire rope, shall be capable of being wrapped two turns in a close helix at a rate not exceeding 15 turns/min around a cylindrical steel mandrel equal to three times the nominal diameter of the wire under test without fracture of the wire.

**6.6 Weight of Zinc Coating**—The weight of the zinc coating on the individual wires prior to the fabrication of the wire rope shall be not less than that specified in Table 7 when tested in accordance with the stripping test of Test Method A 90/A 90M.

**6.7 Adherence of Coating**—The zinc-coated wire, prior to fabrication into wire rope, shall be capable of being wrapped two turns in a close helix at a rate not exceeding 15 turns/min around a cylindrical steel mandrel equal to five times the

**TABLE 2 Properties of Single-Class Zinc-Coated Steel Structural Wire Rope (SI Units)**

Nominal Diameter, mm	Minimum Breaking Strength in Metric Tons			Approximate Gross Metallic Area, mm <sup>2</sup>	Approximate Weight/m, kg
	Class A Coating Throughout	Class B Coating Throughout	Class C Coating Throughout		
9.53	5.9	5.6	5.4	41.9	0.36
11.11	8.0	7.6	7.3	58.7	0.48
12.70	10.4	10.0	9.5	76.8	0.62
14.29	13.2	12.5	12.0	94.8	0.79
15.88	16.3	15.6	14.9	117.4	0.97
17.46	19.5	18.6	17.7	142.6	1.18
19.05	23.6	22.5	21.4	172.9	1.41
20.64	27.2	25.9	24.8	200.7	1.64
22.23	31.8	30.3	28.8	232.9	1.90
23.81	36.3	34.7	33.0	267.1	2.19
25.40	41.5	39.6	37.6	303.9	2.48
28.58	52.4	50.0	47.6	384.5	3.14
31.75	65.5	62.5	59.5	480.7	3.93
34.93	79.7	76.0	72.4	584.6	4.78
38.10	94.3	90.0	85.7	694.2	5.68
41.28	112.0	106.0	101.0	819.4	6.71
44.45	130.0	124.0	118.0	948.4	7.80
47.63	149.0	142.0	135.0	1090.4	8.97
50.80	169.0	161.0	153.0	1238.8	10.19
53.98	190.0	182.0	173.0	1400.1	11.50
57.15	213.0	203.0	194.0	1561.4	12.89
60.33	237.0	226.0	215.0	1735.6	14.30
63.50	261.0	249.0	238.0	1916.2	15.77
66.68	288.0	274.0	261.0	2109.8	17.29
69.85	315.0	300.0	286.0	2309.8	18.96
73.03	344.0	328.0	312.0	2522.7	20.68
76.20	374.0	356.0	340.0	2742.1	22.48
82.55	431.0	411.0	392.0	3251.8	26.78
88.90	504.0	480.0	458.0	3761.5	31.25
95.25	581.0	554.0	528.0	4303.5	35.71
101.60	662.0	632.0	602.0	4897.1	40.18

nominal diameter of the wire under test without cracking or flaking the zinc coating to such an extent that any zinc can be removed by rubbing with the bare fingers. Loosening or detachment during the adherence test of superficial small particles of zinc, formed by mechanical polishing of the surface of zinc-coated wire, shall not be considered cause for rejection.

6.8 *Finish*—The zinc-coated wire surface shall be free of imperfections not consistent with good commercial practice. The coating shall be continuous and reasonably uniform.

NOTE 2—It is recognized that the surface of heavy zinc coatings, particularly those produced by the hot-dip galvanizing process, are not perfectly smooth and not devoid of irregularities.

## 7. Test for Coating Weight

7.1 The weight of the zinc coating shall be determined by a stripping test made on the individual wires prior to fabrication of strand, in accordance with Test Method A 90/A 90M.

## 8. Wire Rope

8.1 The zinc-coated wire rope shall consist of a plurality of strands helically preformed and laid around a core composed of a strand or another wire rope. The number and size of wires and the number of layers of wires in the strands shall be determined by the manufacturer.

8.2 The wire rope properties are shown in Tables 1-4.

8.3 When specified, the wire rope shall be prestretched. The prestretched rope shall meet the minimum modulus of elasticity as shown in Table 8.

## 9. Joints and Splices

9.1 No splicing or joining of strands shall be permitted in the manufactured length of rope.

9.2 Welds made prior to wire drawing are permitted. Joining of wires by welding during the stranding operation is permissible, and such joints shall be dispersed sufficiently so as to maintain the minimum breaking strength as listed in Tables 1-4. Joints made during stranding in any wire shall be recoated in a workmanlike manner with zinc or a lead-zinc compound containing a minimum of 50 % zinc.

## 10. Sampling and Testing of Rope

10.1 If specified, a test specimen shall be taken from each manufactured length of wire rope and tested to minimum breaking strength. If a specimen fails to attain a strength equal to 95 % of the minimum breaking strength requirement, the wire rope represented shall be rejected. If a specimen attains a strength equal to at least 95 % but less than 100 % of the minimum breaking strength requirement, two additional test specimens shall be cut from the same manufactured length and tested. If the average test results of the original specimen and the two retest specimens fail to meet the minimum breaking strength requirement, the wire rope shall be rejected. Any test, however, that fails due to faulty attachment of the sockets shall be disregarded.

## 11. Rejection and Retest of Wire

11.1 If any wire test specimens breaking within the grips or the jaws of the testing machine results in values below the



**TABLE 3 Properties of Multi-Class Zinc-Coated Steel Structural Wire Rope (Inch-Pound Units)**

Nominal Diameter, in.	Minimum Breaking Strength in Tons of 2000 lb			Approximate Gross Metallic Area, in. <sup>2</sup>	Approximate Weight/ft, lb
	Class A Coating Throughout	Class B Coating Outer Wires Class A Coating Inner Wire	Class C Coating Outer Wires Class A Coating Inner Wires		
3/8	6.5	6.3	6.1	0.065	0.24
7/16	8.8	8.5	8.2	0.091	0.32
1/2	11.5	11.1	10.7	0.119	0.42
9/16	14.5	14.0	13.5	0.147	0.53
5/8	18.0	17.4	16.8	0.182	0.65
11/16	21.5	20.8	20.0	0.221	0.79
3/4	26.0	25.1	24.2	0.268	0.95
13/16	30.0	29.0	28.0	0.311	1.10
7/8	35.0	33.8	32.6	0.361	1.28
15/16	40.0	38.6	37.3	0.414	1.47
1	45.7	44.1	42.6	0.471	1.67
1 1/8	57.8	55.8	53.9	0.596	2.11
1 1/4	72.2	69.7	67.3	0.745	2.64
1 3/8	87.8	84.8	81.8	0.906	3.21
1 1/2	104.0	100.0	96.9	1.076	3.82
1 5/8	123.0	120.0	117.0	1.270	4.51
1 3/4	143.0	140.0	136.0	1.470	5.24
1 7/8	164.0	160.0	156.0	1.690	6.03
2	186.0	182.0	177.0	1.920	6.85
2 1/8	210.0	205.0	200.0	2.170	7.73
2 1/4	235.0	230.0	224.0	2.420	8.66
2 3/8	261.0	255.0	249.0	2.690	9.61
2 1/2	288.0	281.0	275.0	2.970	10.60
2 5/8	317.0	310.0	302.0	3.270	11.62
2 3/4	347.0	339.0	331.0	3.580	12.74
2 7/8	379.0	372.0	365.0	3.910	13.90
3	412.0	405.0	397.0	4.250	15.11
3 1/4	475.0	466.0	457.0	5.040	18.00
3 1/2	555.0	545.0	534.0	5.830	21.00
3 3/4	640.0	628.0	616.0	6.670	24.00
4	730.0	717.0	703.0	7.590	27.00

specified limits for tensile strength, stress at 0.7 % extension or elongation, the results shall be considered invalid and retesting shall be required.

11.2 In case there is reasonable doubt in the first trial as the ability of the wire to meet the requirements of Sections 6 and 7, two additional tests shall be made on samples of wire from the same coil or reel. If failure occurs in either of these tests, the wire shall be rejected.

## 12. Inspection

12.1 All tests and inspection shall be made at the place of manufacture unless otherwise specified and shall be so conducted as not to interfere unnecessarily with the operation of the works. The manufacturer shall afford the inspector repre-

senting the purchaser all reasonable facilities to satisfy the inspector that the material is being furnished in accordance with this specification. When specified, inspection may be waived, and certified copies of test reports furnished.

## 13. Packaging

13.1 Structural wire rope shall be packaged in coils or on reels at the discretion of the manufacturer unless otherwise specified. Wire rope shall be packaged in such a manner so that no permanent deformation of wires in the strand or strands in the wire rope will occur.

## 14. Keywords

14.1 steel wire; wire; wire rope; zinc-coated wire

**TABLE 4 Properties of Multi-Class Zinc-Coated Steel Structural Wire Rope (SI Units)**

Nominal Diameter, mm	Minimum Breaking Strength in Metric Tons			Approximate Gross Metallic Area, mm <sup>2</sup>	Approximate Weight/m, kg
	Class A Coating Throughout	Class B Coating Outer Wires Class A Coating Inner Wires	Class C Coating Outer Wires Class A Coating Inner Wire		
9.53	5.9	5.7	5.5	41.9	0.36
11.11	8.0	7.7	7.4	58.7	0.48
12.70	10.4	10.1	9.7	76.8	0.62
14.29	13.2	12.7	12.2	94.8	0.79
15.88	16.3	15.8	15.2	117.4	0.97
17.46	19.5	18.9	18.1	142.6	1.18
19.05	23.6	22.8	22.0	172.9	1.41
20.64	27.2	26.3	25.4	200.7	1.64
22.23	31.8	30.7	29.6	232.9	1.90
23.81	36.3	35.0	33.8	267.1	2.19
25.40	41.5	40.0	38.6	303.9	2.48
28.58	52.4	50.6	48.9	384.5	3.14
31.75	65.5	63.2	61.1	480.7	3.93
34.93	79.7	76.9	74.2	584.6	4.78
38.10	94.3	91.2	87.9	694.2	5.68
41.28	112.0	109.0	106.0	819.4	6.71
44.45	130.0	127.0	124.0	948.4	7.80
47.63	149.0	145.0	142.0	1090.4	8.97
50.80	169.0	165.0	161.0	1238.8	10.19
53.98	190.0	186.0	182.0	1400.1	11.50
57.15	213.0	208.0	203.0	1561.4	12.89
60.33	237.0	231.0	226.0	1735.6	14.30
63.50	261.0	255.0	249.0	1916.2	15.77
66.68	288.0	281.0	274.0	2109.8	17.29
69.85	315.0	308.0	300.0	2309.8	18.96
73.03	344.0	338.0	331.0	2522.7	20.68
76.20	374.0	367.0	360.0	2742.1	22.48
82.55	431.0	423.0	415.0	3251.8	26.78
88.90	504.0	494.0	485.0	3761.5	31.25
92.25	581.0	570.0	559.0	4303.5	35.71
101.60	662.0	650.0	638.0	4897.1	40.18

**TABLE 5 Initial Settings for Determining Stress at 0.7 % Extension**

Nominal Diameter	Initial Stress		Initial Setting of Extensometer, in./in. or mm/mm
	in.	mm	
0.040 to 0.089, incl	1.270 to 2.283, incl	14	0.0005 (0.05 % extension)
0.090 to 0.119, incl	2.286 to 3.045, incl	28	0.0010 (0.10 % extension)
0.120 and larger <sup>A</sup>	3.048 and larger <sup>A</sup>	42	0.0015 (0.15 % extension)

<sup>A</sup> This is not to imply that larger wire will be manufactured to any unlimited diameter. It only implies that the wire sizes chosen by the strand manufacturer must meet the requirements of this specification.

**TABLE 6 Mechanical Requirements**

Zinc Coating Class	Nominal Diameter		Stress at 0.7 % Extension Under Load, min		Tensile Strength, min		Total Elongation in 10 in. or 250 mm, min, %
	in.	mm	psi	MPa	psi	MPa	
A	0.040 to 0.110	1.016 to 2.794	150 000	1030	220 000	1520	2.0
	0.111 and larger <sup>A</sup>	2.820 and larger <sup>A</sup>	160 000	1100	220 000	1520	4.0
B	0.090 and larger <sup>A</sup>	2.286 and larger <sup>A</sup>	150 000	1030	210 000	1450	4.0
C	0.090 and larger <sup>A</sup>	2.286 and larger <sup>A</sup>	140 000	970	200 000	1380	4.0

<sup>A</sup> This is not to imply that larger wire will be manufactured to any unlimited diameter. It only implies that the wire sizes chosen by the strand manufacturer must meet the requirements of this specification.

**TABLE 7 Minimum Weight of Coating**

Nominal Diameter of Coated Wire		Weight of Zinc Coating, min					
		oz/ft <sup>2</sup> of Uncoated Wire Surface			g/m <sup>2</sup> of Uncoated Wire Surface		
in.	mm	Class A Coating	Class B Coating	Class C Coating	Class A Coating	Class B Coating	Class C Coating
0.040 to 0.061, incl	1.016 to 1.549, incl	0.40	0.80	1.20	122	244	366
0.062 to 0.079, incl	1.575 to 2.007, incl	0.50	1.00	1.50	153	305	458
0.080 to 0.092, incl	2.032 to 2.337, incl	0.60	1.20	1.80	183	366	549
0.093 to 0.103, incl	2.362 to 2.616, incl	0.70	1.40	2.10	214	427	641
0.104 to 0.119, incl	2.642 to 3.023, incl	0.80	1.60	2.40	244	488	732
0.120 to 0.142, incl	3.048 to 3.607, incl	0.85	1.70	2.55	259	519	778
0.143 to 0.187, incl	3.632 to 4.750, incl	0.90	1.80	2.70	275	549	824
0.188 and larger <sup>A</sup>	4.775 and larger <sup>A</sup>	1.00	2.00	3.00	305	610	915

<sup>A</sup> This is not to imply that larger wire will be manufactured to any unlimited diameter. It only implies that the wire sizes chosen by the strand manufacturer must meet the requirements of this specification.

**TABLE 8 Minimum Modulus of Elasticity of Prestretched Structural Wire Rope**

Nominal Diameter Wire Rope		Minimum Modulus—Class A Coating <sup>A</sup>	
in.	mm	psi	GPa
3 / 8 to 4	9.52 to 101.60	20 000 000	140

<sup>A</sup> For Class B or Class C weight of zinc-coated outer wires, reduce minimum modulus 1 000 000 psi or 7 GPa. For Class B or Class C weight of zinc-coated wires throughout, consult manufacturer.

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## Standard Specification for Tin Mill Products, General Requirements<sup>1</sup>

This standard is issued under the fixed designation A 623; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon ( $\epsilon$ ) indicates an editorial change since the last revision or reapproval.

*This standard has been approved for use by agencies of the Department of Defense.*

### 1. Scope

1.1 This specification covers a group of common requirements which, unless otherwise specified in the purchase order or in an individual specification, shall apply to tin mill products.

1.2 In case of any conflict in requirements, the requirements of the purchase order, the individual material specification, and this general specification shall prevail in the sequence named.

NOTE 1—A complete metric companion to Specification A 623 has been developed—Specification A 623M; therefore no metric equivalents are presented in this specification.

1.3 The following safety caveat pertains to Annex A3 through Annex A10 of this specification: *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

### 2. Referenced Documents

#### 2.1 ASTM Standards:

- A 370 Test Methods and Definitions for Mechanical Testing of Steel Products<sup>2</sup>
- A 700 Practices for Packaging, Marking, and Loading Methods for Steel Products for Domestic Shipment<sup>3</sup>
- A 987 Test Method for Measuring Shape Characteristics of Tin Mill Products<sup>4</sup>
- D 1125 Test Methods for Electrical Conductivity and Resistivity of Water<sup>5</sup>
- E 18 Test Methods for Rockwell Hardness and Rockwell Superficial Hardness of Metallic Materials<sup>6</sup>

<sup>1</sup> This specification is under the jurisdiction of ASTM Committee A01 on Steel, Stainless Steel, and Related Alloys and is the direct responsibility of Subcommittee A01.20 on Tin Mill Products.

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<sup>2</sup> Annual Book of ASTM Standards, Vol 01.03.

<sup>3</sup> Annual Book of ASTM Standards, Vol 01.05.

<sup>4</sup> Annual Book of ASTM Standards, Vol 01.06.

<sup>5</sup> Annual Book of ASTM Standards, Vol 11.01.

<sup>6</sup> Annual Book of ASTM Standards, Vol 03.01.

E 112 Test Methods for Determining the Average Grain Size<sup>6</sup>

#### 2.2 U.S. Military Standards:

MIL-STD-129 Marking for Shipment and Storage<sup>7</sup>

MIL-STD-163 Steel Mill Products, Preparation for Marking and Storage<sup>7</sup>

#### 2.3 U.S. Federal Standard:

Fed. Std. No. 123 Marking for Shipment (Civil Agencies)<sup>7</sup>

### 3. Terminology

#### 3.1 Definitions:

3.1.1 *base box, n*—a unit of area equivalent to 112 sheets 14 by 20 in. or 31 360 in.<sup>2</sup> (217.78 ft<sup>2</sup>) (see Annex A1).

3.1.2 *base weight, n*—a term used to describe the thickness of tin mill products. The designated base weight multiplied by a factor of 0.00011 is the nominal decimal thickness, in inches of the material. Although it is customary industry-wide to use the term “pound” (for example, 75 lb), following the base weight designation, base weight is correctly used only to define nominal material thickness, and is not a measure of the weight of a base box.

3.1.3 *black plate, n*—light-gage, low-carbon, cold-reduced steel intended for use in the untinned state or for the production of other tin mill products. It is supplied only in a dry or oiled condition.

3.1.4 *box annealing, n*—a process involving slow heating of coils to a subcritical temperature, holding, and cooling therefrom, to soften the strip and relieve stresses produced during cold reduction. It is accomplished in a sealed container. By introducing and maintaining an inert or slightly reducing atmosphere during the cycle, a relatively bright surface is obtained.

3.1.5 *bright finish, n*—a surface that has a melted tin coating.

3.1.6 *bundle, n*—a unit containing two or more packages of a cut size, supported by a platform, generally consisting of ten or more packages. (Also commonly referred to as a multiple-package lift containing two or more packages.)

<sup>7</sup> Available from Standardization Documents Order Desk, Bldg. 4 Section D, 700 Robbins Ave., Philadelphia, PA 19111-5094, Attn: NPODS.

3.1.7 *burr, n*—metal displaced beyond the plane of the surface by slitting or shearing (see 9.1.7 and 9.2.6).

3.1.8 *camber, n*—the greatest deviation of a coil edge from a straight line. The measurement is taken on the concave side and is the perpendicular distance from a straight line to the point of maximum deviation (see 9.1.9 and 9.2.7).

3.1.9 *chemical treatment, electrolytic tin plate, n*—a passivating chemical treatment applied to the surface of electrolytic tin plate to stabilize the plate surface characteristics compatible with a specified end use (see Annex A8 and Annex A10).

3.1.10 *chemically treated steel, n*—light-gage, low-carbon, cold-reduced steel that has a passivating or chemical treatment applied to the surface to provide rust resistance or retard underfilm corrosion, or both.

3.1.11 *cold reduction*—the process of reducing the thickness of the strip cold, generally accomplished by one rolling through a series of four-high mills arranged in tandem.

3.1.12 *continuous annealing*—a process consisting of passing the cold-reduced strip continuously and in a single thickness through a series of vertical passes within a furnace consisting of heating, soaking, and cooling zones to soften the strip and relieve stresses produced during cold reduction. An inert or slightly reducing atmosphere is maintained in the furnace to obtain a relatively bright strip.

3.1.13 *differentially coated tin plate*—electrolytic tin plate with a different weight of tin coating on each surface.

3.1.14 *double-reduced plate*—plate given a second major cold reduction following annealing.

3.1.15 *electrolytic chromium-coated steel*—light-gage, low-carbon, cold-reduced steel on which chromium and chromium oxides have been electrodeposited.

3.1.16 *electrolytic tin plate*—light-gage, low-carbon, cold-reduced steel on which tin has been electrodeposited by an acid or alkaline process.

3.1.16.1 *J Plate*—electrolytic tin plate, No. 50 or heavier tin coating, with improved corrosion performance for some galvanic detinning food products as specified in the table following 3.1.16.2 and as measured by the Special Property Tests for Pickle Lag (*PL*) (see Annex A3), Iron Solution Values (*ISV*) (see Annex A5), Tin Crystal Size (*TCS*) (see Annex A4). The alloy layer is normally light in color, characteristic of the acid tinning process.

3.1.16.2 *K Plate*—electrolytic tin plate, No. 50 or heavier tin coating, with improved corrosion performance for some galvanic detinning food products as specified in the following table and as measured by the Special Property Tests for Pickle Lag (*PL*) (see Annex A3), Iron Solution Value (*ISV*) (see Annex A5), Tin Crystal Size (*TCS*) (see Annex A4), and Alloy Tin Couple (*ATC*) (see Annex A6) and Aerated Media Polarization (*AMP*) (see Annex A9).

Special Properties Aims	
Pickle Lag	10 s max
Iron Solution Value	20 µg Iron max
Tin Crystal Size	ASTM No. 9 or larger
Alloy Tin Couple <sup>A</sup>	0.12 µA/cm <sup>2</sup> max

<sup>A</sup> Good mill practice has demonstrated the ability to average 0.05 µA/cm<sup>2</sup> or less over an extended period of production.

3.1.16.3 The production of J Plate and K Plate require special processing and testing. In order to receive J Plate or K Plate, this requirement must be specified on the order.

3.1.17 *length dimension*—the longer dimension of a cut size.

3.1.18 *lot*—each 20 000 sheets or part thereof or the equivalent in coils, of an item in a specific shipment having the same order specifications.

3.1.19 *matte finish*—a surface that has an unmelted tin coating, generally on a shot-blast finish (SBF) base steel.

3.1.20 *mechanical designation*—an arbitrary number to designate Rockwell hardness and ultimate tensile strength characteristics for double-reduced plate (see 8.2).

3.1.21 *oiling*—a lubricant film applied to both surfaces of the plate.

3.1.22 *package*—a unit quantity of 112 sheets.

3.1.23 *passivating treatment*—a surface chemical treatment (see 3.1.9).

3.1.24 *ratio*—the number of base boxes in a package of a given size (see 3.1.1 and Annex A1).

3.1.25 *Rockwell hardness test*—a test for determining hardness (see Annex A2).

3.1.26 *rolling width*—the dimension of the sheet perpendicular to the rolling direction.

3.1.27 *single-reduced plate*—plate produced with one major cold reduction.

3.1.28 *steel Type D*—base-metal steel aluminum killed, sometimes required to minimize severe fluting and stretcher-strain hazards or for severe drawing applications (see Table 1).

3.1.29 *steel Type L*—base-metal steel, low in metalloids and residual elements, sometimes used for improved internal corrosion resistance for certain food-product containers (see Table 1).

3.1.30 *steel Type MR*—base-metal steel, similar in metalloid content to Type L but less restrictive in residual elements, commonly used for most tin mill products (see Table 1).

3.1.31 *surface appearance*—visual characteristics determined primarily by the steel surface finish. For electrolytic tin plate, the appearance is also influenced by the weight of coating and by melting or not melting the tin coating.

**TABLE 1 Chemical Requirements for Tin Mill Products**

Element	Cast Composition, max %		
	Type D	Type L	Type MR
Carbon	0.12	0.13	0.13
Manganese	0.60	0.60	0.60
Phosphorus	0.020	0.015	0.020
Sulfur	0.03	0.03	0.03
Silicon <sup>A,B</sup>	0.020	0.020	0.020
Copper	0.20	0.06	0.20
Nickel	0.15	0.04	0.15
Chromium	0.10	0.06	0.10
Molybdenum	0.05	0.05	0.05
Aluminum <sup>C</sup>	0.20	0.10	0.20
Other elements, each	0.02	0.02	0.02

<sup>A</sup>When steel produced by the silicon killed method is ordered, the silicon maximum may be increased to 0.080 %.

<sup>B</sup>When strand cast steel produced by the aluminum killed method is ordered or furnished, the silicon maximum may be increased to 0.030 % when approved by the purchaser.

<sup>C</sup>Types L and MR may be supplied as non-killed or killed which would respectively be produced without and with aluminum additions. Minimum aluminum level for Type D is usually 0.02 %.

3.1.32 *surface finishes*—steel surface finishes for tin mill products imparted by the finishing-mill work rolls. These may be either ground or blasted-roll finishes.

3.1.33 *temper designation*—an arbitrary number to designate a Rockwell hardness range for single-reduced products which indicates the forming properties of the plate (see Section 8 and Tables 2 and 3).

3.1.34 *temper mill*—a mill for rolling basemetal steel after annealing to obtain proper temper, flatness, and surface finish. It may consist of one stand or two stands arranged in tandem.

3.1.35 *tin coating weight*—the weight of tin applied to the steel surface, usually stated as pounds per base box, distributed evenly over both surfaces of a base box, the total coated area being 62 720 in.<sup>2</sup> Thus 0.25 lb/bb has a nominal weight of 0.125 lb on each of the two surfaces. Frequently, the coating is referred to as a designation number, and the decimal point is omitted. Thus, 0.25 lb/bb is 25.

3.1.35.1 For differentially coated tin plate, twice the nominal coating weight on each side is designated, usually by the number method; hence, 10/25 designates the nominal weight of 0.05 lb/bb on one side and 0.125 lb/bb on the other side.

3.1.36 *vapor vacuum deposition*—the condensation and solidification of the metal or metal containing vapors, under high vacuum, to form deposits onto a steel surface.

3.1.37 *width dimension*—the shorter dimension of a cut size.

**4. Base Metal**

4.1 The steel shall be made by the open-hearth, electric-furnace, or basic-oxygen process.

**TABLE 2 Temper Designations and Hardness Values Single-Reduced Tin Mill Products — Box Annealed**

NOTE 1—Thinner plate (0.0083 in. ordered thickness and lighter) is normally tested using the Rockwell 15T scale and the results converted to the Rockwell 30T scale (see Annex A2 and Table A2.1).

Temper Designation	Rockwell Hardness Values All Thicknesses HR30T <sup>A</sup>		Characteristics and Typical End Uses
	Nominal	Range	
T-1 (T49)	49	45–53	soft for drawing parts such as nozzles, spouts, and oil filter shells
T-2 (T53)	53	49–57	moderately soft for drawing shallow parts such as rings, plugs, and pie pans
T-3 (T57)	57	53–61	fairly stiff for parts such as can ends and bodies, closures, and crown caps
T-4 (T61)	61	57–65	increased stiffness for can ends and bodies, crown caps, and large closures

<sup>A</sup>These ranges are based on the use of the diamond spot anvil and a 1/16 in. hardened steel ball indenter.

Test conditions:  
 1. For referee purposes, samples of blackplate, unreflowed ETP, and ECCS shall be aged prior to testing by holding at 400°F for 10 min.  
 2. The hardness test area on material produced with SBF or equivalent rolls shall be sanded smooth on both surfaces.  
 3. To avoid incorrect results due to the cantilever effect, samples shall have an area no larger than 4 in.<sup>2</sup> and the point of testing shall be no more than 1/2 in. off the center of the samples.

**TABLE 3 Temper Designations and Hardness Values Single-Reduced Tin Mill Products—Continuously Annealed**

NOTE 1—Thinner plate (0.0083-in. ordered thickness and lighter) is normally tested using the Rockwell 15T scale and the results converted to the Rockwell 30T scale (see Annex A2 and Table A2.1).

Temper Designation	Rockwell Hardness Values All Thicknesses HR30T <sup>A</sup>		Characteristics and Typical End Uses
	Nominal	Range	
T-1	49	45–53	soft for drawing parts such as nozzles, spouts, and oil filter shells
T-2	53	49–57	moderately soft for drawing shallow parts such as rings, plugs, and pie pans
T-3 (T57)	57	53–61	moderate stiffness for parts such as can ends and bodies, closures, and crown caps
T-4 (T61)	61	57–65	increased stiffness for can ends, drawn (and ironed) can bodies, and large closures
T-5 (T65)	65	61–69	moderately high stiffness for can ends and bodies

<sup>A</sup> These ranges are based on the use of the diamond spot anvil and a 1/16 in. hardened steel ball indenter.

Test Conditions:  
 1. For referee purposes, samples of blackplate, unreflowed ETP, and ECCS shall be aged prior to testing by holding at 400°F for 10 min.  
 2. The hardness test area on material produced with SBF or equivalent rolls shall be sanded smooth on both surfaces.  
 3. To avoid incorrect results due to the cantilever effect, samples shall have an area no larger than 4 in.<sup>2</sup> and the point of testing shall be no more than 1/2 in. off the center of the samples.

**5. Chemical Composition**

5.1 The steel shall conform to the chemical composition requirements as prescribed in Table 1 except as otherwise agreed upon between the manufacturer and the purchaser.

**6. Cast or Heat Analysis**

6.1 For Type D, MR, and L an analysis of each heat of steel shall be made by the supplier to determine the percentage of carbon, manganese, phosphorus, sulfur, silicon, and residual elements shown in Table 1. Other elements, unless agreed upon between the manufacturer and the purchaser, individually shall not exceed 0.02 %, maximum and while not necessarily analyzed are dependent on the suppliers’ practices and controls.

**7. Product Analysis**

7.1 Rimmed or capped steels are characterized by a lack of uniformity in their chemical composition, and for this reason, product analysis is not technologically appropriate unless misapplication is clearly indicated.

**8. Mechanical Requirements**

8.1 *Single-Reduced Tin Mill Products, Temper*—The term *temper* when applied to single-reduced tin mill products summarizes a combination of interrelated mechanical properties. No single mechanical test can measure all the various factors which contribute to the fabrication characteristics of the material. The Rockwell 30T hardness value is a quick test which serves as a guide to the properties of the plate. This test forms the basis for a system of temper designations as shown in Tables 2 and 3. A given temper shall have hardness values

meeting the limits shown. The mechanical properties of continuously annealed plate and batch annealed plate of the same Rockwell 30T temper designation are not identical. It is important to keep in mind that the Rockwell 30T test does not measure all the various factors which contribute to the fabrication characteristics of the plate.

8.2 *Double-Reduced Tin Mill Products, Mechanical Characteristics*—No test or group of tests have been developed that adequately predict the fabricating performance of double-reduced tin mill products. Designations for mechanical properties showing typical applications are arranged in generally ascending level of strength as shown in Table 4.

8.3 Rockwell testing shall be in accordance with the latest revision of Test Methods and Definitions A 370 and Test Methods E 18 (see Annex A2).

9. Permissible Variation in Dimensions

9.1 Dimensional Characteristics, Coils:

9.1.1 *Thickness, Method for Determination*—When the purchaser wishes to make tests to ascertain compliance with the requirements of this specification for thickness of an item in a specific shipment of tin mill products in coils having the same order specification, the following procedure shall be used: Random and representative measurements using a hand micrometer must be made throughout the coil length. Measurements may be made at any location across the coil width except within 1 in. from the mill trimmed edge. The hand micrometers are assumed to be accurate to ±0.0001 in. No measurements are to be made within 3 ft of a weld.

9.1.2 *Thickness Tolerances* shall conform to those prescribed in Table 5 (also see Table 6).

9.1.3 *Transverse Thickness Profile* is the change in sheet thickness from strip center to edge at right angles to the rolling direction. Thickness measured near the edge is normally less than the center thickness. The gage measured ¼ in. in from the mill trimmed edge shall be no more than either 13 % below the ordered thickness or 10 % less than the center thickness of the individual sheet being measured. Common components of transverse thickness profile are crown and feather edge.

TABLE 4 Mechanical Designations Double-Reduced Tin Mill Products

NOTE 1—Thinner plate (0.0083 in. ordered thickness and lighter) is normally tested using Rockwell 15T scale and the results converted to the Rockwell 30T scale (see Annex A2 and Table A2.1).

Designation	Nominal Longitudinal Ultimate Tensile Strength psi	Nominal Rockwell Hardness HR30-T <sup>A</sup>	Examples of Usage
DR-7.5	75 000	71	can bodies
DR-8	80 000	72	can bodies and ends
DR-8.5	85 000	73	can bodies and ends
DR-9	90 000	75	can bodies and ends
DR-9.5	95 000	76	can ends

<sup>A</sup> These values are based on the use of the diamond spot anvil and a ¼ in. hardened steel ball indenter. Testing will be in accordance with Test Methods and Definitions A 370. Rockwell values are too varied to permit establishment of ranges. For details see *AISI Contributions to the Metallurgy of Steel*, "Survey of Mechanical Properties of Double Reduced Tin Plate," January 1966.

TABLE 5 Thickness Tolerances

NOTE 1—When coils are specified, this does not afford the supplier the opportunity to discard all off-gage product and for that reason the following thickness tolerances are applicable for various lot sizes.

Lot Size, lb	Tolerance
0 to 12 000	95 % of the product of the coils shall be within the tolerances stated in Table 6
Over 12 000 to 30 000	97.5 % of the product of the coils shall be within the tolerances stated in Table 6
Over 30 000 to 150 000	99.0 % of the product of the coils shall be within the tolerances stated in Table 6
Over 150 000	99.5 % of the product of the coils shall be within the tolerances stated in Table 6

TABLE 6 Ordered Thickness and Thickness Tolerances

NOTE 1—Thickness tolerances are +5 % and -8 % from the ordered thickness.

Ordered Thickness, in.	Thickness Tolerance, Over, in.	Thickness Tolerances Under, in.
0.0050	0.0003	0.0004
0.0055	0.0003	0.0004
0.0061	0.0003	0.0005
0.0066	0.0003	0.0005
0.0072	0.0004	0.0006
0.0077	0.0004	0.0006
0.0083	0.0004	0.0007
0.0088	0.0004	0.0007
0.0094	0.0005	0.0008
0.0099	0.0005	0.0008
0.0105	0.0005	0.0008
0.0110	0.0006	0.0009
0.0113	0.0006	0.0009
0.0118	0.0006	0.0009
0.0123	0.0006	0.0010
0.0130	0.0007	0.0010
0.0141	0.0007	0.0011
0.0149	0.0007	0.0012

9.1.4 *Crown* is the difference in strip thickness from the center of roll width and the locations 1 in. in from both mill-trimmed edges.

9.1.5 *Feather Edge* is the maximum difference in thickness across the strip width between points measured at ¼ in. and 1 in. from both mill-trimmed edges. The thickness ¼ in. from an edge is usually less than the thickness measured 1 in. or more from the same edge.

9.1.6 *Width*—Coils are trimmed to ¼ in. over the ordered width. The slit dimension shall not vary over the designated overrun by more than -0, +1/8 in.

9.1.7 *Burr*—A maximum of 0.002 in. is permissible.

9.1.8 *Coil Length*—Variation between the measured length by the purchaser versus the supplier's billed length shall not exceed the limits prescribed in Table 7.

9.1.8.1 Since it is a common practice for each consumer's shearing operation to keep a running measurement of their supplier's coil shipments, any length variation in small lots (1

TABLE 7 Coil Length Variation

No. of Coils	Variation, ±, %
1	3
100	0.1

to 5 coils) for a given period will automatically be included in this summary. Before concluding there is a length variation in these small lots the total length received from the supplier, regardless of base weight, over periods of one month or one quarter, or both should be checked.

9.1.9 *Camber* is limited to a maximum of  $\frac{1}{4}$  in. in 20 ft of length, in accordance with the latest revision of measuring methods and definitions in Test Method A 987.

9.1.10 *Inside Coil Diameters*—The standard inside diameter produced is approximately 16 in.

#### 9.2 *Dimensional Characteristics, Cut Sizes:*

9.2.1 *Thickness, Method for Determination*—Random measurements must be made at least 1 in. from the edge of the sheet using a hand micrometer. The hand micrometers are assumed to be accurate to  $\pm 0.0001$  in.

9.2.2 *Thickness Tolerances*—Tin mill products in cut sizes are produced within thickness tolerances of +5 %, –8 % of the ordered thickness (see Table 6). Any sheets not meeting this requirement are subject to rejection.

9.2.3 *Transverse Thickness Profile* is the change in sheet thickness from strip center to edge at right angles to the rolling direction. Thickness measured near the edge is normally less than the center thickness. The gage measured  $\frac{1}{4}$  in. in from the mill trimmed edge shall be no more than either 13 % below the ordered thickness or 10 % less than the center thickness of the individual sheet being measured. Common components of transverse thickness profile are crown and feather edge.

9.2.4 *Crown* is the difference in strip thickness from the center of roll width and the locations 1 in. in from both mill-trimmed edges.

9.2.5 *Feather Edge* is the maximum difference in thickness across the strip width between points measured at  $\frac{1}{4}$  in. and 1 in. from both mill-trimmed edges. The thickness  $\frac{1}{4}$  in. from an edge is usually less than the thickness measured 1 in. or more from the same edge.

9.2.6 *Burr*—A maximum of 0.002 in. is permissible.

9.2.7 *Camber*—The maximum permissible deviation is  $\frac{1}{16}$  in. for each 48 in. of length or fraction thereof, in accordance with the latest revision of measuring methods and definitions in Test Method A 987.

9.2.8 *Out-of-Square* is the deviation of an end edge from a straight line which is placed at a right angle to the side of the plate, touching one corner and extending to the opposite side. The amount of deviation is customarily limited to  $\frac{1}{16}$  in. for any edge measurement, except that a bundle may contain a maximum of four sheets with a deviation up to  $\frac{1}{8}$  in.

9.2.9 *Shearing Practice*—Tin mill products are sheared to  $\frac{1}{8}$  in. over the ordered width and  $\frac{1}{4}$  in. over the ordered length. The greater dimension is considered length. The slit dimension shall not vary over the designated overrun by more than –0,  $+\frac{1}{8}$  in. and the drum cut dimension shall not vary over the designated overrun by more than –0,  $+\frac{1}{4}$  in.

## 10. Special Requirements

10.1 *Welds*—Coils may contain lap or mash welds, the locations of which are marked. A hole may be punched adjacent to the weld for automatic rejection of the weld during shearing. The leading ends of lap welds shall not exceed 1 in.

10.2 *Cores*—If coil centers must be supported to minimize damage, this requirement should be so stated on the order as a special requirement.

## 11. Sheet Count—Cut Sizes

11.1 Small variations in sheet count/bundle should average out to at least the proper exact count in quantities of 400 packages or more.

## 12. Retest Procedure

12.1 In the event the material fails to meet the specified requirements, two further series of samples are to be selected by the purchaser in accordance with the applicable procedures. Both retests must meet the specification limits to qualify as meeting the requirements.

## 13. Conditions of Manufacture

13.1 The purchaser should be informed of any alterations in the method of manufacture which will significantly affect the properties of the purchased product. Similarly, the purchaser should inform the manufacturer of modifications in their fabrication methods which will significantly affect the way in which the purchased product is used.

## 14. Inspection

14.1 The inspector representing the purchaser shall have entry, at all times while work on the contract of the purchaser is being performed, to all parts of the manufacturer's works that concern the manufacture of the material ordered. The supplier shall afford the inspector all reasonable facilities to satisfy him that the material is being furnished in accordance with this specification. Unless otherwise specified, all inspection and tests shall be made prior to shipment at the supplier's works and such inspection or sampling shall be made in conjunction with and to the extent of the manufacturer's regular inspection operations.

## 15. Rejection

15.1 Material that shows excessive number of injurious imperfections subsequent to its acceptance at the manufacturer's works, except as noted in the basis of purchase of the applicable specification, shall be rejected and the supplier notified.

## 16. Packaging

16.1 Unless otherwise specified, the tin plate shall be packaged and loaded in accordance with Practices A 700.

16.2 When specified in the contract or order, and for direct procurement by or direct shipment to the Government, when Level A is specified, preservation, packaging and packing shall be in accordance with the Level A requirements of MIL-STD-163.

16.3 The standard method of shipping coils is with the eye of the coil vertical.



**17. Marking**

17.1 As a minimum requirement, the material shall be identified by having the manufacturer's name, ASTM designation, weight, purchaser's order number, and material identification legibly stenciled on top of each lift or shown on a tag attached to each coil or shipping unit.

17.2 When specified in the contract or order, and for direct procurement by or direct shipment to the Government, marking

for shipment, in addition to requirements specified in the contract or order, shall be in accordance with MIL-STD-129 for military agencies and in accordance with Federal Std. No. 123 for civil agencies.

**18. Keywords**

18.1 tin mill products

**ANNEXES****(Mandatory Information)****A1. ABBREVIATED RATIO TABLES FOR TIN MILL PRODUCTS**

A1.1 The base box is the unit of area of 112 sheets 14 by 20 in. or 31 360 in.<sup>2</sup>(217.78 ft<sup>2</sup>).

A1.2 To determine the number of base boxes represented by 112 sheets of any other dimensions, a computation is necessary. The computation is carried out using ratio tables.

A1.2.1 Tables A1.1-A1.6<sup>8</sup> are an abbreviated set of such ratio tables which can be used to determine the number of base boxes represented by 112 and 1000 sheets in sizes from 1/16 in. square to 50 in. square.

A1.2.2 The following example demonstrates the use of these tables. The example applies to various sheet dimensions as follows:

A1.2.2.1 *Sheet with No Fractional Dimensions*—Step 1 only.

A1.2.2.2 *Sheet with Fractional Dimensions on Only One Dimension*—Steps 1 and 2.

A1.2.2.3 *Sheet with Fractional Dimensions on Both Dimensions*—Steps 1, 2, 3, and 4.

A1.2.3 An example of the use of abbreviated ratio tables to develop the number of base boxes represented by 112 and 1000 sheets with specified dimensions 28 1/16 by 34 1/2 in. is given in Table A1.7.

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<sup>8</sup> These tables are reproduced, by permission of the American Iron and Steel Institute, from "Tin Mill Products," *Steel Products Manual*, AISI, 1963.

**TABLE A1.1 Tin Plate Ratios—Base Boxes per 112 Sheets Full-Inch Widths**

Full-Inch Lengths	0	1	2	3	4	5	6	7	8	9
1	.0000	.0036	.0071	.0107	.0143	.0179	.0214	.0250	.0286	.0321
2	.0000	.0071	.0143	.0214	.0286	.0357	.0429	.0500	.0571	.0643
3	.0000	.0107	.0214	.0321	.0429	.0536	.0643	.0750	.0857	.0964
4	.0000	.0143	.0286	.0429	.0571	.0714	.0857	.1000	.1143	.1286
5	.0000	.0179	.0357	.0536	.0714	.0893	.1071	.1250	.1429	.1607
6	.0000	.0214	.0429	.0643	.0857	.1071	.1286	.1500	.1714	.1929
7	.0000	.0250	.0500	.0750	.1000	.1250	.1500	.1750	.2000	.2250
8	.0000	.0286	.0571	.0857	.1143	.1429	.1714	.2000	.2286	.2571
9	.0000	.0321	.0643	.0964	.1286	.1607	.1929	.2250	.2571	.2893
10	.0000	.0357	.0714	.1071	.1429	.1786	.2143	.2500	.2857	.3214
11	.0000	.0393	.0786	.1179	.1571	.1964	.2357	.2750	.3143	.3536
12	.0000	.0429	.0857	.1286	.1714	.2143	.2571	.3000	.3429	.3857
13	.0000	.0464	.0929	.1393	.1857	.2321	.2786	.3250	.3714	.4179
14	.0000	.0500	.1000	.1500	.2000	.2500	.3000	.3500	.4000	.4500
15	.0000	.0536	.1071	.1607	.2143	.2679	.3214	.3750	.4286	.4821
16	.0000	.0571	.1143	.1714	.2286	.2857	.3429	.4000	.4571	.5143
17	.0000	.0607	.1214	.1821	.2429	.3036	.3643	.4250	.4857	.5464
18	.0000	.0643	.1286	.1929	.2571	.3214	.3857	.4500	.5143	.5786
19	.0000	.0679	.1357	.2036	.2714	.3393	.4071	.4750	.5429	.6107
20	.0000	.0714	.1429	.2143	.2857	.3571	.4286	.5000	.5714	.6429
21	.0000	.0750	.1500	.2250	.3000	.3750	.4500	.5250	.6000	.6750
22	.0000	.0786	.1571	.2357	.3143	.3929	.4714	.5500	.6286	.7071
23	.0000	.0821	.1643	.2464	.3286	.4107	.4929	.5750	.6571	.7393
24	.0000	.0857	.1714	.2571	.3429	.4286	.5143	.6000	.6857	.7714
25	.0000	.0893	.1786	.2679	.3571	.4464	.5357	.6250	.7143	.8036
26	.0000	.0929	.1857	.2786	.3714	.4643	.5571	.6500	.7429	.8357
27	.0000	.0964	.1929	.2893	.3857	.4821	.5786	.6750	.7714	.8679
28	.0000	.1000	.2000	.3000	.4000	.5000	.6000	.7000	.8000	.9000
29	.0000	.1036	.2071	.3107	.4143	.5179	.6214	.7250	.8286	.9321
30	.0000	.1071	.2143	.3214	.4286	.5357	.6429	.7500	.8571	.9643
31	.0000	.1107	.2214	.3321	.4429	.5536	.6643	.7750	.8857	.9964
32	.0000	.1143	.2286	.3429	.4571	.5714	.6857	.8000	.9143	1.0286
33	.0000	.1179	.2357	.3536	.4714	.5893	.7071	.8250	.9429	1.0607
34	.0000	.1214	.2429	.3643	.4857	.6071	.7286	.8500	.9714	1.0929
35	.0000	.1250	.2500	.3750	.5000	.6250	.7500	.8750	1.0000	1.1250
36	.0000	.1286	.2571	.3857	.5143	.6429	.7714	.9000	1.0286	1.1571
37	.0000	.1321	.2643	.3964	.5286	.6607	.7929	.9250	1.0571	1.1893
38	.0000	.1357	.2714	.4071	.5429	.6786	.8143	.9500	1.0857	1.2214
39	.0000	.1393	.2786	.4179	.5571	.6964	.8357	.9750	1.1143	1.2536
40	.0000	.1429	.2857	.4286	.5714	.7143	.8571	1.0000	1.1429	1.2857
41	.0000	.1464	.2929	.4393	.5857	.7321	.8786	1.0250	1.1714	1.3179
42	.0000	.1500	.3000	.4500	.6000	.7500	.9000	1.0500	1.2000	1.3500
43	.0000	.1536	.3071	.4607	.6143	.7679	.9214	1.0750	1.2286	1.3821
44	.0000	.1571	.3143	.4714	.6286	.7857	.9429	1.1000	1.2571	1.4143
45	.0000	.1607	.3214	.4821	.6429	.8036	.9643	1.1250	1.2857	1.4464
46	.0000	.1643	.3286	.4929	.6571	.8214	.9857	1.1500	1.3143	1.4786
47	.0000	.1679	.3357	.5036	.6714	.8393	1.0071	1.1750	1.3429	1.5107
48	.0000	.1714	.3429	.5143	.6857	.8571	1.0286	1.2000	1.3714	1.5429
49	.0000	.1750	.3500	.5250	.7000	.8750	1.0500	1.2250	1.4000	1.5750
50	.0000	.1786	.3571	.5357	.7143	.8929	1.0714	1.2500	1.4286	1.6071

**TABLE A1.1** *Continued*

Full-Inch Lengths	10	11	12	13	14	15	16	17	18	19
	10	.3571	.3929	.4286	.4643	.5000	.5357	.5714	.6071	.6429
11	.3929	.4321	.4714	.5107	.5500	.5893	.6286	.6679	.7071	.7464
12	.4286	.4714	.5143	.5571	.6000	.6429	.6857	.7286	.7714	.8143
13	.4643	.5107	.5571	.6036	.6500	.6964	.7429	.7893	.8357	.8821
14	.5000	.5500	.6000	.6500	.7000	.7500	.8000	.8500	.9000	.9500
15	.5357	.5893	.6429	.6964	.7500	.8036	.8571	.9107	.9643	1.0179
16	.5714	.6286	.6857	.7429	.8000	.8571	.9143	.9714	1.0286	1.0857
17	.6071	.6679	.7286	.7893	.8500	.9107	.9714	1.0321	1.0929	1.1536
18	.6429	.7071	.7714	.8357	.9000	.9643	1.0286	1.0929	1.1571	1.2214
19	.6786	.7464	.8143	.8821	.9500	1.0179	1.0857	1.1536	1.2214	1.2893
20	.7143	.7857	.8571	.9286	1.0000	1.0714	1.1429	1.2143	1.2857	1.3571
21	.7500	.8250	.9000	.9750	1.0500	1.1250	1.2000	1.2750	1.3500	1.4250
22	.7857	.8643	.9429	1.0214	1.1000	1.1786	1.2571	1.3357	1.4143	1.4929
23	.8214	.9036	.9857	1.0679	1.1500	1.2321	1.3143	1.3964	1.4786	1.5607
24	.8571	.9429	1.0286	1.1143	1.2000	1.2857	1.3714	1.4571	1.5429	1.6286
25	.8929	.9821	1.0714	1.1607	1.2500	1.3393	1.4286	1.5179	1.6071	1.6964
26	.9286	1.0214	1.1143	1.2071	1.3000	1.3929	1.4857	1.5786	1.6714	1.7643
27	.9643	1.0607	1.1571	1.2536	1.3500	1.4464	1.5429	1.6393	1.7357	1.8321
28	1.0000	1.1000	1.2000	1.3000	1.4000	1.5000	1.6000	1.7000	1.8000	1.9000
29	1.0357	1.1393	1.2429	1.3464	1.4500	1.5536	1.6571	1.7607	1.8643	1.9679
30	1.0714	1.1786	1.2857	1.3929	1.5000	1.6071	1.7143	1.8214	1.9286	2.0357
31	1.1071	1.2179	1.3286	1.4393	1.5500	1.6607	1.7714	1.8821	1.9929	2.1036
32	1.1429	1.2571	1.3714	1.4857	1.6000	1.7143	1.8286	1.9429	2.0571	2.1714
33	1.1786	1.2964	1.4143	1.5321	1.6500	1.7679	1.8857	2.0036	2.1214	2.2393
34	1.2143	1.3357	1.4571	1.5786	1.7000	1.8214	1.9429	2.0643	2.1857	2.3071
35	1.2500	1.3750	1.5000	1.6250	1.7500	1.8750	2.0000	2.1250	2.2500	2.3750
36	1.2857	1.4143	1.5429	1.6714	1.8000	1.9286	2.0571	2.1857	2.3143	2.4429
37	1.3214	1.4536	1.5857	1.7179	1.8500	1.9821	2.1143	2.2464	2.3786	2.5107
38	1.3571	1.4929	1.6286	1.7643	1.9000	2.0357	2.1714	2.3071	2.4429	2.5786
39	1.3929	1.5321	1.6714	1.8107	1.9500	2.0893	2.2286	2.3679	2.5071	2.6464
40	1.4286	1.5714	1.7143	1.8571	2.0000	2.1429	2.2857	2.4286	2.5714	2.7143
41	1.4643	1.6107	1.7571	1.9036	2.0500	2.1964	2.3429	2.4893	2.6357	2.7821
42	1.5000	1.6500	1.8000	1.9500	2.1000	2.2500	2.4000	2.5500	2.7000	2.8500
43	1.5357	1.6893	1.8429	1.9964	2.1500	2.3036	2.4571	2.6107	2.7643	2.9179
44	1.5714	1.7286	1.8857	2.0429	2.2000	2.3571	2.5143	2.6714	2.8286	2.9857
45	1.6071	1.7679	1.9286	2.0893	2.2500	2.4107	2.5714	2.7321	2.8929	3.0536
46	1.6429	1.8071	1.9714	2.1357	2.3000	2.4643	2.6286	2.7929	2.9571	3.1214
47	1.6786	1.8464	2.0143	2.1821	2.3500	2.5179	2.6857	2.8536	3.0214	3.1893
48	1.7143	1.8857	2.0571	2.2286	2.4000	2.5714	2.7429	2.9143	3.0857	3.2571
49	1.7500	1.9250	2.1000	2.2750	2.4500	2.6250	2.8000	2.9750	3.1500	3.3250
50	1.7857	1.9643	2.1429	2.3214	2.5000	2.6786	2.8571	3.0357	3.2143	3.3929

TABLE A1.1 *Continued*

Full-Inch Lengths	20	21	22	23	24	25	26	27	28	29
	<b>20</b>	1.4286	1.5000	1.5714	1.6429	1.7143	1.7857	1.8571	1.9286	2.0000
<b>21</b>	1.5000	1.5750	1.6500	1.7250	1.8000	1.8750	1.9500	2.0250	2.1000	2.1750
<b>22</b>	1.5714	1.6500	1.7286	1.8071	1.8857	1.9643	2.0429	2.1214	2.2000	2.2786
<b>23</b>	1.6429	1.7250	1.8071	1.8893	1.9714	2.0536	2.1357	2.2179	2.3000	2.3821
<b>24</b>	1.7143	1.8000	1.8857	1.9714	2.0571	2.1429	2.2286	2.3143	2.4000	2.4857
<b>25</b>	1.7857	1.8750	1.9643	2.0536	2.1429	2.2321	2.3214	2.4107	2.5000	2.5893
<b>26</b>	1.8571	1.9500	2.0429	2.1357	2.2286	2.3214	2.4143	2.5071	2.6000	2.6929
<b>27</b>	1.9286	2.0250	2.1214	2.2179	2.3143	2.4107	2.5071	2.6036	2.7000	2.7964
<b>28</b>	2.0000	2.1000	2.2000	2.3000	2.4000	2.5000	2.6000	2.7000	2.8000	2.9000
<b>29</b>	2.0714	2.1750	2.2786	2.3821	2.4857	2.5893	2.6929	2.7964	2.9000	3.0036
<b>30</b>	2.1429	2.2500	2.3571	2.4643	2.5714	2.6786	2.7857	2.8929	3.0000	3.1071
<b>31</b>	2.2143	2.3250	2.4357	2.5464	2.6571	2.7679	2.8786	2.9893	3.1000	3.2107
<b>32</b>	2.2857	2.4000	2.5143	2.6286	2.7429	2.8571	2.9714	3.0857	3.2000	3.3143
<b>33</b>	2.3571	2.4750	2.5929	2.7107	2.8286	2.9464	3.0643	3.1821	3.3000	3.4179
<b>34</b>	2.4286	2.5500	2.6714	2.7929	2.9143	3.0357	3.1571	3.2786	3.4000	3.5214
<b>35</b>	2.5000	2.6250	2.7500	2.8750	3.0000	3.1250	3.2500	3.3750	3.5000	3.6250
<b>36</b>	2.5714	2.7000	2.8286	2.9571	3.0857	3.2143	3.3429	3.4714	3.6000	3.7286
<b>37</b>	2.6429	2.7750	2.9071	3.0393	3.1714	3.3036	3.4357	3.5679	3.7000	3.8321
<b>38</b>	2.7143	2.8500	2.9857	3.1214	3.2571	3.3929	3.5286	3.6643	3.8000	3.9357
<b>39</b>	2.7857	2.9250	3.0643	3.2036	3.3429	3.4821	3.6214	3.7607	3.9000	4.0393
<b>40</b>	2.8571	3.0000	3.1429	3.2857	3.4286	3.5714	3.7143	3.8571	4.0000	4.1429
<b>41</b>	2.9286	3.0750	3.2214	3.3679	3.5143	3.6607	3.8071	3.9536	4.1000	4.2464
<b>42</b>	3.0000	3.1500	3.3000	3.4500	3.6000	3.7500	3.9000	4.0500	4.2000	4.3500
<b>43</b>	3.0714	3.2250	3.3786	3.5321	3.6857	3.8393	3.9929	4.1464	4.3000	4.4536
<b>44</b>	3.1429	3.3000	3.4571	3.6143	3.7714	3.9286	4.0857	4.2429	4.4000	4.5571
<b>45</b>	3.2143	3.3750	3.5357	3.6964	3.8571	4.0179	4.1786	4.3393	4.5000	4.6607
<b>46</b>	3.2857	3.4500	3.6143	3.7786	3.9429	4.1071	4.2714	4.4357	4.6000	4.7643
<b>47</b>	3.3571	3.5250	3.6929	3.8607	4.0286	4.1964	4.3643	4.5321	4.7000	4.8679
<b>48</b>	3.4286	3.6000	3.7714	3.9429	4.1143	4.2857	4.4571	4.6286	4.8000	4.9714
<b>49</b>	3.5000	3.6750	3.8500	4.0250	4.2000	4.3750	4.5500	4.7250	4.9000	5.0750
<b>50</b>	3.5714	3.7500	3.9286	4.1071	4.2857	4.4643	4.6429	4.8214	5.0000	5.1786

**TABLE A1.1** *Continued*

Full-inch Lengths	30	31	32	33	34	35	36	37	38	39
	<b>30</b>	3.2143	3.3214	3.4286	3.5357	3.6429	3.7500	3.8571	3.9643	4.0714
<b>31</b>	3.3214	3.4321	3.5429	3.6536	3.7643	3.8750	3.9857	4.0964	4.2071	4.3179
<b>32</b>	3.4286	3.5429	3.6571	3.7714	3.8857	4.0000	4.1143	4.2286	4.3429	4.4571
<b>33</b>	3.5357	3.6536	3.7714	3.8893	4.0071	4.1250	4.2429	4.3607	4.4786	4.5964
<b>34</b>	3.6429	3.7643	3.8857	4.0071	4.1286	4.2500	4.3714	4.4929	4.6143	4.7357
<b>35</b>	3.7500	3.8750	4.0000	4.1250	4.2500	4.3750	4.5000	4.6250	4.7500	4.8750
<b>36</b>	3.8571	3.9857	4.1143	4.2429	4.3714	4.5000	4.6286	4.7571	4.8857	5.0143
<b>37</b>	3.9643	4.0964	4.2286	4.3607	4.4929	4.6250	4.7571	4.8893	5.0214	5.1536
<b>38</b>	4.0714	4.2071	4.3429	4.4786	4.6143	4.7500	4.8857	5.0214	5.1571	5.2929
<b>39</b>	4.1786	4.3179	4.4571	4.5964	4.7357	4.8750	5.0143	5.1536	5.2929	5.4321
<b>40</b>	4.2857	4.4286	4.5714	4.7143	4.8571	5.0000	5.1429	5.2857	5.4286	5.5714
<b>41</b>	4.3929	4.5393	4.6857	4.8321	4.9786	5.1250	5.2714	5.4179	5.5643	5.7107
<b>42</b>	4.5000	4.6500	4.8000	4.9500	5.1000	5.2500	5.4000	5.5500	5.7000	5.8500
<b>43</b>	4.6071	4.7607	4.9143	5.0679	5.2214	5.3750	5.5286	5.6821	5.8357	5.9893
<b>44</b>	4.7143	4.8714	5.0286	5.1857	5.3429	5.5000	5.6571	5.8143	5.9714	6.1286
<b>45</b>	4.8214	4.9821	5.1429	5.3036	5.4643	5.6250	5.7857	5.9464	6.1071	6.2679
<b>46</b>	4.9286	5.0929	5.2571	5.4214	5.5857	5.7500	5.9143	6.0786	6.2429	6.4071
<b>47</b>	5.0357	5.2036	5.3714	5.5393	5.7071	5.8750	6.0429	6.2107	6.3786	6.5464
<b>48</b>	5.1429	5.3143	5.4857	5.6571	5.8286	6.0000	6.1714	6.3429	6.5143	6.6857
<b>49</b>	5.2500	5.4250	5.6000	5.7750	5.9500	6.1250	6.3000	6.4750	6.6500	6.8250
<b>50</b>	5.3571	5.5357	5.7143	5.8929	6.0714	6.2500	6.4286	6.6071	6.7857	6.9643

Full-inch Lengths	40	41	42	43	44	45	46	47	48	49
	<b>40</b>	5.7143	5.8571	6.0000	6.1429	6.2857	6.4286	6.5714	6.7143	6.8571
<b>41</b>	5.8571	6.0036	6.1500	6.2964	6.4429	6.5893	6.7357	6.8821	7.0286	7.1750
<b>42</b>	6.0000	6.1500	6.3000	6.4500	6.6000	6.7500	6.9000	7.0500	7.2000	7.3500
<b>43</b>	6.1429	6.2964	6.4500	6.6036	6.7571	6.9107	7.0643	7.2179	7.3714	7.5250
<b>44</b>	6.2857	6.4429	6.6000	6.7571	6.9143	7.0714	7.2286	7.3857	7.5429	7.7000
<b>45</b>	6.4286	6.5893	6.7500	6.9107	7.0714	7.2321	7.3929	7.5536	7.7143	7.8750
<b>46</b>	6.5714	6.7357	6.9000	7.0643	7.2286	7.3929	7.5571	7.7214	7.8857	8.0500
<b>47</b>	6.7143	6.8821	7.0500	7.2179	7.3857	7.5536	7.7214	7.8893	8.0571	8.2250
<b>48</b>	6.8571	7.0286	7.2000	7.3714	7.5429	7.7143	7.8857	8.0571	8.2286	8.4000
<b>49</b>	7.0000	7.1750	7.3500	7.5250	7.7000	7.8750	8.0500	8.2250	8.4000	8.5750
<b>50</b>	7.1429	7.3214	7.5000	7.6786	7.8571	8.0357	8.2143	8.3929	8.5714	8.7500

<b>50</b>	8.9286
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**TABLE A1.2 Tin Plate Ratios—Base Boxes per 112 Sheets Full-Inch Widths**

Full-Inch Lengths	Tin Plate Ratios														
	$1/16$	$1/8$	$3/16$	$1/4$	$5/16$	$3/8$	$7/16$	$1/2$	$9/16$	$5/8$	$11/16$	$3/4$	$13/16$	$7/8$	$15/16$
<b>1</b>	.0002	.0004	.0007	.0009	.0011	.0013	.0016	.0018	.0020	.0022	.0025	.0027	.0029	.0031	.0033
<b>2</b>	.0004	.0009	.0013	.0018	.0022	.0027	.0031	.0036	.0040	.0045	.0049	.0054	.0058	.0063	.0067
<b>3</b>	.0007	.0013	.0020	.0027	.0033	.0040	.0047	.0054	.0060	.0067	.0074	.0080	.0087	.0094	.0100
<b>4</b>	.0009	.0018	.0027	.0036	.0045	.0054	.0063	.0071	.0080	.0089	.0098	.0107	.0116	.0125	.0134
<b>5</b>	.0011	.0022	.0033	.0045	.0056	.0067	.0078	.0089	.0100	.0112	.0123	.0134	.0145	.0156	.0167
<b>6</b>	.0013	.0027	.0040	.0054	.0067	.0080	.0094	.0107	.0121	.0134	.0147	.0161	.0174	.0188	.0201
<b>7</b>	.0016	.0031	.0047	.0063	.0078	.0094	.0109	.0125	.0141	.0156	.0172	.0188	.0203	.0219	.0234
<b>8</b>	.0018	.0036	.0054	.0071	.0089	.0107	.0125	.0143	.0161	.0179	.0196	.0214	.0232	.0250	.0268
<b>9</b>	.0020	.0040	.0060	.0080	.0100	.0121	.0141	.0161	.0181	.0201	.0221	.0241	.0261	.0281	.0301
<b>10</b>	.0022	.0045	.0067	.0089	.0112	.0134	.0156	.0179	.0201	.0223	.0246	.0268	.0290	.0313	.0335
<b>11</b>	.0025	.0049	.0074	.0098	.0123	.0147	.0172	.0196	.0221	.0246	.0270	.0295	.0319	.0344	.0368
<b>12</b>	.0027	.0054	.0080	.0107	.0134	.0161	.0188	.0214	.0241	.0268	.0295	.0321	.0348	.0375	.0402
<b>13</b>	.0029	.0058	.0087	.0116	.0145	.0174	.0203	.0232	.0261	.0290	.0319	.0348	.0377	.0406	.0435
<b>14</b>	.0031	.0063	.0094	.0125	.0156	.0188	.0219	.0250	.0281	.0313	.0344	.0375	.0406	.0438	.0469
<b>15</b>	.0033	.0067	.0100	.0134	.0167	.0201	.0234	.0268	.0301	.0335	.0368	.0402	.0435	.0469	.0502
<b>16</b>	.0036	.0071	.0107	.0143	.0179	.0214	.0250	.0286	.0321	.0357	.0393	.0429	.0464	.0500	.0536
<b>17</b>	.0038	.0076	.0114	.0152	.0190	.0228	.0266	.0304	.0342	.0379	.0417	.0455	.0493	.0531	.0569
<b>18</b>	.0040	.0080	.0121	.0161	.0201	.0241	.0281	.0321	.0362	.0402	.0442	.0482	.0522	.0563	.0603
<b>19</b>	.0042	.0085	.0127	.0170	.0212	.0254	.0297	.0339	.0382	.0424	.0467	.0509	.0551	.0594	.0636
<b>20</b>	.0045	.0089	.0134	.0179	.0223	.0268	.0313	.0357	.0402	.0446	.0491	.0536	.0580	.0625	.0670
<b>21</b>	.0047	.0094	.0141	.0188	.0234	.0281	.0328	.0375	.0422	.0469	.0516	.0563	.0609	.0656	.0703
<b>22</b>	.0049	.0098	.0147	.0196	.0246	.0295	.0344	.0393	.0442	.0491	.0540	.0589	.0638	.0688	.0737
<b>23</b>	.0051	.0103	.0154	.0205	.0257	.0308	.0359	.0411	.0462	.0513	.0565	.0616	.0667	.0719	.0770
<b>24</b>	.0054	.0107	.0161	.0214	.0268	.0321	.0375	.0429	.0482	.0536	.0589	.0643	.0696	.0750	.0804
<b>25</b>	.0056	.0112	.0167	.0223	.0279	.0335	.0391	.0446	.0502	.0558	.0614	.0670	.0725	.0781	.0837
<b>26</b>	.0058	.0116	.0174	.0232	.0290	.0348	.0406	.0464	.0522	.0580	.0638	.0696	.0754	.0813	.0871
<b>27</b>	.0060	.0121	.0181	.0241	.0301	.0362	.0422	.0482	.0542	.0603	.0663	.0723	.0783	.0844	.0904
<b>28</b>	.0063	.0125	.0188	.0250	.0313	.0375	.0438	.0500	.0563	.0625	.0688	.0750	.0813	.0875	.0938
<b>29</b>	.0065	.0129	.0194	.0259	.0324	.0388	.0453	.0518	.0583	.0647	.0712	.0777	.0842	.0906	.0971
<b>30</b>	.0067	.0134	.0201	.0268	.0335	.0402	.0469	.0536	.0603	.0670	.0737	.0804	.0871	.0938	.1004
<b>31</b>	.0069	.0138	.0208	.0277	.0346	.0415	.0484	.0554	.0623	.0692	.0761	.0830	.0900	.0969	.1038
<b>32</b>	.0071	.0143	.0214	.0286	.0357	.0429	.0500	.0571	.0643	.0714	.0786	.0857	.0929	.1000	.1071
<b>33</b>	.0074	.0147	.0221	.0295	.0368	.0442	.0516	.0589	.0663	.0737	.0810	.0884	.0958	.1031	.1105
<b>34</b>	.0076	.0152	.0228	.0304	.0379	.0455	.0531	.0607	.0683	.0759	.0835	.0911	.0987	.1063	.1138
<b>35</b>	.0078	.0156	.0234	.0313	.0391	.0469	.0547	.0625	.0703	.0781	.0859	.0938	.1016	.1094	.1172
<b>36</b>	.0080	.0161	.0241	.0321	.0402	.0482	.0563	.0643	.0723	.0804	.0884	.0964	.1045	.1125	.1205
<b>37</b>	.0083	.0165	.0248	.0330	.0413	.0496	.0578	.0661	.0743	.0826	.0908	.0991	.1074	.1156	.1239
<b>38</b>	.0085	.0170	.0254	.0339	.0424	.0509	.0594	.0679	.0763	.0848	.0933	.1018	.1103	.1188	.1272
<b>39</b>	.0087	.0174	.0261	.0348	.0435	.0522	.0609	.0696	.0783	.0871	.0958	.1045	.1132	.1219	.1306
<b>40</b>	.0089	.0179	.0268	.0357	.0446	.0536	.0625	.0714	.0804	.0893	.0982	.1071	.1161	.1250	.1339
<b>41</b>	.0092	.0183	.0275	.0366	.0458	.0549	.0641	.0732	.0824	.0915	.1007	.1098	.1190	.1281	.1373
<b>42</b>	.0094	.0188	.0281	.0375	.0469	.0563	.0656	.0750	.0844	.0938	.1031	.1125	.1219	.1313	.1406
<b>43</b>	.0096	.0192	.0288	.0384	.0480	.0576	.0672	.0768	.0864	.0960	.1056	.1152	.1248	.1344	.1440
<b>44</b>	.0098	.0196	.0295	.0393	.0491	.0589	.0688	.0786	.0884	.0982	.1080	.1179	.1277	.1375	.1473
<b>45</b>	.0100	.0201	.0301	.0402	.0502	.0603	.0703	.0804	.0904	.1004	.1105	.1205	.1306	.1406	.1507
<b>46</b>	.0103	.0205	.0308	.0411	.0513	.0616	.0719	.0821	.0924	.1027	.1129	.1232	.1335	.1438	.1540
<b>47</b>	.0105	.0210	.0315	.0420	.0525	.0629	.0734	.0839	.0944	.1049	.1154	.1259	.1364	.1469	.1574
<b>48</b>	.0107	.0214	.0321	.0429	.0536	.0643	.0750	.0857	.0964	.1071	.1179	.1286	.1393	.1500	.1607
<b>49</b>	.0109	.0219	.0328	.0438	.0547	.0656	.0766	.0875	.0984	.1094	.1203	.1313	.1422	.1531	.1641
<b>50</b>	.0112	.0223	.0335	.0446	.0558	.0670	.0781	.0893	.1004	.1116	.1228	.1339	.1451	.1563	.1674

**TABLE A1.3 Tin Plate Ratios—Base Boxes per 112 Sheets Fractional Widths and Length**

	$\frac{1}{16}$	$\frac{1}{8}$	$\frac{3}{16}$	$\frac{1}{4}$	$\frac{5}{16}$	$\frac{3}{8}$	$\frac{7}{16}$	$\frac{1}{2}$	$\frac{9}{16}$	$\frac{5}{8}$	$\frac{11}{16}$	$\frac{3}{4}$	$\frac{13}{16}$	$\frac{7}{8}$	$\frac{15}{16}$
$\frac{1}{16}$	.0000	.0001	.0002	.0003	.0004	.0005	.0006	.0007	.0008	.0009	.0010	.0011	.0012	.0013	.0014
$\frac{1}{8}$	.0000	.0001	.0002	.0003	.0004	.0005	.0006	.0007	.0008	.0009	.0010	.0011	.0012	.0013	.0014
$\frac{3}{16}$	.0000	.0001	.0002	.0003	.0004	.0005	.0006	.0007	.0008	.0009	.0010	.0011	.0012	.0013	.0014
$\frac{1}{4}$	.0001	.0001	.0002	.0002	.0003	.0003	.0004	.0004	.0005	.0005	.0006	.0006	.0007	.0007	.0008
$\frac{5}{16}$	.0001	.0001	.0002	.0003	.0003	.0004	.0005	.0005	.0006	.0006	.0007	.0008	.0008	.0009	.0010
$\frac{3}{8}$	.0001	.0002	.0003	.0003	.0004	.0005	.0006	.0007	.0008	.0008	.0009	.0010	.0011	.0012	.0013
$\frac{7}{16}$	.0001	.0002	.0003	.0004	.0005	.0006	.0007	.0008	.0009	.0010	.0011	.0012	.0013	.0014	.0015
$\frac{1}{2}$	.0001	.0002	.0003	.0004	.0005	.0006	.0007	.0008	.0009	.0010	.0011	.0012	.0013	.0014	.0015
$\frac{9}{16}$	.0001	.0003	.0004	.0005	.0006	.0008	.0009	.0010	.0011	.0013	.0014	.0015	.0016	.0018	.0019
$\frac{5}{8}$	.0001	.0003	.0004	.0006	.0007	.0008	.0010	.0011	.0013	.0014	.0015	.0017	.0018	.0020	.0021
$\frac{11}{16}$	.0002	.0003	.0005	.0006	.0008	.0009	.0011	.0012	.0014	.0015	.0017	.0018	.0020	.0021	.0023
$\frac{3}{4}$	.0002	.0003	.0005	.0007	.0008	.0010	.0012	.0013	.0015	.0017	.0018	.0020	.0022	.0023	.0025
$\frac{13}{16}$	.0002	.0004	.0005	.0007	.0009	.0011	.0013	.0015	.0016	.0018	.0020	.0022	.0024	.0025	.0027
$\frac{7}{8}$	.0002	.0004	.0006	.0008	.0010	.0012	.0014	.0016	.0018	.0020	.0021	.0023	.0025	.0027	.0029
$\frac{15}{16}$	.0002	.0004	.0006	.0008	.0010	.0013	.0015	.0017	.0019	.0021	.0023	.0025	.0027	.0029	.0031

**TABLE A1.4 Tin Plate Ratios—Base Boxes per 1000 Sheets Full-Inch Widths**

Full-Inch Lengths	0	1	2	3	4	5	6	7	8	9
	1	.00	.03	.06	.10	.13	.16	.19	.22	.26
2	.00	.06	.13	.19	.26	.32	.38	.45	.51	.57
3	.00	.10	.19	.29	.38	.48	.57	.67	.77	.86
4	.00	.13	.26	.38	.51	.64	.77	.89	1.02	1.15
5	.00	.16	.32	.48	.64	.80	.96	1.12	1.28	1.43
6	.00	.19	.38	.57	.77	.96	1.15	1.34	1.53	1.72
7	.00	.22	.45	.67	.89	1.12	1.34	1.56	1.79	2.01
8	.00	.26	.51	.77	1.02	1.28	1.53	1.79	2.04	2.30
9	.00	.29	.57	.86	1.15	1.43	1.72	2.01	2.30	2.58
10	.00	.32	.64	.96	1.28	1.59	1.91	2.23	2.55	2.87
11	.00	.35	.70	1.05	1.40	1.75	2.10	2.46	2.81	3.16
12	.00	.38	.77	1.15	1.53	1.91	2.30	2.68	3.06	3.44
13	.00	.41	.83	1.24	1.66	2.07	2.49	2.90	3.32	3.73
14	.00	.45	.89	1.34	1.79	2.23	2.68	3.13	3.57	4.02
15	.00	.48	.96	1.43	1.91	2.39	2.87	3.35	3.83	4.30
16	.00	.51	1.02	1.53	2.04	2.55	3.06	3.57	4.08	4.59
17	.00	.54	1.08	1.63	2.17	2.71	3.25	3.79	4.34	4.88
18	.00	.57	1.15	1.72	2.30	2.87	3.44	4.02	4.59	5.17
19	.00	.61	1.21	1.82	2.42	3.03	3.64	4.24	4.85	5.45
20	.00	.64	1.28	1.91	2.55	3.19	3.83	4.46	5.10	5.74
21	.00	.67	1.34	2.01	2.68	3.35	4.02	4.69	5.36	6.03
22	.00	.70	1.40	2.10	2.81	3.51	4.21	4.91	5.61	6.31
23	.00	.73	1.47	2.20	2.93	3.67	4.40	5.13	5.87	6.60
24	.00	.77	1.53	2.30	3.06	3.83	4.59	5.36	6.12	6.89
25	.00	.80	1.59	2.39	3.19	3.99	4.78	5.58	6.38	7.17
26	.00	.83	1.66	2.49	3.32	4.15	4.97	5.80	6.63	7.46
27	.00	.86	1.72	2.58	3.44	4.30	5.17	6.03	6.89	7.75
28	.00	.89	1.79	2.68	3.57	4.46	5.36	6.25	7.14	8.04
29	.00	.92	1.85	2.77	3.70	4.62	5.55	6.47	7.40	8.32
30	.00	.96	1.91	2.87	3.83	4.78	5.74	6.70	7.65	8.61
31	.00	.99	1.98	2.97	3.95	4.94	5.93	6.92	7.91	8.90
32	.00	1.02	2.04	3.06	4.08	5.10	6.12	7.14	8.16	9.18
33	.00	1.05	2.10	3.16	4.21	5.26	6.31	7.37	8.42	9.47
34	.00	1.08	2.17	3.25	4.34	5.42	6.51	7.59	8.67	9.76
35	.00	1.12	2.23	3.35	4.46	5.58	6.70	7.81	8.93	10.04
36	.00	1.15	2.30	3.44	4.59	5.74	6.89	8.04	9.18	10.33
37	.00	1.18	2.36	3.54	4.72	5.90	7.08	8.26	9.44	10.62
38	.00	1.21	2.42	3.64	4.85	6.06	7.27	8.48	9.69	10.91
39	.00	1.24	2.49	3.73	4.97	6.22	7.46	8.71	9.95	11.19
40	.00	1.28	2.55	3.83	5.10	6.38	7.65	8.93	10.20	11.48
41	.00	1.31	2.61	3.92	5.23	6.54	7.84	9.15	10.46	11.77
42	.00	1.34	2.68	4.02	5.36	6.70	8.04	9.38	10.71	12.05
43	.00	1.37	2.74	4.11	5.48	6.86	8.23	9.60	10.97	12.34
44	.00	1.40	2.81	4.21	5.61	7.02	8.42	9.82	11.22	12.63
45	.00	1.43	2.87	4.30	5.74	7.17	8.61	10.04	11.48	12.91
46	.00	1.47	2.93	4.40	5.87	7.33	8.80	10.27	11.73	13.20
47	.00	1.50	3.00	4.50	5.99	7.49	8.99	10.49	11.99	13.49
48	.00	1.53	3.06	4.59	6.12	7.65	9.18	10.71	12.24	13.78
49	.00	1.56	3.13	4.69	6.25	7.81	9.38	10.94	12.50	14.06
50	.00	1.59	3.19	4.78	6.38	7.97	9.57	11.16	12.76	14.35



**TABLE A1.4** *Continued*

Full-Inch Lengths	<b>10</b>	<b>11</b>	<b>12</b>	<b>13</b>	<b>14</b>	<b>15</b>	<b>16</b>	<b>17</b>	<b>18</b>	<b>19</b>
<b>10</b>	3.19	3.51	3.83	4.15	4.46	4.78	5.10	5.42	5.74	6.06
<b>11</b>	3.51	3.86	4.21	4.56	4.91	5.26	5.61	5.96	6.31	6.66
<b>12</b>	3.83	4.21	4.59	4.97	5.36	5.74	6.12	6.51	6.89	7.27
<b>13</b>	4.15	4.56	4.97	5.39	5.80	6.22	6.63	7.05	7.46	7.88
<b>14</b>	4.46	4.91	5.36	5.80	6.25	6.70	7.14	7.59	8.04	8.48
<b>15</b>	4.78	5.26	5.74	6.22	6.70	7.17	7.65	8.13	8.61	9.09
<b>16</b>	5.10	5.61	6.12	6.63	7.14	7.65	8.16	8.67	9.18	9.69
<b>17</b>	5.42	5.96	6.51	7.05	7.59	8.13	8.67	9.22	9.76	10.30
<b>18</b>	5.74	6.31	6.89	7.46	8.04	8.61	9.18	9.76	10.33	10.91
<b>19</b>	6.06	6.66	7.27	7.88	8.48	9.09	9.69	10.30	10.91	11.51
<b>20</b>	6.38	7.02	7.65	8.29	8.93	9.57	10.20	10.84	11.48	12.12
<b>21</b>	6.70	7.37	8.04	8.71	9.38	10.04	10.71	11.38	12.05	12.72
<b>22</b>	7.02	7.72	8.42	9.12	9.82	10.52	11.22	11.93	12.63	13.33
<b>23</b>	7.33	8.07	8.80	9.53	10.27	11.00	11.73	12.47	13.20	13.93
<b>24</b>	7.65	8.42	9.18	9.95	10.71	11.48	12.24	13.01	13.78	14.54
<b>25</b>	7.97	8.77	9.57	10.36	11.16	11.96	12.76	13.55	14.35	15.15
<b>26</b>	8.29	9.12	9.95	10.78	11.61	12.44	13.27	14.09	14.92	15.75
<b>27</b>	8.61	9.47	10.33	11.19	12.05	12.91	13.78	14.64	15.50	16.36
<b>28</b>	8.93	9.82	10.71	11.61	12.50	13.39	14.29	15.18	16.07	16.96
<b>29</b>	9.25	10.17	11.10	12.02	12.95	13.87	14.80	15.72	16.65	17.57
<b>30</b>	9.57	10.52	11.48	12.44	13.39	14.35	15.31	16.26	17.22	18.18
<b>31</b>	9.89	10.87	11.86	12.85	13.84	14.83	15.82	16.80	17.79	18.78
<b>32</b>	10.20	11.22	12.24	13.27	14.29	15.31	16.33	17.35	18.37	19.39
<b>33</b>	10.52	11.58	12.63	13.68	14.73	15.78	16.84	17.89	18.94	19.99
<b>34</b>	10.84	11.93	13.01	14.09	15.18	16.26	17.35	18.43	19.52	20.60
<b>35</b>	11.16	12.28	13.39	14.51	15.63	16.74	17.86	18.97	20.09	21.21
<b>36</b>	11.48	12.63	13.78	14.92	16.07	17.22	18.37	19.52	20.66	21.81
<b>37</b>	11.80	12.98	14.16	15.34	16.52	17.70	18.88	20.06	21.24	22.42
<b>38</b>	12.12	13.33	14.54	15.75	16.96	18.18	19.39	20.60	21.81	23.02
<b>39</b>	12.44	13.68	14.92	16.17	17.41	18.65	19.90	21.14	22.39	23.63
<b>40</b>	12.76	14.03	15.31	16.58	17.86	19.13	20.41	21.68	22.96	24.23
<b>41</b>	13.07	14.38	15.69	17.00	18.30	19.61	20.92	22.23	23.53	24.84
<b>42</b>	13.39	14.73	16.07	17.41	18.75	20.09	21.43	22.77	24.11	25.45
<b>43</b>	13.71	15.08	16.45	17.83	19.20	20.57	21.94	23.31	24.68	26.05
<b>44</b>	14.03	15.43	16.84	18.24	19.64	21.05	22.45	23.85	25.26	26.66
<b>45</b>	14.35	15.78	17.22	18.65	20.09	21.52	22.96	24.39	25.83	27.26
<b>46</b>	14.67	16.14	17.60	19.07	20.54	22.00	23.47	24.94	26.40	27.87
<b>47</b>	14.99	16.49	17.98	19.48	20.98	22.48	23.98	25.48	26.98	28.48
<b>48</b>	15.31	16.84	18.37	19.90	21.43	22.96	24.49	26.02	27.55	29.08
<b>49</b>	15.63	17.19	18.75	20.31	21.88	23.44	25.00	26.56	28.13	29.69
<b>50</b>	15.94	17.54	19.13	20.73	22.32	23.92	25.51	27.10	28.70	30.29

**TABLE A1.4** *Continued*

Foil-Inch Lengths	<b>20</b>	<b>21</b>	<b>22</b>	<b>23</b>	<b>24</b>	<b>25</b>	<b>26</b>	<b>27</b>	<b>28</b>	<b>29</b>
<b>20</b>	12.76	13.39	14.03	14.67	15.31	15.94	16.58	17.22	17.86	18.49
<b>21</b>	13.39	14.06	14.73	15.40	16.07	16.74	17.41	18.08	18.75	19.42
<b>22</b>	14.03	14.73	15.43	16.14	16.84	17.54	18.24	18.94	19.64	20.34
<b>23</b>	14.67	15.40	16.14	16.87	17.60	18.34	19.07	19.80	20.54	21.27
<b>24</b>	15.31	16.07	16.84	17.60	18.37	19.13	19.90	20.66	21.43	22.19
<b>25</b>	15.94	16.74	17.54	18.34	19.13	19.93	20.73	21.52	22.32	23.12
<b>26</b>	16.58	17.41	18.24	19.07	19.90	20.73	21.56	22.39	23.21	24.04
<b>27</b>	17.22	18.08	18.94	19.80	20.66	21.52	22.39	23.25	24.11	24.97
<b>28</b>	17.86	18.75	19.64	20.54	21.43	22.32	23.21	24.11	25.00	25.89
<b>29</b>	18.49	19.42	20.34	21.27	22.19	23.12	24.04	24.97	25.89	26.82
<b>30</b>	19.13	20.09	21.05	22.00	22.96	23.92	24.87	25.83	26.79	27.74
<b>31</b>	19.77	20.76	21.75	22.74	23.72	24.71	25.70	26.69	27.68	28.67
<b>32</b>	20.41	21.43	22.45	23.47	24.49	25.51	26.53	27.55	28.57	29.59
<b>33</b>	21.05	22.10	23.15	24.20	25.26	26.31	27.36	28.41	29.46	30.52
<b>34</b>	21.68	22.77	23.85	24.94	26.02	27.10	28.19	29.27	30.36	31.44
<b>35</b>	22.32	23.44	24.55	25.67	26.79	27.90	29.02	30.13	31.25	32.37
<b>36</b>	22.96	24.11	25.26	26.40	27.55	28.70	29.85	30.99	32.14	33.29
<b>37</b>	23.60	24.78	25.96	27.14	28.32	29.50	30.68	31.86	33.04	34.22
<b>38</b>	24.23	25.45	26.66	27.87	29.08	30.29	31.51	32.72	33.93	35.14
<b>39</b>	24.87	26.12	27.36	28.60	29.85	31.09	32.33	33.58	34.82	36.07
<b>40</b>	25.51	26.79	28.06	29.34	30.61	31.89	33.16	34.44	35.71	36.99
<b>41</b>	26.15	27.46	28.76	30.07	31.38	32.68	33.99	35.30	36.61	37.91
<b>42</b>	26.79	28.13	29.46	30.80	32.14	33.48	34.82	36.16	37.50	38.84
<b>43</b>	27.42	28.79	30.17	31.54	32.91	34.28	35.65	37.02	38.39	39.76
<b>44</b>	28.06	29.46	30.87	32.27	33.67	35.08	36.48	37.88	39.29	40.69
<b>45</b>	28.70	30.13	31.57	33.00	34.44	35.87	37.31	38.74	40.18	41.61
<b>46</b>	29.34	30.80	32.27	33.74	35.20	36.67	38.14	39.60	41.07	42.54
<b>47</b>	29.97	31.47	32.97	34.47	35.97	37.47	38.97	40.47	41.96	43.46
<b>48</b>	30.61	32.14	33.67	35.20	36.73	38.27	39.80	41.33	42.86	44.39
<b>49</b>	31.25	32.81	34.38	35.94	37.50	39.06	40.63	42.19	43.75	45.31
<b>50</b>	31.89	33.48	35.08	36.67	38.27	39.86	41.45	43.05	44.64	46.24

TABLE A1.4 *Continued*

Full-Inch Lengths	30	31	32	33	34	35	36	37	38	39
30	28.70	29.66	30.61	31.57	32.53	33.48	34.44	35.40	36.35	37.31
31	29.66	30.64	31.63	32.62	33.61	34.60	35.59	36.58	37.56	38.55
32	30.61	31.63	32.65	33.67	34.69	35.71	36.73	37.76	38.78	39.80
33	31.57	32.62	33.67	34.73	35.78	36.83	37.88	38.93	39.99	41.04
34	32.53	33.61	34.69	35.78	36.86	37.95	39.03	40.11	41.20	42.28
35	33.48	34.60	35.71	36.83	37.95	39.06	40.18	41.29	42.41	43.53
36	34.44	35.59	36.73	37.88	39.03	40.18	41.33	42.47	43.62	44.77
37	35.40	36.58	37.76	38.93	40.11	41.29	42.47	43.65	44.83	46.01
38	36.35	37.56	38.78	39.99	41.20	42.41	43.62	44.83	46.05	47.26
39	37.31	38.55	39.80	41.04	42.28	43.53	44.77	46.01	47.26	48.50
40	38.27	39.54	40.82	42.09	43.37	44.64	45.92	47.19	48.47	49.74
41	39.22	40.53	41.84	43.14	44.45	45.76	47.07	48.37	49.68	50.99
42	40.18	41.52	42.86	44.20	45.54	46.88	48.21	49.55	50.89	52.23
43	41.14	42.51	43.88	45.25	46.62	47.99	49.36	50.73	52.10	53.48
44	42.09	43.49	44.90	46.30	47.70	49.11	50.51	51.91	53.32	54.72
45	43.05	44.48	45.92	47.35	48.79	50.22	51.66	53.09	54.53	55.96
46	44.01	45.47	46.94	48.41	49.87	51.34	52.81	54.27	55.74	57.21
47	44.96	46.46	47.96	49.46	50.96	52.46	53.95	55.45	56.95	58.45
48	45.92	47.45	48.98	50.51	52.04	53.57	55.10	56.63	58.16	59.69
49	46.88	48.44	50.00	51.56	53.13	54.69	56.25	57.81	59.38	60.94
50	47.83	49.43	51.02	52.61	54.21	55.80	57.40	58.99	60.59	62.18
40	51.02	52.30	53.57	54.85	56.12	57.40	58.67	59.95	61.22	62.50
41	52.30	53.60	54.91	56.22	57.53	58.83	60.14	61.45	62.76	64.06
42	53.57	54.91	56.25	57.59	58.93	60.27	61.61	62.95	64.29	65.63
43	54.85	56.22	57.59	58.96	60.33	61.70	63.07	64.45	65.82	67.19
44	56.12	57.53	58.93	60.33	61.73	63.14	64.54	65.94	67.35	68.75
45	57.40	58.83	60.27	61.70	63.14	64.57	66.01	67.44	68.88	70.31
46	58.67	60.14	61.61	63.07	64.54	66.01	67.47	68.94	70.41	71.88
47	59.95	61.45	62.95	64.45	65.94	67.44	68.94	70.44	71.94	73.44
48	61.22	62.76	64.29	65.82	67.35	68.88	70.41	71.94	73.47	75.00
49	62.50	64.06	65.63	67.19	68.75	70.31	71.88	73.44	75.00	76.56
50	63.78	65.37	66.96	68.56	70.15	71.75	73.34	74.94	76.53	78.13
50	79.72									

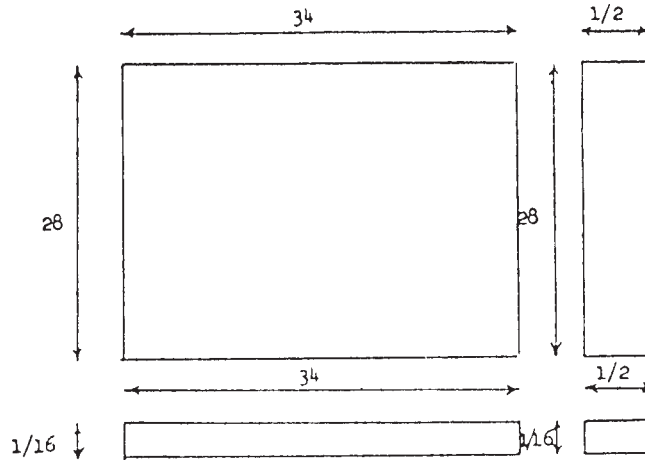
**TABLE A1.5 Tin Plate Ratios—Base Boxes per 1000 Sheets Fractional Widths**

Full-Inch Lengths	Fractional Widths														
	1/16	1/8	3/16	1/4	5/16	3/8	7/16	1/2	9/16	5/8	11/16	3/4	13/16	7/8	15/16
<b>1</b>	.00	.00	.01	.01	.01	.01	.01	.02	.02	.02	.02	.02	.03	.03	.03
<b>2</b>	.00	.01	.01	.02	.02	.02	.03	.03	.04	.04	.04	.05	.05	.06	.06
<b>3</b>	.01	.01	.02	.02	.03	.04	.04	.05	.05	.06	.07	.07	.08	.08	.09
<b>4</b>	.01	.02	.02	.03	.04	.05	.06	.06	.07	.08	.09	.10	.10	.11	.12
<b>5</b>	.01	.02	.03	.04	.05	.06	.07	.08	.09	.10	.11	.12	.13	.14	.15
<b>6</b>	.01	.02	.04	.05	.06	.07	.08	.10	.11	.12	.13	.14	.16	.17	.18
<b>7</b>	.01	.03	.04	.06	.07	.08	.10	.11	.13	.14	.15	.17	.18	.20	.21
<b>8</b>	.02	.03	.05	.06	.08	.10	.11	.13	.14	.16	.18	.19	.21	.22	.24
<b>9</b>	.02	.04	.05	.07	.09	.11	.13	.14	.16	.18	.20	.22	.23	.25	.27
<b>10</b>	.02	.04	.06	.08	.10	.12	.14	.16	.18	.20	.22	.24	.26	.28	.30
<b>11</b>	.02	.04	.07	.09	.11	.13	.15	.18	.20	.22	.24	.26	.28	.31	.33
<b>12</b>	.02	.05	.07	.10	.12	.14	.17	.19	.22	.24	.26	.29	.31	.33	.36
<b>13</b>	.03	.05	.08	.10	.13	.16	.18	.21	.23	.26	.28	.31	.34	.36	.39
<b>14</b>	.03	.06	.08	.11	.14	.17	.20	.22	.25	.28	.31	.33	.36	.39	.42
<b>15</b>	.03	.06	.09	.12	.15	.18	.21	.24	.27	.30	.33	.36	.39	.42	.45
<b>16</b>	.03	.06	.10	.13	.16	.19	.22	.26	.29	.32	.35	.38	.41	.45	.48
<b>17</b>	.03	.07	.10	.14	.17	.20	.24	.27	.30	.34	.37	.41	.44	.47	.51
<b>18</b>	.04	.07	.11	.14	.18	.22	.25	.29	.32	.36	.39	.43	.47	.50	.54
<b>19</b>	.04	.08	.11	.15	.19	.23	.27	.30	.34	.38	.42	.45	.49	.53	.57
<b>20</b>	.04	.08	.12	.16	.20	.24	.28	.32	.36	.40	.44	.48	.52	.56	.60
<b>21</b>	.04	.08	.13	.17	.21	.25	.29	.33	.38	.42	.46	.50	.54	.59	.63
<b>22</b>	.04	.09	.13	.18	.22	.26	.31	.35	.39	.44	.48	.53	.57	.61	.66
<b>23</b>	.05	.09	.14	.18	.23	.28	.32	.37	.41	.46	.50	.55	.60	.64	.69
<b>24</b>	.05	.10	.14	.19	.24	.29	.33	.38	.43	.48	.53	.57	.62	.67	.72
<b>25</b>	.05	.10	.15	.20	.25	.30	.35	.40	.45	.50	.55	.60	.65	.70	.75
<b>26</b>	.05	.10	.16	.21	.26	.31	.36	.41	.47	.52	.57	.62	.67	.73	.78
<b>27</b>	.05	.11	.16	.22	.27	.32	.38	.43	.48	.54	.59	.65	.70	.75	.81
<b>28</b>	.06	.11	.17	.22	.28	.33	.39	.45	.50	.56	.61	.67	.73	.78	.84
<b>29</b>	.06	.12	.17	.23	.29	.35	.40	.46	.52	.58	.64	.69	.75	.81	.87
<b>30</b>	.06	.12	.18	.24	.30	.36	.42	.48	.54	.60	.66	.72	.78	.84	.90
<b>31</b>	.06	.12	.19	.25	.31	.37	.43	.49	.56	.62	.68	.74	.80	.87	.93
<b>32</b>	.06	.13	.19	.26	.32	.38	.45	.51	.57	.64	.70	.77	.83	.89	.96
<b>33</b>	.07	.13	.20	.26	.33	.39	.46	.53	.59	.66	.72	.79	.86	.92	.99
<b>34</b>	.07	.14	.20	.27	.34	.41	.47	.54	.61	.68	.75	.81	.88	.95	1.02
<b>35</b>	.07	.14	.21	.28	.35	.42	.49	.56	.63	.70	.77	.84	.91	.98	1.05
<b>36</b>	.07	.14	.22	.29	.36	.43	.50	.57	.65	.72	.79	.86	.93	1.00	1.08
<b>37</b>	.07	.15	.22	.29	.37	.44	.52	.59	.66	.74	.81	.88	.96	1.03	1.11
<b>38</b>	.08	.15	.23	.30	.38	.45	.53	.61	.68	.76	.83	.91	.98	1.06	1.14
<b>39</b>	.08	.16	.23	.31	.39	.47	.54	.62	.70	.78	.86	.93	1.01	1.09	1.17
<b>40</b>	.08	.16	.24	.32	.40	.48	.56	.64	.72	.80	.88	.96	1.04	1.12	1.20
<b>41</b>	.08	.16	.25	.33	.41	.49	.57	.65	.74	.82	.90	.98	1.06	1.14	1.23
<b>42</b>	.08	.17	.25	.33	.42	.50	.59	.67	.75	.84	.92	1.00	1.09	1.17	1.26
<b>43</b>	.09	.17	.26	.34	.43	.51	.60	.69	.77	.86	.94	1.03	1.11	1.20	1.29
<b>44</b>	.09	.18	.26	.35	.44	.53	.61	.70	.79	.88	.96	1.05	1.14	1.23	1.32
<b>45</b>	.09	.18	.27	.36	.45	.54	.63	.72	.81	.90	.99	1.08	1.17	1.26	1.35
<b>46</b>	.09	.18	.28	.37	.46	.55	.64	.73	.83	.92	1.01	1.10	1.19	1.28	1.38
<b>47</b>	.09	.19	.28	.37	.47	.56	.66	.75	.84	.94	1.03	1.12	1.22	1.31	1.41
<b>48</b>	.10	.19	.29	.38	.48	.57	.67	.77	.86	.96	1.05	1.15	1.24	1.34	1.43
<b>49</b>	.10	.20	.29	.39	.49	.59	.68	.78	.88	.98	1.07	1.17	1.27	1.37	1.46
<b>50</b>	.10	.20	.30	.40	.50	.60	.70	.80	.90	1.00	1.10	1.20	1.30	1.40	1.49

**TABLE A1.6 Tin Plate Ratios—Base Boxes per 1000 Sheets Fractional Widths and Lengths**

	$1/16$	$1/8$	$3/16$	$1/4$	$5/16$	$3/8$	$7/16$	$1/2$	$9/16$	$5/8$	$11/16$	$3/4$	$13/16$	$7/8$	$15/16$
$1/16$	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
$1/8$	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
$3/16$	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.01	.01
$1/4$	.00	.00	.00	.00	.00	.00	.00	.00	.00	.01	.01	.01	.01	.01	.01
$5/16$	.00	.00	.00	.00	.00	.00	.00	.01	.01	.01	.01	.01	.01	.01	.01
$3/8$	.00	.00	.00	.00	.00	.00	.01	.01	.01	.01	.01	.01	.01	.01	.01
$7/16$	.00	.00	.00	.00	.00	.01	.01	.01	.01	.01	.01	.01	.01	.01	.01
$1/2$	.00	.00	.00	.00	.01	.01	.01	.01	.01	.01	.01	.01	.01	.01	.01
$9/16$	.00	.00	.00	.00	.01	.01	.01	.01	.01	.01	.01	.01	.01	.02	.02
$5/8$	.00	.00	.00	.01	.01	.01	.01	.01	.01	.01	.01	.01	.02	.02	.02
$11/16$	.00	.00	.00	.01	.01	.01	.01	.01	.01	.01	.02	.02	.02	.02	.02
$3/4$	.00	.00	.00	.01	.01	.01	.01	.01	.01	.01	.02	.02	.02	.02	.02
$13/16$	.00	.00	.00	.01	.01	.01	.01	.01	.01	.02	.02	.02	.02	.02	.02
$7/8$	.00	.00	.01	.01	.01	.01	.01	.01	.02	.02	.02	.02	.02	.02	.03
$15/16$	.00	.00	.01	.01	.01	.01	.01	.01	.02	.02	.02	.02	.02	.03	.03

**TABLE A1.7 Example of the Use of Abbreviated Ratio Tables**



**Dimensional Components of a 28 1/16 by 34 1/2-in. Sheet for Use in Abbreviated Ratio Tables**

Step	Components	112 Sheet Ratio <sup>A</sup>	Table	1000 Sheet Ratio <sup>B</sup>	Table
1	34 by 28	3.4000	A1.1	30.36	A1.4
2	28 by 1/2	0.0500	A1.2	0.45	A1.5
3	1/16 by 34	0.0076	A1.2	0.07	A1.5
4	1/16 by 1/2	0.0001	A1.3	0.00	A1.6
Total		3.4577		30.88	

<sup>A</sup> One-hundred twelve sheets measuring 28 1/16 by 34 1/2 in. represents 3.4577 base boxes.

<sup>B</sup> One-thousand sheets measuring 28 1/16 by 34 1/2 in. represents 30.88 base boxes.

## A2. ROCKWELL HARDNESS TESTING OF TIN MILL PRODUCTS

### A2.1 Scope

A2.1.1 This annex covers the application to tin mill products of Rockwell superficial hardness tests using the 15T and 30T scales. Tests shall be made in accordance with the latest revision of Test Methods and Definitions A 370 and with the methods outlined in Test Methods E 18, with the exceptions given in the following sections.

### A2.2 Anvil

A2.2.1 All tests shall be made using the diamond spot anvil and a 1/16 in. hardened steel ball indenter.

### A2.3 Specimens

A2.3.1 *Thickness*—The recommendations given in Table 12 of Test Methods E 18 shall not apply to tests on tin mill products. The Rockwell superficial scale to be used shall be determined from the nominal thickness of the material as given in the following table:

Nominal Sheet Thickness, in.	Rockwell Superficial Scale	Major Load, kgf
0.0083 and less	15T	15
0.0215–0.0084	30T	30

**A2.3.2 Surface Finish**—The surface of the specimen in contact with the diamond spot anvil shall be flat, smooth, and free from dirt or surface irregularities. When necessary the surface shall be finished with fine emery paper. Unless otherwise agreed upon, the tin coating shall not be removed from the surface on which the indentation is made.

#### A2.4 Reports

**A2.4.1 Number of Tests**—The Rockwell scale value to be reported shall be the average of at least three impressions.

**A2.4.2 Conversion**—Hardness tests made on the 15T scale may be converted to the 30T scale by the use of Table A2.1. It is recognized that such conversions are for convenience in reporting and that conversion, particularly from tests on thin and soft materials, is not an accurate process.

**TABLE A2.1 Conversion Table (Approximation) Rockwell Hardness Testing**

HR 30T	HR 15T	HR 30T	HR 15T
82.0	93.0	65.0	84.0
81.5	92.5	64.0	...
81.0	...	63.5	83.5
80.5	92.0	62.5	83.0
80.0	...	62.0	...
79.0	91.5	61.5	82.5
78.5	...	60.5	82.0
78.0	91.0	60.0	...
77.5	90.5	59.5	81.5
77.0	...	58.5	81.0
76.0	90.0	58.0	...
75.5	89.5	57.0	80.5
75.0	...	56.5	...
74.5	89.0	56.0	80.0
74.0	88.5	55.0	79.5
73.5	...	54.5	...
73.0	88.0	54.0	79.0
72.0	87.5	53.0	78.5
71.5	...	52.5	...
71.0	87.0	51.5	78.0
70.0	86.5	51.0	77.5
69.5	...	50.5	...
69.0	86.0	49.5	77.0
68.0	85.5	49.0	76.5
67.5	...	48.5	...
67.0	85.0	47.5	76.0
66.0	...	47.0	75.5
65.5	84.5	46.0	...

### A3. METHOD FOR DETERMINATION OF PICKLE LAG ON STEEL FOR ELECTROLYTIC TIN PLATE

#### INTRODUCTION

It is not intended that variations in apparatus, sample preparation, or procedures from those described in this specification method be precluded. Suppliers or consumers may employ such variations for control purposes provided test results agree with results obtained by the standard method.

#### A3.1 Scope

A3.1.1 The rate of pickling test,<sup>9</sup> also called the pickle lag test, is one of four special property tests used to measure certain characteristics of electrolytic tin plate which affect internal corrosion resistance. The test is applicable to No. 50, No. 50/25, and heavier electrolytic tin plate (for K-plate, see 3.1.16.2 and J-plate, see 3.1.16.1). It is not applicable to No. 25 and lighter electrolytic tin plate.

#### A3.2 Summary of Method

A3.2.1 The time lag for a piece of steel to attain constant dissolution rate in acid under controlled conditions is determined. The change in pressure in a closed system caused by hydrogen evolution from the steel is continuously plotted on a chart through use of an electro-mechanical linkage and mercury manometer.

#### A3.3 Apparatus

A3.3.1 *Reaction Vessel*, consisting of a specially modified 125-mL Erlenmeyer flask. The flask shall have a 10-mm bore stopcock, glass sealed to the mouth and a small-diameter glass tube side arm sealed in the side just below the mouth of the original flask. The bottom of the flask shall be rounded out. A mercury switch shall be attached to the stop-cock plug with a metal band.

A3.3.2 *Constant-Temperature Water Bath*, large enough to accommodate the reaction vessel and maintain a temperature of  $90 \pm 0.5^\circ\text{C}$ .

A3.3.3 *Recording Mercury Manometer*, to measure the rate of increase in pressure in the vessel generated by hydrogen. Initial setup of the recorder is described in Section 10.

A3.3.4 A 15 by  $\frac{1}{8}$ -in. magnetized-steel rod for removal of test specimen. (A one-hole rubber stopper may be positioned near the upper end to prevent the bottom of the rod from striking the bottom of the reaction flask.)

A3.3.5 *Coordinate Paper*, 4 by 11 in., with either 10 or 20 gradations to the inch.

#### A3.4 Reagents and Materials

A3.4.1 *Purity of Reagents*—Reagent grade chemicals shall be used in all tests. Unless otherwise indicated, it is intended that all reagents shall conform to the specifications of the Committee on Analytical Reagents of the American Chemical

Society, where such specifications are available.<sup>10</sup> Other grades may be used, provided it is first ascertained that the reagent is of sufficiently high purity to permit its use without lessening the accuracy of the determination.

A3.4.2 *Purity of Water*— Unless otherwise indicated, references to water shall be understood to mean distilled water or water of equal purity.

A3.4.3 *For Rate of Pickling Test:*

A3.4.3.1 *Hydrochloric Acid (HCl)*, (6 N).

A3.4.4 *For Sample Preparation:*

A3.4.4.1 *Acetone*.

A3.4.4.2 *Antimony Trichloride Solution* (120 g/L)— Dissolve 120 g of antimony trichloride ( $\text{SbCl}_3$ ) in 1 L of concentrated HCl.

A3.4.4.3 *Sodium Carbonate Solution* ( $\text{Na}_2\text{CO}_3$ ) (0.5 %).

A3.4.4.4 *Sodium Hydroxide Solution* ( $\text{NaOH}$ ) (10 %).

A3.4.4.5 *Sodium Peroxide* ( $\text{Na}_2\text{O}_2$ ), granulated.

A3.4.5 *For Water Bath:*

A3.4.5.1 *Paraffin Oil*.

#### A3.5 Test Specimen Preparation

A3.5.1 *Test Specimen*— A piece of steel  $\frac{5}{16}$  by  $2\frac{1}{2}$  in. with the long dimension perpendicular to the rolling direction of the steel.

A3.5.1.1 Cut a piece of metal  $\frac{5}{16}$  by 4 in. or longer. The added length above the  $2\frac{1}{2}$  in. serves as a handle during preparation.

A3.5.1.2 Remove surface oil and grease by dipping the specimen in acetone and wiping with a cloth or paper towel.

A3.5.1.3 Cathodically clean the specimen in 0.5 % solution of  $\text{Na}_2\text{CO}_3$ , rinse in water, and dry.

A3.5.1.4 Detin the specimen by immersing in  $\text{SbCl}_3$ -HCl solution at room temperature. Allow the specimen to remain in solution 10 to 20 s after bubbling ceases.

A3.5.1.5 Remove the specimen, rinse in tap water, and wipe surface clean of antimony. (A wet cellulose sponge with a little non-ionic detergent has been found effective.)

A3.5.1.6 Immerse specimen in 10 % NaOH solution held at  $90^\circ\text{C}$  for approximately 1 min. During this time add granulated  $\text{Na}_2\text{O}_2$  slowly to keep solution bubbling freely. This treatment removes the last traces of antimony and any iron-tin alloy not removed during detinning. More than one specimen may be

<sup>9</sup> Willey, A. R., Krickl, J. L., and Hartwell, R. R., "Steel Surface Properties Affect Internal Corrosion Performance of Tin Plate Containers," *Corrosion*, Vol 12, No. 9, 1956, p. 433.

<sup>10</sup> *Reagent Chemicals, American Chemical Society Specifications*, American Chemical Society, Washington, DC. For suggestions on the testing of reagents not listed by the American Chemical Society, see *Analar Standards for Laboratory U.K. Chemicals*, BDH Ltd., Poole, Dorset, U.K., and the *United States Pharmacopeia and National Formulary*, U.S. Pharmacopeial Convention, Inc. (USPC), Rockville, MD.

treated at one time. A stainless steel beaker with specimens contacting the beaker appears to facilitate removal of the antimony and iron-tin alloy.

A3.5.1.7 Rinse specimen successively in tap water, distilled or deionized water and acetone. Alternatively rinse specimen in tap water and wipe dry with a clean towel.

A3.5.1.8 Trim specimen to  $\frac{5}{16}$  by  $2\frac{1}{2}$  in.

A3.5.1.9 Handle the specimen with forceps as touching with the fingers may produce erratic test results.

### A3.6 Procedure

A3.6.1 Bring the constant-temperature water bath to  $90 \pm 0.5^\circ\text{C}$ , making certain the 6 N HCl in the reaction vessel has also reached  $90^\circ\text{C}$ , if it has been freshly transferred.

A3.6.2 Start recorder and place the pen against the graph paper near the bottom.

A3.6.3 Drop the specimen into the reaction vessel and immediately close the stopcock. The mercury switch will start the recorder drum turning. The pressure generated by reaction of the acid on the specimen will cause the pen to rise.

A3.6.4 Allow approximately 2 to  $2\frac{1}{2}$  in. of vertical pen travel. Remove pen from paper and immediately open stopcock.

A3.6.5 Remove the specimen with a magnetized rod.

A3.6.6 Reposition the pen for the next determination and repeat the procedure.

A3.6.7 Change acid after every ten specimens.

### A3.7 Calculation

A3.7.1 Extrapolate the upper straight-line portion of the curve to the horizontal base line.

A3.7.2 Measure the time in seconds along the horizontal base line between the origin of the curve and the point where the extrapolation intersects the base line. This time in seconds is defined as the *pickle lag*. A typical curve is shown in Fig. A3.1.

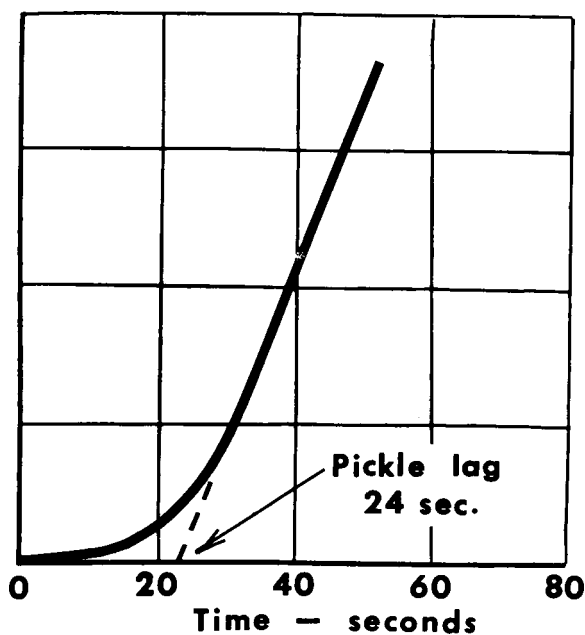


FIG. A3.1 Pickle Lag

### A3.8 Interferences

A3.8.1 Do not use rubber stoppers and tubing in contact with the acid. Some substance is extracted from the rubber which acts as an inhibitor and increases lag time.

A3.8.2 Headspace in the vessel affects the slope of the corrosion—time curve. The total volume of headspace in the reaction vessel between the liquid level and the plug of the stopcock should be approximately 40 mL including the volume of the side arm to the manometer. Lag time is not affected by small variation in headspace volume.

A3.8.3 It is essential that the system be gastight. A periodic test to check the system is recommended. Attach an aspirator bulb to the reaction vessel inlet. Raise pressure to about 2 in. Hg. Close the stopcock and start the recording drum and holding pressure in system. If the system is gastight, the recording pen will draw a straight horizontal line.

### A3.9 Assembly and Preparation of Apparatus

A3.9.1 It has been found convenient to alter the manometer (see A3.3.3) furnished with the equipment to avoid occasional problems of air entrapment in the mercury reservoir. The reservoir may be replaced with a stainless steel U-tube and connected to the two glass tubes with rubber tubing.

A3.9.2 Remove the front panel and the circular plate on top of the recorder (see A3.3.3) to install the mercury manometer. Make an electrical connection from the mercury reservoir or the stainless steel U-tube to the electrical relay. With the traveling rack about  $\frac{1}{4}$  in. from its bottom position insert the moving electrical contact in the manometer arm with the reservoir trap at top and attach it to the top of the rack. Add mercury to the trap to bring the level up to the bottom of the moving contact. Add a drop of 6 N HCl to the straight manometer arm to keep the wall clean. The arm should be cleaned or replaced when it becomes coated with mercury compounds.

A3.9.3 Connect the straight manometer arm to the reaction vessel with an 18-in. length of rubber or vinyl tubing,  $\frac{3}{16}$ -in. inside diameter.

A3.9.4 Connect the mercury switch in series with the motor drive for the recorder drum. The switch is adjusted so the motor turns on when the stopcock of the reaction vessel is in the closed position. The rack should oscillate vertically when the switch on the top of the recorder is turned to the *on* position.

A3.9.5 Add a layer of paraffin oil approximately  $\frac{1}{4}$  in. thick to the water bath in order to minimize evaporation.

A3.9.6 Mount the reaction vessel in the constant-temperature water bath using a corrosion-resistant buret holder so that the side arm is  $\frac{1}{2}$  in. below the level of the bath. Stopcock grease or equivalent is used to lubricate the stopcock which is firmly held in place by a  $\frac{1}{2}$ -in. wide rubber band or other means.

A3.9.7 Fill the reaction vessel with 6 N HCl to the stopcock. Remove enough acid to provide a constant headspace of 40 mL in the reaction vessel and side arm. This is readily accomplished by lowering a glass tube of convenient bore to a predetermined depth (the glass tube should be marked for this purpose) and connecting it to a water aspirator. Any acid in the



side arm should be expelled by squeezing the tubing connected to the side arm.

## A4. METHODS FOR TIN CRYSTAL SIZE TEST FOR ELECTROLYTIC TIN PLATE

### INTRODUCTION

The three methods described in this annex for estimating tin crystal size on electrolytic tin plate are typical of several possible methods to obtain the same result. Publication of these methods is not intended to preclude any other method that produces the same result.

#### A4.1 Scope

A4.1.1 The tin crystal size test is one of four special property tests used to measure certain characteristics of electrolytic tin plate which affect internal corrosion resistance. The test is applicable to No. 50, No. 50/25, and heavier electrolytic tin plate (for K-plate, see 3.1.16.2 and J-plate, see 3.1.16.1). It is not applicable to No. 25 and lighter electrolytic tin plate.

#### A4.2 Summary of Methods

A4.2.1 The surface of a piece of electrolytic tin plate is chemically etched or examined under polarized light to reveal the tin crystal pattern. The size of the tin crystals is estimated by comparison with ASTM macro-grain size number standards.

#### A4.3 Apparatus (Required Only for Method No. 3)

A4.3.1 *Polarized Light Source and Analyzer.*

#### A4.4 Reagents and Materials (Required Only for Method No. 1)

A4.4.1 *Purity of Reagents*—Reagent grade chemicals shall be used in all tests. Unless otherwise indicated, it is intended that all reagents shall conform to the specifications of the Committee on Analytical Reagents of the American Chemical Society, where such specifications are available.<sup>10</sup> Other grades may be used, provided it is first ascertained that the reagent is of sufficiently high purity to permit its use without lessening the accuracy of the determination.

A4.4.2 *Purity of Water*—Unless otherwise indicated, references to water shall be understood to mean distilled water or water of equal purity.

A4.4.2.1 *Cotton or Soft Cloth.*

A4.4.2.2 *Ferric Chloride* ( $\text{FeCl}_3 \cdot 6\text{H}_2\text{O}$ )—Chemically pure grade.

A4.4.2.3 *Hydrochloric Acid* (HCl) (1 N)—Chemically pure grade.

A4.4.2.4 *Sodium Sulfide* ( $\text{Na}_2\text{S} \cdot 9\text{H}_2\text{O}$ ) or *Sodium Bisulfate* ( $\text{NaHSO}_3 \cdot \text{H}_2\text{O}$ )—Chemically pure grade.

#### A4.5 Test Specimen

A4.5.1 The sample consists of any convenient size piece of fused electrolytic tin plate 4 in.<sup>2</sup> or larger.

#### A4.6 Procedure

A4.6.1 *Method No. 1*—Ferric chloride etch.

A4.6.1.1 Prepare etching solution by dissolving 100 g of  $\text{FeCl}_3 \cdot 6\text{H}_2\text{O}$  and 1 g of  $\text{Na}_2\text{S} \cdot 9\text{H}_2\text{O}$  or  $\text{NaHSO}_3 \cdot \text{H}_2\text{O}$  in 1000 mL of 1 N HCl. Solution is reusable but should be replaced when etching of specimen takes longer than 30 s.

A4.6.1.2 Buff surface of specimen vigorously but with light pressure with cotton or soft cloth. This disrupts the passive film and permits the etching solution to attack the tin readily.

A4.6.1.3 As an alternative to A4.6.1.2 and, if the equipment is available, cathodically clean specimen in 0.5 % sodium carbonate ( $\text{Na}_2\text{CO}_3$ ) solution for 30 s. Reversing the polarity of the current for 1 s near the beginning of the cleaning cycle assists in removal of the passive layer. Rinse in tap water.

A4.6.1.4 Immerse specimen in etching solution for 5 to 15 s or until a crystal pattern develops. Remove, rinse in tap water, and dry. (Do not allow the specimen to remain in the etching solution too long as complete detinning will occur.)

A4.6.1.5 Estimate the tin crystal size number by comparing the specimen with ASTM macro-grain size number standards. (See Test Methods E 112.) For routine testing, it is convenient to use a set of secondary standards consisting of actual tin plate specimens or photographs thereof at 1× magnification.

A4.6.2 *Method No. 2*—Iron solution value disk.

A4.6.2.1 Examine the specimen after completion of the ISV test (see Annex A5) as it will already be suitably etched.

A4.6.2.2 Estimate tin crystal size same as in Method No. 1.

A4.6.3 *Method No. 3*—Polarized light.

A4.6.3.1 This is a rapid nondestructive method.

A4.6.3.2 Place the specimen in a beam of polarized light so the beam strikes the surface obliquely.

A4.6.3.3 Examine the reflected light beam through an analyzer. Rotate the analyzer to obtain best definition of tin crystal pattern.

A4.6.3.4 Estimate tin crystal size same as in Method No. 1.

## A5. METHOD FOR DETERMINATION OF IRON SOLUTION VALUE ON ELECTROLYTIC TIN PLATE

### INTRODUCTION

It is not intended that variations in apparatus, sample preparation, or procedures from those described in this standard method be precluded. Suppliers or consumers may employ such variations for control purposes provided results agree with those obtained by the standard method.

#### A5.1 Scope

A5.1.1 The iron solution test,<sup>9</sup> also called the *ISV* test, is one of four special property tests used to measure certain characteristics of electrolytic tin plate which affect internal corrosion resistance. The test is applicable to No. 50, No. 50/25, and heavier electrolytic tin plate (for K-plate, see 3.1.16.2 and J-plate, see 3.1.16.1). It is not applicable to No. 25 and lighter electrolytic tin plate.

#### A5.2 Summary of Method

A5.2.1 The iron solution test involves the colorimetric determination of the total amount of iron dissolved when 3.14 in.<sup>2</sup> of tin plate surface area are exposed for 2 h at 80 ± 1°F to 50 mL of a mixture of dilute sulfuric acid (H<sub>2</sub>SO<sub>4</sub>), hydrogen peroxide (H<sub>2</sub>O<sub>2</sub>), and ammonium thiocyanate (NH<sub>4</sub>SCN). The amount of iron dissolved expressed as micrograms is arbitrarily called the *iron solution value (ISV)*.

#### A5.3 Apparatus

A5.3.1 *Cabinet, Room, or Other Means* of maintaining 80 ± 1°F during the test run.

A5.3.2 *Test Vessels*, round, tall-form, wide-mouth, 8-oz glass bottles with 63-mm diameter plastic caps.

A5.3.3 *Gaskets* made from 1/16-in. thick vinyl sheeting. Gaskets have 2-in. inside diameter (ID) and 2.42-in. outside diameter (OD).

A5.3.4 *Burets*—Two 25-mL automatic filling rapid dispensing burets.

A5.3.5 *Equipment for Cathodically Cleaning Test Specimens*—The power source should be capable of supplying 1 to 1½ A per test specimen (4-in.<sup>2</sup> disk). A stainless steel beaker or tank is recommended as the cleaning vessel as it may also serve as the anode.

A5.3.6 *Spectrophotometer and Cuvettes*.

#### A5.4 Reagents and Materials

A5.4.1 *Purity of Reagents*—Reagent grade chemicals shall be used in all tests. Unless otherwise indicated, it is intended that all reagents shall conform to the specifications of the Committee on Analytical Reagents of the American Chemical Society, where such specifications are available.<sup>10</sup> Other grades may be used, provided it is first ascertained that the reagent is of sufficiently high purity to permit its use without lessening the accuracy of the determination.

A5.4.2 *Purity of Water*—Unless otherwise indicated, references to water shall be understood to mean distilled water or water of equal purity.

A5.4.3 *For Cleaning Test Specimen:*

A5.4.3.1 *Acetone.*

A5.4.3.2 *Sodium Carbonate Solution* (Na<sub>2</sub>CO<sub>3</sub>) (0.5 %).

A5.4.4 *For Iron Solution Test:*

A5.4.4.1 *Ammonium Thiocyanate* (NH<sub>4</sub>SCN) *Solution (Iron-Free).*

A5.4.4.2 *Hydrogen Peroxide Solution* (H<sub>2</sub>O<sub>2</sub>) (30 %).

A5.4.4.3 *Sulfuric Acid* (H<sub>2</sub>SO<sub>4</sub>) (2.18 N).

A5.4.5 *For Calibration:*

A5.4.5.1 *Iron Wire, Analytical.*

A5.4.5.2 *Sulfuric Acid* (H<sub>2</sub>SO<sub>4</sub>) (10 N).

#### A5.5 Procedure

A5.5.1 *Test Solutions:*

A5.5.1.1 Prepare a 3 % solution of H<sub>2</sub>O<sub>2</sub> by dilution of the 30 % grade.

A5.5.1.2 Prepare acid-peroxide stock solution by mixing in following proportions: 23 mL of H<sub>2</sub>SO<sub>4</sub> (2.18 N) to 2 mL of H<sub>2</sub>O<sub>2</sub> (3 %). (This mixture remains stable for several weeks.) Connect acid-peroxide stock solution bottle to one of the 25-mL automatic filling rapid-dispensing burets.

A5.5.1.3 Prepare a stock solution of NH<sub>4</sub>SCN (40 g/L) and connect the stock bottle to the other buret.

A5.5.2 *Sample Preparation:*

A5.5.2.1 The specimen consists of a flat-circular piece of tin plate 2.257 ± 0.001 in. in diameter. This is equivalent to 4 in.<sup>2</sup> The specimen must be typical of the plate being tested and free of incidental deep scratches and surface conditions that are not representative of the tin plate under test.

A5.5.2.2 Cathodically clean the specimen in 0.5 % Na<sub>2</sub>CO<sub>3</sub> solution for 30 s. Near the beginning of the cleaning cycle reverse the polarity of the current for 1 s. This 1-s anodic flash assists in removal of the oxides on the surface.

A5.5.2.3 Rinse the specimen successively in tap water and distilled or deionized water. Dry in acetone vapors. Do not touch the test surface.

A5.5.3 *Iron Solution Test:*

A5.5.3.1 Place the cleaned specimen, test surface up, in the plastic cap. (Paper liner should previously have been removed. To facilitate seating of gasket, the last 1/16 in. of cap thread may be removed by machining on a lathe.)

A5.5.3.2 Place the vinyl gasket over the specimen, seating it so that the gasket lies flat and holds the specimen firmly in place.

A5.5.3.3 Add 25 mL of the H<sub>2</sub>SO<sub>4</sub>-H<sub>2</sub>O<sub>2</sub> stock solution and 25 mL of the NH<sub>4</sub>SCN solution to the test vessel. Swirl to assure thorough mixing.

A5.5.3.4 Affix the cap with specimen and gasket to the test vessel. Secure tightly. Invert the vessel immediately and let stand for 2 h at 80°F without agitation or vibration.

A5.5.3.5 Provide one extra test vessel for each run. Add 25 mL each of the two stock solutions, cover with a plastic cap, but do not invert. This mixture will act as a blank during the calculation of the iron solution value.

A5.5.3.6 After 2 h, swirl the liquid once, turn the vessel upright, and remove cap, gasket, and specimen immediately. Repeat for all test vessels in the run. Remove cap from the blank.

NOTE A5.1—**Caution:** A small amount of hydrogen cyanide gas may be liberated during test run. Be sure the vessels are opened in a well-ventilated room or preferably under a hood.

A5.5.3.7 Add 1 mL of 3 % H<sub>2</sub>O<sub>2</sub> to each test vessel including the blank. Add the peroxide just before transferring the liquid in each test vessel to the cuvette. (See A5.8.)

A5.5.3.8 Set the spectrophotometer at 485 nm. Zero the instrument by setting the scale for 100 % transmission on distilled or deionized water.

A5.5.3.9 Transfer a portion of the liquid to a cuvette and record the optical density or percent transmission, depending on the original calibration. If the instrument has been fitted with an *ISV* scale, read the *ISV* directly.

A5.5.3.10 Rinse the vessels successively with tap water and distilled or deionized water as soon after test as possible. Quick rinsing minimizes the buildup of a yellow sulfur deposit. Periodically the vessels should be cleaned with sulfuric acid-dichromate cleaning solution to remove the deposit.

A5.5.3.11 Soak gaskets for a few minutes in dilute H<sub>2</sub>SO<sub>4</sub>, rinse with distilled or deionized water and hang on a glass rod to dry. (Heating the H<sub>2</sub>SO<sub>4</sub> to around 150°F during the soaking of the gaskets assists in removal of any iron compounds and helps retain resiliency of the gaskets.)

### A5.6 Calibration

A5.6.1 The spectrophotometer and cuvettes should be calibrated with standard solutions containing known amounts of iron. A typical calibration might proceed as follows:

A5.6.1.1 Prepare standard iron solution by dissolving 0.100 g of iron wire in 100 mL of 10 *N* H<sub>2</sub>SO<sub>4</sub>. Dilute with distilled water to 1000 mL in a volumetric flask.

A5.6.1.2 Using aliquots, also prepare 10+1 and 100+1 dilutions of this solution. These three will give standard iron solutions containing 0.1, 0.01, and 0.001 mg Fe/mL, respectively.

A5.6.1.3 Mix 25 mL of the H<sub>2</sub>SO<sub>4</sub>-H<sub>2</sub>O<sub>2</sub> and 25 mL of the NH<sub>4</sub>SCN stock solutions as in A5.5.3.3. Add 1 mL of the standard iron solution containing 0.1 mg Fe/mL. Repeat using the 0.01 and 0.001 mg Fe/mL standard iron solutions. The three mixtures will give iron solution values (*ISV*) of 100, 10, and 1, respectively.

A5.6.1.4 Measure the optical densities at a wavelength of 485 nm in a spectrophotometer and plot these against the *ISV*'s. The *ISV* is directly proportional to optical density. A typical calibration curve using a spectrophotometer and 19 by 150-mm round cuvettes is shown in Fig. A5.1. A full logarithmic plot is used to enhance the definition at the low end of the *ISV* scale where most readings occur. Once the calibration is established the simplest procedure is to make and attach a scale to the spectrophotometer which reads directly in *ISV*.

### A5.7 Calculation

A5.7.1 If the spectrophotometer does not have an *ISV* scale, determine the *ISV* from the calibration curve for each sample including the blank.

A5.7.2 Subtract the blank *ISV* from each of the scale *ISV* readings or from the *ISV*'s obtained in A5.7.1. This is the true *ISV*.

### A5.8 Interferences

A5.8.1 *Leakers*—Sometimes leaks will occur. These are generally discovered when the vessels are opened at the end of the test. If a leak has occurred, a local spot of iron-tin alloy or bare steel will show near the edge of the specimen or etching may be seen on the reverse side of the disk, or both. Sometimes the leak will not affect the *ISV*; at other times it may cause an extremely high *ISV*. Any test showing a leak or other irregularity should be discarded and a retest made.

A5.8.2 Detinning or etching of the tin plate disk by any other cause than the normal exposure to the reagents may cause erroneously high results. Such detinning or etching could be caused by, (1) inadvertent too long anodic flash or too long exposure to Na<sub>2</sub>CO<sub>3</sub> in sample preparation (see A5.5.2.2), (2) agitation, swirling, or vibration of test vessel during 2-h test time, (3) leakers, and (4) rise in temperature.

A5.8.3 Fading of the red ferric thiocyanate complex color may occur due to decomposition of the complex by excess peroxide. Delay between the adding of the peroxide at the end of the test and the reading of the optical density should be avoided. Also care should be exercised not to add more than the 1 mL of peroxide.

### A5.9 Precision

A5.9.1 The principal source of error in reproducibility of test results is variation in the tin plate itself. Variation may occur across the rolling width and along different portions of the same coil of tin plate. Generally plate with low *ISV* has much less variation than plate with high *ISV*. Plate Lots B, D, E, and F as follows show the type of variation that can occur when replicates of a given plate lot with all specimens closely adjacent to each other are run at one time. Plate Lots A and C show the type of variation that can occur when replicates of a given plate lot are run singly in tests over a long period of time.

Plate Lot	Average	Iron Solution Values, mg Iron		Number of Samples
		Range	Standard Deviation	
A	4.4	2–8	1.6	56
B	9.4	8–19 <sup>A</sup>	1.9	36
C	34	19–55	7.2	47
D	36	25–42	5.8	8
E	87	72–95	6.5	8
F	97	74–120	14	8

<sup>A</sup>35 of 36 samples in range from 8 to 12.

A5.9.2 It is recommended that at least one specimen from a lot of plate with known *ISV* be included in each test run as a control. Preferably two controls should be used; one with low *ISV* (2–10) and one with a higher *ISV* (20–40).

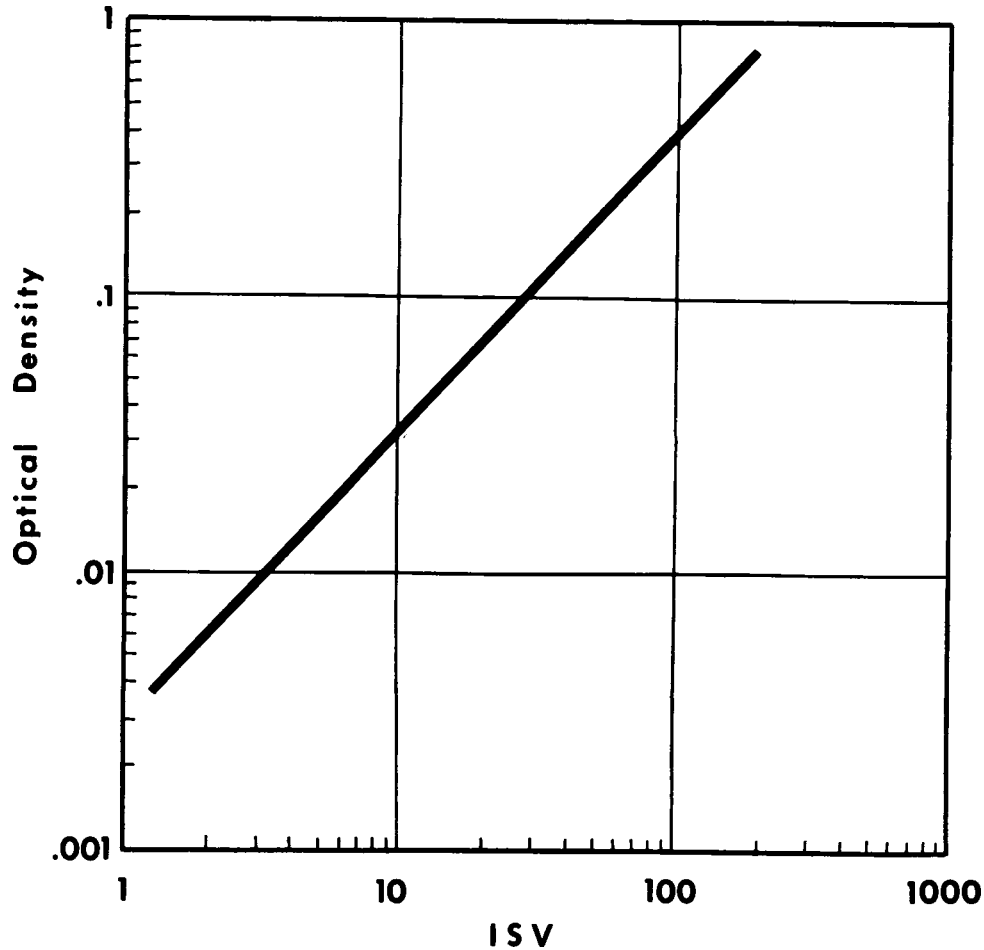


FIG. A5.1 Typical Iron Solution Value Calibration Curve

## A6. METHOD FOR ALLOY-TIN COUPLE TEST FOR ELECTROLYTIC TIN PLATE

### INTRODUCTION

The method described in this specification for conducting the alloy-tin couple test is one of several possible methods to obtain the same test result. It is not intended that other methods or variants of this method be precluded. Variation in apparatus, reagents, test media, and procedure from those specified may be employed for control purposes by the consumer or the supplier provided satisfactory results are obtained which correlate with the specified method.

#### A6.1 Scope

A6.1.1 The alloy-tin couple test,<sup>11</sup> also called the *ATC* test, is one of four special property tests used to measure certain characteristics of electrolytic tin plate which affect internal corrosion resistance. The test is applicable to No. 50, No. 50/25, and heavier electrolytic tin plate (for K-plate, see 3.1.16.2). It is not applicable to No. 25 and lighter electrolytic tin plate.

<sup>11</sup> Kamm, G. G., Willey, A. R., Beese, R. E., and Krickl, J. L., "Corrosion Resistance of Electrolytic Tin Plate, Part 2, The Alloy-Tin Couple Test—A New Research Tool", *Corrosion*, Vol 17, 1961, p. 84.

#### A6.2 Summary of Method

A6.2.1 The *ATC* test is an electrochemical procedure which involves measuring the current flowing between a pure tin electrode and an electrode consisting of a piece of tin plate from which the free (unalloyed) tin has been removed to expose the iron-tin alloy. The measurement is made after 20-h exposure of the electrodes in a medium consisting essentially of deaerated aged grapefruit juice.

#### A6.3 Apparatus

A6.3.1 *Constant-Temperature Cabinet or Room* ( $80 \pm 1^\circ\text{F}$ ).

A6.3.2 Test Cell (Fig. A6.1):

A6.3.2.1 Borosilicate Glass Test Cell, approximately 1-mL capacity.

A6.3.2.2 Polymethylmethacrylate Plastic Cover for test cell approximately 1/2 in. thick drilled with 5/8-in. diameter holes to accommodate cell elements.

A6.3.2.3 Polychloroprene or Similar Synthetic Rubber O-Ring Gasket to effect seal between glass vessel and plastic cover or equivalent method to effect gas-tight seal.

A6.3.2.4 Silicone Rubber 1/4 -in. Thick Grommets to act as gas-tight holders for cell elements inserted through the plastic cover.

A6.3.3 Magnetic Stirrer.

A6.3.4 Low-Resistance, High-Sensitivity Galvanometer.

A6.3.5 Potentiometer to measure the tin electrode potential. Any high-impedance voltage-measuring device such as a pH meter with a 0 to 1300-mV scale is satisfactory.

A6.3.6 Calomel Reference Electrode (Either saturated or 0.1 N is satisfactory).

A6.3.7 Power Source capable of supplying variable d-c voltage for use in sample preparation (cathodic cleaning 10-V dc and tin stripping 0.4-V dc reducible to 0.2 V).

A6.3.8 Various Electrical Components such as plugs, jacks, switches, and resistors to permit construction of circuit depicted in schematic diagram (Fig. A6.2).

A6.3.9 (Optional) Special Die for applying microcrystalline wax to mask off known areas on test specimen.

A6.4 Reagents and Materials

A6.4.1 Purity of Reagents—Reagent grade chemicals shall be used in all tests. Unless otherwise indicated, it is intended that all reagents shall conform to the specifications of the Committee on Analytical Reagents of the American Chemical Society, where such specifications are available.<sup>10</sup> Other grades may be used, provided it is first ascertained that the reagent is of sufficiently high purity to permit its use without lessening the accuracy of the determination.

A6.4.2 Purity of Water—Unless otherwise indicated, references to water shall be understood to mean distilled water or water of equal purity.

A6.4.3 Test Medium:

A6.4.3.1 Distilled Water or Deionized Water of equal purity.

A6.4.3.2 Ethanol, Denatured (70 % volume).

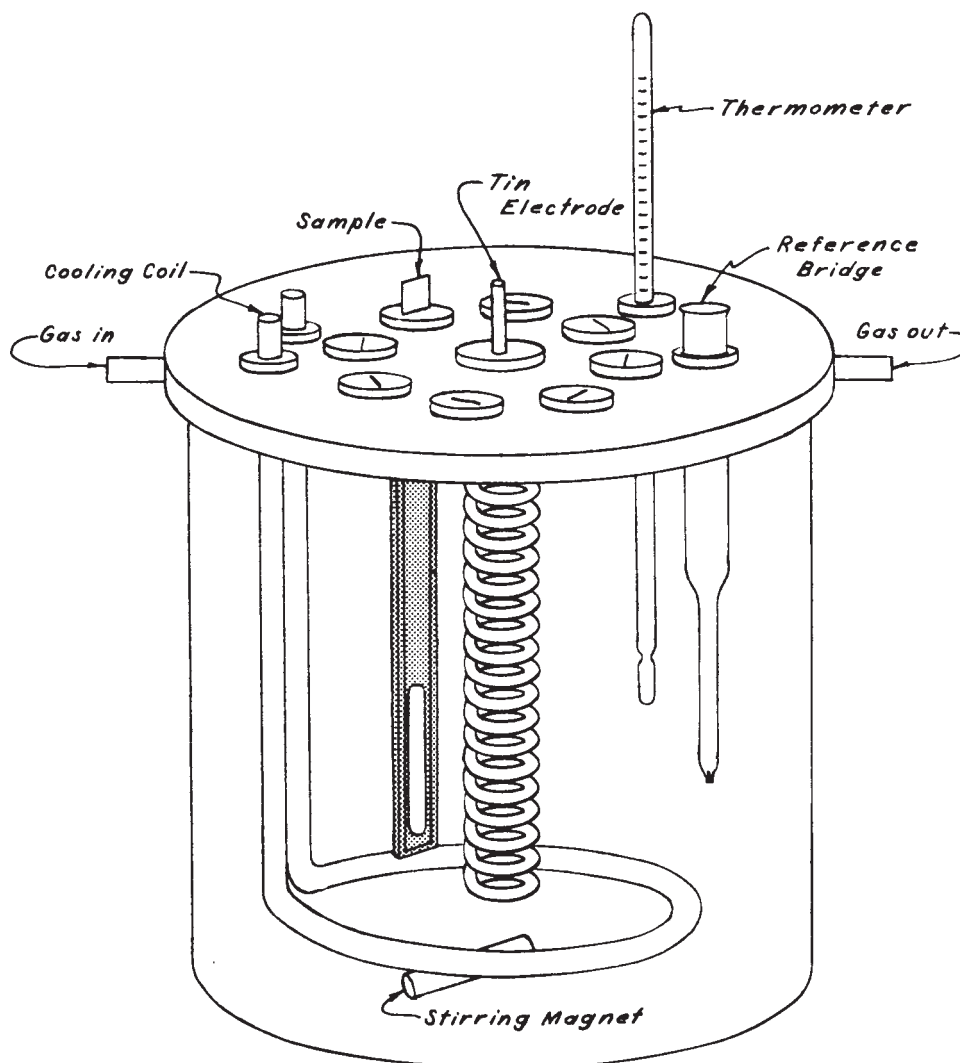


FIG. A6.1 Test Cell Used in the ATC Test

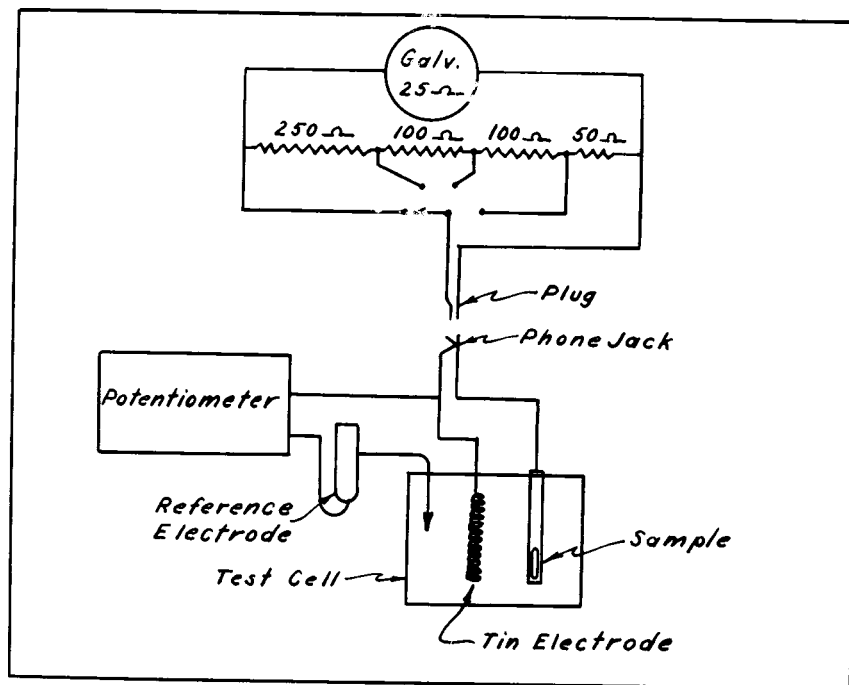


FIG. A6.2 Schematic Diagram of ATC Test Circuit

A6.4.3.3 *Frozen Concentrated Grapefruit Juice.*

A6.4.3.4 *Nitrogen Gas (High-Purity Oxygen-Free Dry Tank Nitrogen).*

A6.4.3.5 *Potassium Sorbate.*

A6.4.3.6 *Pure Tin Wire* (approximately 1/8-in. diameter).

A6.4.3.7 *Sodium Hydroxide Solution* (NaOH) (10 %).

A6.4.3.8 *Stannous Chloride Solution* (SnCl<sub>2</sub>·2 H<sub>2</sub>O).

A6.4.4 *Sample Preparation:*

A6.4.4.1 *Acetone.*

A6.4.4.2 *Microcrystalline Wax* (140 to 145°F melting point).

A6.4.4.3 *Polymethylmethacrylate Plastic Strips* (1/16 by 3/16 by 3/4 in.).

A6.4.4.4 *Sodium Carbonate Solution* (Na<sub>2</sub>CO<sub>3</sub>) (0.5 %).

A6.4.4.5 *Sodium Hydroxide Solution* (NaOH) (5 %).

## A6.5 Test Specimen

A6.5.1 The specimen consists of a piece of tin plate cut 1/2 by 4 1/2 in. with the long dimension transverse to the rolling direction.

A6.5.2 Eight test specimens can be accommodated at one time in the apparatus described above. Only the number of specimens to be included in one run should be prepared at one time.

A6.5.3 Details of sample preparation are given in A6.7.

## A6.6 Preparation of Apparatus (Fig. A6.1)

A6.6.1 Drill 5/8-in. diameter holes in 1/2-in. thick plastic cover to accommodate eight test specimens, the pure tin anode, a thermometer, and cooling coil. The reference electrode bridge can be inserted through one of the test specimen openings during potential measurement. Drill smaller diameter holes into the cover to accommodate gas inlet and outlet tubes.

A6.6.2 Cut stoppers or grommets from 1/4-in. thick silicone rubber to fit snugly in 5/8-in. diameter openings. Cut holes or slits in stoppers and grommets to hold various cell elements. Boil all rubber parts including O-ring gasket in 10 % NaOH solution for 5 min and rinse thoroughly before use in distilled or deionized water.

A6.6.3 Thoroughly clean test cell and its components and finally rinse them in ethanol just prior to use to guard against mold and yeast growth in test medium.

A6.6.4 Fit silicone rubber parts, cooling coil, thermometer, and gas tubes into the cover. Do not insert pure tin anode or test specimens at this time.

A6.6.5 Form 1/8-in. diameter pure tin wire into a loosely wound coil to give a total surface area of approximately 100 cm<sup>2</sup>. Cathodically clean in 0.5 % Na<sub>2</sub>CO<sub>3</sub> solution, rinse in tap water and in acetone.

## A6.7 Procedure

A6.7.1 *Test Medium:*

A6.7.1.1 Place a polytetrafluoroethylene-covered magnetic stirring bar in the bottom of the test cell.

A6.7.1.2 In a separate vessel, dilute frozen concentrated grapefruit juice 3+1 with distilled or deionized water, add preservative potassium sorbate to give concentration of 0.5 g/L, deaerate by heating to boiling, and transfer to the test cell and age for not less than two days. Leave approximately 1/4-in. headspace. Turn on the magnetic stirrer.

A6.7.1.3 Assemble the plastic cover to the test cell with an O-ring or by other leak-proof seal. Begin the flow of nitrogen through the headspace. Bubble nitrogen through distilled or deionized water before entering the test cell in order to minimize evaporation of test medium. Maintain a slight positive pressure in the cell during actual test run by bubbling

nitrogen from the gas outlet tube through 1 or 2 in. of water or ½ in. of dibutyl phthalate.

A6.7.1.4 Allow the transferred hot juice to cool for 5 min; then start cold water through the cooling coil. This minimizes settling of the pulp. Continue cooling until the test medium reaches 80°F.

A6.7.1.5 Insert the cleaned pure tin anode into the test cell.

A6.7.1.6 Add  $\text{SnCl}_2 \cdot 2\text{H}_2\text{O}$  to produce a concentration of 0.190 g/L. This yields a  $\text{Sn}^{++}$  concentration of 100 ppm. Continue stirring for 5 or 10 min to make sure the  $\text{SnCl}_2 \cdot 2\text{H}_2\text{O}$  has been dissolved.

A6.7.1.7 Discontinue stirring.

A6.7.1.8 Measure the potential of the tin electrode with a high-impedance device such as a pH meter, using calomel reference electrode. The potential of the tin anode should be  $-615$  mV against a saturated calomel electrode or  $-705$  mV against a 0.1 N calomel electrode.

A6.7.2 *Test Specimen:*

A6.7.2.1 Degrease the specimen in acetone and allow to dry.

A6.7.2.2 Clean the specimen cathodically in 0.5 %  $\text{Na}_2\text{CO}_3$  solution (carbon anode) using a current density of approximately 25 mA/cm<sup>2</sup>. A 10-V d-c power source with a polarity reversing switch and the following sequence of test specimen polarity is suggested: 2 s cathodic, 0.1 s anodic, 2 s cathodic, 0.1 s anodic, 2 s cathodic. The two short anodic flash treatments enhance the ability of the cathodic treatments to remove oxides and impurities from the surface and secure absence of water break on the test specimen. Rinse the specimen in tap water, distilled water, and acetone and allow to dry.

A6.7.2.3 Detin the specimen electrolytically in a 5 % NaOH solution at room temperature. The specimen is the anode and a piece of stainless steel is the cathode. The area of the stainless steel cathode should be 5 to 10 times as large as the area being detinned in order to give a high anode current density and hence rapid detinning. Carry out the detinning at a constant 0.40-V dc maximum (in this method a 0.1-Ω resistor is placed in parallel with the detinning circuit to assure constant voltage). As detinning nears completion, it is possible a small area or a few isolated spots will be slow to detin. Reducing the voltage to 0.20 V speeds up the detinning of these last few spots. For convenience, detin several specimens simultaneously all connected in parallel to the power source. When this is done it is usually necessary to reduce the voltage to 0.20 V only for the last sample remaining in the detinning set up. Remove the specimen from the detinning solution with the power on to prevent reversal of the current and replating of tin as a result of the primary cell effect. Do not leave the detinned specimen in the detinning bath longer than 5 min. The electrolyte and the detinning procedure have been so chosen to remove completely all the free (unalloyed) tin and to prevent any attack whatever on the iron-tin alloy layer. Rinse specimen sequentially in tap water, distilled water, and acetone and allow to dry.

A6.7.2.4 Mask the specimen with hot microcrystalline wax to expose a given test area. This may be done by hand brushing

or by mechanical means provided the test surface is not damaged or contaminated in the process. Area variations between 0.5 and 4.0 cm<sup>2</sup> do not affect the *ATC* measurement. It is strongly recommended that an area of 2.3 cm<sup>2</sup> be used in the test. A die that produces an outline of wax exposing 2.3 cm<sup>2</sup> is available (A6.3.9). After the test area has been outlined, manually wax the specimen to a thin plastic backing (A6.4.4.3) making certain all edges and surfaces other than the test area are covered.

A6.7.3 *Current Measurement:*

A6.7.3.1 Connect the test specimen to the tin anode electrically before inserting the specimen in the test cell to assure continuous galvanic protection of the alloy surface (for the same reason, refer to Fig. A6.2 and note that the phone jacks are the *shorting* type). All test specimens are coupled to the single tin anode.

A6.7.3.2 After 20 h, measure the current flowing between the tin anode and each individual specimen with a low-resistance, high-sensitivity galvanometer (A6.3.4). The test cell must be free from vibration during the time the specimens are in the cell.

A6.7.3.3 Include at least one test specimen with known *ATC* value in each run in each cell to act as a control for that run. Preferably two controls should be used: one with a known low *ATC* value and one with a known high *ATC* value.

A6.7.3.4 Use a given batch of aged juice for repeated test runs for a period of about 3 to 4 weeks. Make a fresh batch sooner if there are signs of mold growth or fermentation.

## A6.8 Calculations

A6.8.1 Divide the current flowing between the electrodes by the area of the exposed alloy on the test specimen measured in square centimetres. Report the *ATC* in microamperes per square centimetre.

## A6.9 Hazards

A6.9.1 It is important to maintain oxygen-free conditions in the cell. During insertion and removal of the test specimen in the cell increase the nitrogen flow somewhat to prevent entry of air. Air causes increased *ATC* values and reduces differences between good and poor plate.

A6.9.2 Take care to avoid vibration during the test run. Do not bump or disturb the electrodes before taking current measurements.

A6.9.3 Different batches of juice will vary slightly in corrosivity or pH or both. This could affect the potential of the tin anode. Regardless of the original potential in a given batch of juice, the addition of 100 ppm  $\text{Sn}^{++}$  shifts the potential approximately 50 mV in the cathodic (positive) direction.

A6.9.4 Temperature of microcrystalline wax during masking should be sufficiently high to assure good adhesion to the test specimen but not so high as to run and distort the test area.

A6.9.5 Reliable *ATC* data depend to a large extent on proper test specimen preparation. Once preparation has begun the test area should not be touched, scratched, or otherwise contaminated in any way.

## A7. METHODS FOR DETERMINATION OF TOTAL SURFACE OIL ON TIN MILL PRODUCTS

### A7.1 Scope

A7.1.1 This method covers the determination of the total extracted oil on the surface of tin mill products.

### A7.2 Summary of Methods

A7.2.1 The oil on the surface of the strips of plate is removed with boiling chloroform or equivalent. The chloroform or equivalent is evaporated to dryness and the residue is weighed.

### A7.3 Significance and Use

A7.3.1 The amount of surface lubricating oil on the surfaces of tin mill products is critical and can be cause for users complaint. Insufficient lubricant can contribute to poor sheet mobility and poor lithography; excessive lubricant can contribute to eyeholing or dewetting of certain organic coatings.

### A7.4 Apparatus

A7.4.1 *Slotted Mandrel* with handle for coiling the strips.

A7.4.1.1 A ½-in. diameter slotted mandrel is used for high-temper materials and a 1-in. diameter slotted mandrel is used for low-temper plate.

### A7.5 Reagents and Materials

A7.5.1 *Chloroform* (CHCl<sub>3</sub>), distilled reagent grade or equivalent.

### A7.6 Hazards

A7.6.1 **Warning**—Chloroform vapors present a potential health hazard. The cleaning of equipment, extraction, and evaporation of the chloroform should be done in an exhaust hood.

### A7.7 Test Specimen

A7.7.1 The samples are generally sheets of plate such as used for can making. The sample sheets should be transported between two protection sheets and the edges covered with masking or equivalent tape. The four edges of the test sheets should be trimmed to remove possible contaminant of the tape adhesive.

### A7.8 Preparation of Apparatus

A7.8.1 Clean the shears for cutting the plate into strips, coiling mandrel, pliers, and forceps with chloroform or equivalent.

A7.8.2 The glassware must be rinsed with boiling chloroform or equivalent.

A7.8.3 Wear clean white cloth gloves when handling plate.

### A7.9 Procedure

A7.9.1 Cut the sample of plate at least 500 in.<sup>2</sup>(preferably 1000 in.<sup>2</sup>) into 2-in. wide strips.

A7.9.2 Determine the exact area of plate (length by width by number of strips).

A7.9.3 Coil strips using the coiling mandrel by holding one end of the strip with pliers. Insert the other end in the slot of the mandrel. Coil the strips around the mandrel tightly using the pliers to maintain tension.

A7.9.4 Heat two 250-mL beakers of chloroform or equivalent to boiling. Using forceps dip the coils 4 or 5 times in one beaker and then rinse similarly in the second beaker. After all the coils have been extracted, filter the chloroform or equivalent, while hot, through filter paper into a 500-mL Erlenmeyer flask. Boil off the chloroform or equivalent to a volume of approximately 10 mL. Transfer this to a previously cleaned, dried, and weighed 10-mL beaker. While the chloroform or equivalent is boiling from the small beaker, rinse the Erlenmeyer flask two or three times with small portions of chloroform or equivalent and add each rinsing to the 10-mL beaker. When nearly all the chloroform or equivalent has evaporated from the 10-mL beaker, place the beaker in an oven at 105°C for 10 min, cool in a desiccator, and reweigh. Make a blank determination using a similar volume of chloroform or equivalent. The blank should not exceed 0.0002 g.

### A7.10 Calculations

A7.10.1 Calculate the weight of oil per base box as follows:

$$\text{weight of oil per base box, g} = (W \times 31\,360) / A$$

where:

W = weight of oil, g,  
 A = area of sample, in.<sup>2</sup> and  
 31 360 = area of base box, in.<sup>2</sup>

### A7.11 Precision and Bias

A7.11.1 Make all weighings to the nearest 0.0001 g.

## A8. DETERMINATION OF CHROMIUM ON TIN PLATE BY THE DIPHENYL CARBAZIDE METHOD

### A8.1 Scope

A8.1.1 This method<sup>12</sup> covers the determination of chromium on tin plate with the use of diphenylcarbazide.

### A8.2 Reagents and Materials

A8.2.1 *Purity of Reagents*—Reagent grade chemicals shall be used in all tests. Unless otherwise indicated, it is intended that all reagents shall conform to the specifications of the Committee on Analytical Reagents of the American Chemical Society, where such specifications are available.<sup>10</sup> Other grades may be used, provided it is first ascertained that the reagent is

<sup>12</sup> Furman, N. H., "Chromium in Acid Solution with Diphenylcarbazide," *Scott's Standard Methods of Chemical Analysis*, Vol 1, 1962, pp. 357–359.



of sufficiently high purity to permit its use without lessening the accuracy of the determination.

**A8.2.2 Purity of Water**—Unless otherwise indicated, references to water shall be understood to mean distilled water or water of equal purity.

**A8.2.3 Chromate, Standard Solution A** (1 mL = 0.5 mg Cr) Dissolve 1.410 g of  $K_2Cr_2O_7$  in water and dilute to 1.0 L.

**A8.2.4 Chromate, Standard Solution B** (1 mL = 10.0  $\mu$ g Cr)—Pipet 20 mL of the chromate Standard Solution A into a 1.0-L volumetric flask and add water to 1.0 L.

**A8.2.5 Diphenylcarbazide Reagent**—Add 10.0 mL of acetone, 10.0 mL of 95 % ethyl alcohol, and 20.0 mL of  $H_3PO_4$  (85 % acid diluted with an equal volume of water).

**A8.2.6 Hydrochloric Acid (HCl)** (sp gr 1.19).

**A8.2.7 Potassium Permanganate, Saturated Solution** ( $KMnO_4$ ).

**A8.2.8 Sodium Hydroxide (1.0 N)**—Trisodium Phosphate (5 %) Solution—Dissolve 40.0 g of NaOH and 50.0 g of  $Na_3PO_4$  in water and dilute to 1.0 L.

**A8.2.9 Sulfuric Acid (1+3)**—Add 100 mL of  $H_2SO_4$  (sp gr 1.84) slowly and with stirring to 300 mL of water.

### A8.3 Procedure

**A8.3.1** Use for analysis a sample having 8.0 in.<sup>2</sup> of surface area (one 4-in.<sup>2</sup> disk). If both sides of the sample are to be stripped, slightly bend the disk through the center so it will not lie entirely flat. If only one side of the sample is to be stripped, hold the disk tightly against a rubber stopper. The stopper should be slightly larger in diameter than the disk and grooved to allow vacuum from a tube in the center to be applied to most of the surface of the disk. Leave intact a band approximately 1/8 in. wide at the perimeter of the stopper.

**A8.3.2** Place the sample in a 250-mL beaker, add 25 mL of NaOH- $Na_3PO_4$  solution, and heat to boiling. Boil for 1 1/2 min. Transfer the solution to another 250-mL beaker, washing disk and beaker once with water. Add 25 mL of  $H_2SO_4$ (1+3) to the original beaker and sample, heat to boiling, and boil 1 min. Transfer the acid solution to the beaker containing the alkaline stripping solution, washing sample and beaker with two small portions of water. If both sides of the disk are being stripped, it is necessary to swirl the beaker continually over the flame while the  $H_2SO_4$  is boiling. This is necessary to keep the

surface completely wetted and strip all of the chromium from the surface of the tin plate.

**A8.3.3** Heat the sample solution to boiling and add 1 to 2 drops of saturated  $KMnO_4$  solution. This amount is usually sufficient to maintain a pink color. Boil 3 to 4 min for complete oxidation of chrome. Add 5 drops of HCl (sp gr 1.19) to the sample and continue to boil until all pink color is dispelled. More acid may be used if needed. The beaker should be covered when boiling to avoid any loss that may be caused by spattering.

**A8.3.4** Transfer to a 100-mL volumetric flask and cool to approximately 70°F in a water bath. Add 3.0 mL of diphenylcarbazide reagent, make to mark with distilled water, and mix.

**A8.3.5** Determine optical density, within 30 min after the addition of diphenylcarbazide reagent to the sample, at 540 nm.

**A8.3.6** A reagent blank and a standard including all solutions used in treating a sample should be carried along with each set of samples.

### A8.4 Calibration of Spectrophotometer

**A8.4.1** Add to 250-mL beakers duplicate 0.5, 1.0, 1.5, 2.0, 2.5, and 3.0-mL aliquots of the chromate Standard Solution B and carry through the entire procedure for a sample. Also run reagent blanks in duplicate.

**A8.4.2** Calculate a constant, *K*, for the instrument as follows:

$$K = (\mu\text{g Cr})/(\text{O.D.}_1 - \text{O.D.}_2)$$

where:

O.D.<sub>1</sub> = optical density for the standard, and  
O.D.<sub>2</sub> = optical density for the blank.

### A8.5 Calculation of Chromium on Tin Plate

**A8.5.1** Report chromium on tin plate as micrograms of chromium per square foot of surface area, as follows:

$$\text{Cr, } \mu\text{g/ft}^2 = [144 K (\text{O.D.}_1 - \text{O.D.}_2)]/A$$

where:

*K* = constant for spectrophotometer and cell used to determine optical density,  
O.D.<sub>1</sub> = optical density of sample,  
O.D.<sub>2</sub> = optical density of reagent blank, and  
*A* = area of sample used.

## A9. METHOD FOR AERATED MEDIA POLARIZATION TEST FOR ELECTROLYTIC TIN PLATE

### INTRODUCTION

The Aerated Media Polarization (AMP) test was originally developed at Weirton Steel Corporation by James A. Bray and J. Robert Smith (see U.S. Patent No. 3,479,256) as a quick, accurate replacement for the Alloy Tin Couple (ATC) test developed by G. Kamm at American Can Company. The AMP test results are obtained in a few minutes as compared to a minimum 20 h for ATC results. This has proven invaluable to tinfoil producers who then can make adjustments during actual production.

**A9.1 Scope**

A9.1.1 The AMP test is one of four special property tests used to measure certain characteristics of electrolytic tin plate which affects internal corrosion resistance. The test is applicable to No. 50 (5.6), No. 50/25 (5.6/2.8), and heavier electrolytic tin plate, used for K-plate (for K-Plate see 3.1.16.2).

**A9.2 Summary of Method**

A9.2.1 This test is an electrochemical procedure that involves measuring the current flowing between a pure tin electrode and an electrode consisting of a piece of tin plate from which the free (unalloyed) tin has been removed to expose the iron-tin alloy. Both electrodes are immersed in grapefruit juice concentrate (GFJ) or its equivalent.

**A9.3 Apparatus**

- A9.3.1 *Test Cell* (see Fig. A9.1).
- A9.3.2 *AMP Analyzer* (see Fig. A9.2).
- A9.3.3 *d-c Power Supply*, capable of supplying 3 to 4 A at 10 to 12 V and a means of reversing polarity.
- A9.3.4 *Three Laboratory Hot Plates*.
- A9.3.5 *Crystallizing Dish*, 5.9-in. diameter, 2.9-in. depth.
- A9.3.6 *Watch Glass*, 4.5-in. diameter.
- A9.3.7 *Two 3.4-oz Beakers*—low form.
- A9.3.8 *Two Watch Glasses*, for the 13.5-oz beakers.
- A9.3.9 *Three 13.5-oz Beakers*—tall form without pouring spout.
- A9.3.10 *Timer or Stopwatch*, capable of reading to the nearest second.
- A9.3.11 *13.5-oz Beaker*, stainless steel.
- A9.3.12 *Levelling Funnel*.
- A9.3.13 *0.875-in. Inside Diameter O-Ring*—0.60 in.<sup>2</sup>

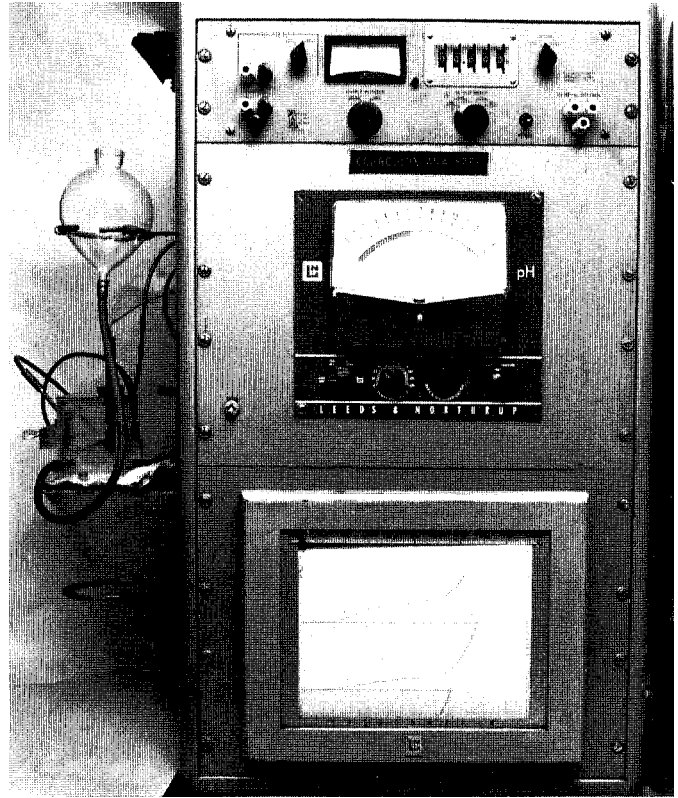


FIG. A9.2 Corrosion Analyzer (AMP)

**A9.4 Reagents and Materials**

A9.4.1 *Purity of Reagents*—Reagent grade chemicals shall be used in all tests. Unless otherwise indicated, it is intended that all reagents shall conform to the specifications of the Committee on Analytical Reagents of the American Chemical

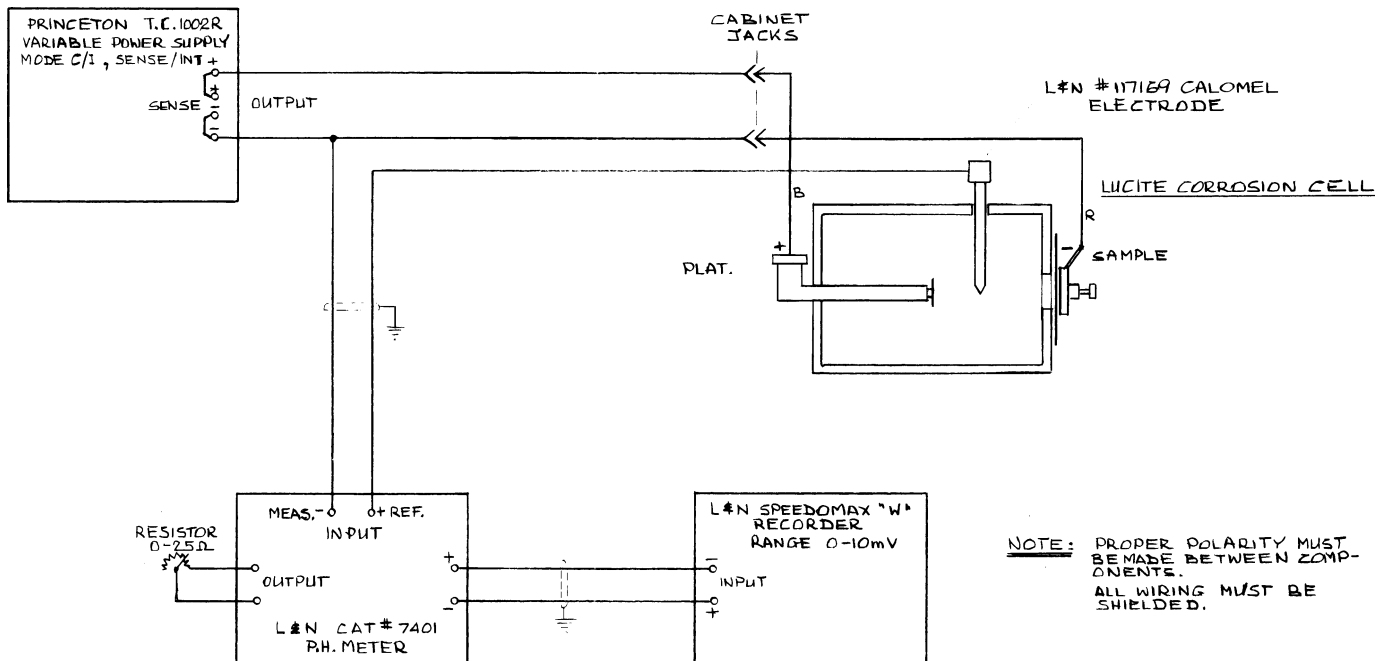


FIG. A9.1 Wiring Schematic for AMP Test

Society, where such specifications are available.<sup>10</sup> Other grades may be used, provided it is first ascertained that the reagent is of sufficiently high purity to permit its use without lessening the accuracy of the determination.

A9.4.2 *Purity of Water*— Unless otherwise indicated, references to water shall be understood to mean distilled water or water of equal purity.

A9.4.3 *Anhydrous Acetone*.

A9.4.4 *Stripping Solution*:

A9.4.4.1 5.0 % (by weight) sodium hydroxide, NaOH, in distilled water.

A9.4.4.2 1.0 % (by weight) potassium iodate KIO<sub>3</sub> in distilled water.

A9.4.5 *0.5 M Citric Acid*—3.2 oz anhydrous citric acid per 14.5 oz of distilled water.

A9.4.6 *Potassium Sorbate*.

A9.4.7 *Frozen Sweetened Grapefruit Juice Concentrate (GFJ)*.

A9.4.8 *Equivalent to GFJ when dissolved in 7.25 oz of distilled water*:

A9.4.8.1 0.176 oz citric acid,

A9.4.8.2 0.088 oz sodium citrate,

A9.4.8.3 0.617 oz fructose,

A9.4.8.4 0.882 oz sucrose, or

A9.4.8.5 0.0088 oz potassium sorbate.

A9.4.8.6 Prepare fresh for each occasion of testing.

A9.4.9 *Cleaning Solution*—1% (by weight) sodium carbonate in 21.78 oz of distilled water.

## A9.5 Test Media

A9.5.1 Six-ounce size cans of grapefruit juice concentrate are thawed, opened, and diluted with 16.9 oz of distilled water per can. The resulting single strength GFJ is filtered under vacuum through silica sand to remove most of the pulpy material.

A9.5.2 To retard spoilage, 0.02 oz of potassium sorbate per can is added to the GFJ. It has been found convenient to prepare the GFJ in five can batches and keep it refrigerated until needed. The GFJ must be prepared at least 24 h prior to usage to allow it to stabilize.

A9.5.3 Enough GFJ to fill the cell, 13.5 oz, is brought to room temperature, 72 to 74°F, and poured into the levelling funnel.

A9.5.4 Under normal conditions, this 13.5-oz aliquot of juice will yield about 200 results before it need be discarded. Worn-out juice is indicated by a marked decrease offset, or both, in the slope of the standard curve.

## A9.6 Test Specimen

A9.6.1 Samples, 1½ in. wide by any convenient length, 5 to 10 in., are cut from the tin plate area to be tested. The sample identification is scribed across the top side (or heavy-coated side) of the test piece. The following procedure is recommended for cathodic cleaning to remove the oil film and chemical treatment films without opening pores in the free tin and alloy layers.

## A9.7 Sample Preparation

A9.7.1 In a 1 % solution of Na<sub>2</sub>CO<sub>3</sub> at room temperature, using mild steel anodes, make the sample cathodic for 3 s, then anodic for 3 s, and finally cathodic for 3 s. Current densities of 20 to 30 A/ft<sup>2</sup> are satisfactory. Rinse the sample thoroughly in distilled water, dip in hot acetone, and dry in air.

NOTE A9.1—The final current polarity *must be cathodic* for rapid removal of the free tin in subsequent steps.

A9.7.2 Two of the hot plates should be located near a sink where distilled (or deionized) water is plentiful. The third hot plate should be next to the AMP analyzer.

A9.7.3 The crystallizing dish, with the 4.5-in. watch glass placed in it, is filled to a depth of 1½ in. with stripping solution and placed on one of the two hot plates. The hot plate should be adjusted to maintain the solution at 105°F.

A9.7.4 The two 3.4-oz beakers and the 13.5-oz stainless steel beaker are placed on the second hot plate. Fill one of the 3.4-oz beakers with stripping solution to a depth slightly less than 1½ in. Fill the second 3.4-oz beaker with a 0.5 M citric acid solution to a depth of about 2 in. Fill the 13.5-oz beaker two thirds full of acetone. Adjust this hot plate so that the acetone almost boils.

A9.7.5 The remaining two 13.5-mL beakers are placed on the hot plate located adjacent to the analyzer. One should be two thirds full of acetone. The other is two thirds filled with water for rinsing samples following testing. The samples can then be dried and stored for possible retesting.

A9.7.6 Place a sample upright in the crystallizing dish of stripping solution allowing it to lean against the side of the dish. The submerged 4.5-in. watch glass prevents the sample from falling into the solution. When the last visible trace of free tin dissolves, immediately transfer the sample to the 3.4-oz beaker containing a second stripping solution. After 30 ± 5 s, remove the sample and rinse in running distilled water.

A9.7.7 Place the sample in the beaker containing citric acid. Swish around 4 to 5 times. Remove the sample and rinse very thoroughly in running distilled water. Dry the sample in the first beaker of hot acetone and transfer it to the second beaker of hot acetone. The sample is now ready for insertion into the cell.

## A9.8 Aerated Media Polarization Test

A9.8.1 The AMP analyzer settings should be as follows:

Mode Switch:	Position 1 (range card switch in recorder set to Position B)
Zero Adjust Pot:	200 mV (on upper scale)
Current Range:	0.5–5.0 mA
Polarizing Current:	0.800 mA

A9.8.2 Remove the sample from the acetone beaker and allow it to air dry.

A9.8.3 Place the detinned portion of the sample between the O-ring and the follower plate (heavy-coated side to be facing electrode). Tighten the follower just enough to prevent leakage around the O-ring.

NOTE A9.2—Overtightening will drastically reduce the life of the O-ring and may even cause it to be torn loose from the cell.

A9.8.4 Open the stopcock on the levelling funnel and allow the cell to fill with GFJ. (As the cell fills, it is a good technique to tip the cell slightly to preclude trapping air bubbles on the test area.)

A9.8.4.1 Turn the voltage switch on.

A9.8.4.2 Turn the chart switch on.

A9.8.4.3 As pen point reaches an accented line on the chart paper, turn the current switch on.

A9.8.4.4 After 90 s (3 in.) of chart travel read the end potential as chart divisions (to nearest tenth).

A9.8.4.5 Repeat A9.8.4.1 to A9.8.4.4, in reverse order, turning switches off to discontinue test.

A9.8.5 Lower the levelling funnel to drain the cell, loosen the follower plate, and remove sample. Dry the O-ring and follower plate to remove any droplets of GFJ which may have

spilled during removal of sample. (It has been found convenient to do this by folding 4 to 5 paper towels together and cutting them into 1½-in. widths. These can be inserted between the O-ring and the follower plate to effect the removal of any spillage.) The cell and analyzer are now ready for another test.

### **A9.9 Interpretation of Results**

A9.9.1 In any batch of samples to be run several standards, covering the range of ATC values from about 0.015 to 0.300  $\mu\text{a}/\text{cm}^2$ , are interspersed. The potential values (chart readings at 90 s) for these are plotted versus their known ATC values on 1.2 cycle ( $E_{90}$ ) by 2 cycle (ATC) log-log paper. The best straight line is then drawn through these points to obtain the standard curve (Fig. A9.3).

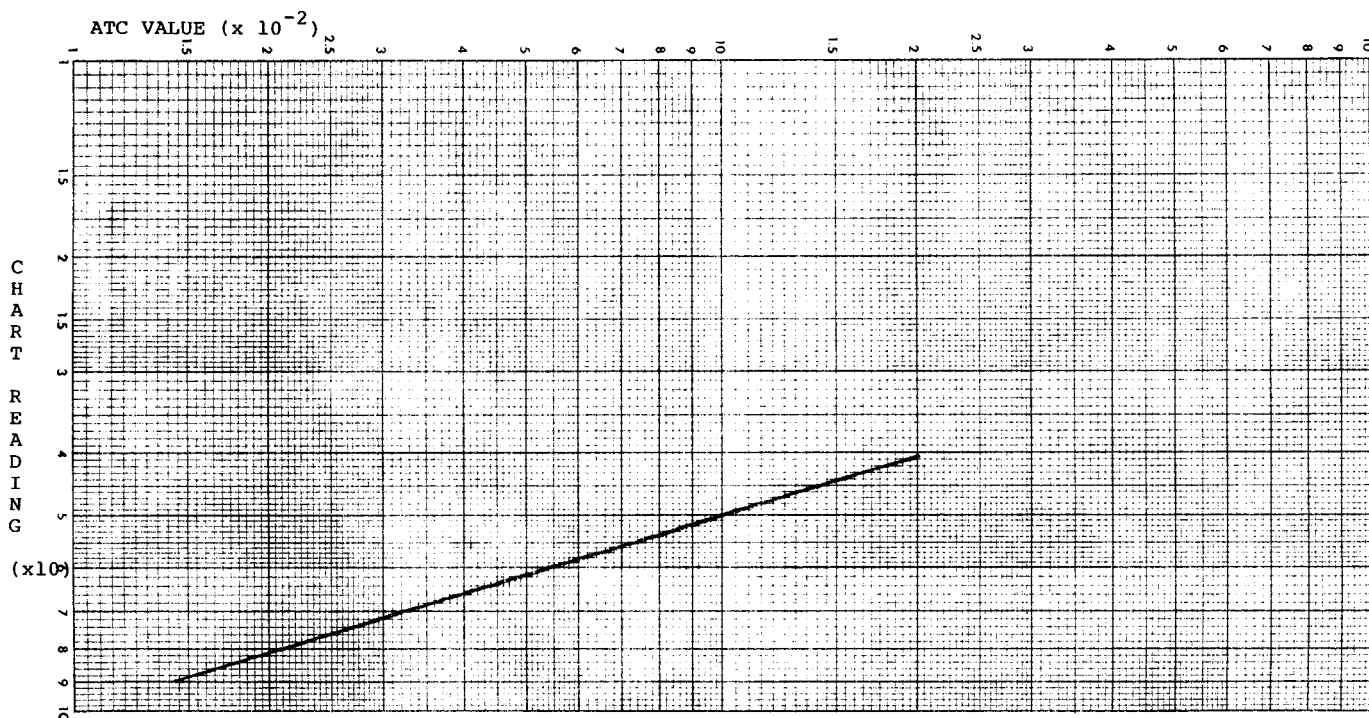


FIG. A9.3 ATC Conversion Chart from Typical Calibration Curve

**A10. DETERMINATION OF CHROMIUM ON TIN PLATE USING ATOMIC ABSORPTION**

**A10.1 Scope**

A10.1.1 The test method covers the determination of chromium on tin plate using atomic absorption.

**A10.2 Summary of Test Method**

A10.2.1 The chromium passivation level on the surface of tin plate is dissolved into, solution using concentrated hydrochloric acid. This solution is diluted to a specific volume and aspirated into an air acetylene flame. The absorbance at 357.9 nm is compared to the absorbance obtained from a series of standard chromium solutions, and the chromium present is calculated in milligrams per square foot.

**A10.3 Reagents and Materials**

A10.3.1 *Purity of Reagents*—Reagent grade chemicals shall be used in all tests. Unless otherwise indicated, it is intended that all reagents shall conform to the specifications of the Committee on Analytical Reagents of the American Chemical Society, where such specifications are available.<sup>10</sup> Other grades may be used, provided it is first ascertained that the reagent is of sufficiently high purity to permit its use without lessening the accuracy of the determination.

A10.3.2 *Purity of Water*—Deionized or distilled water having a volume resistivity of greater than 1 MΩ cm at 25°C as determined by Test Method B of Test Methods D 1125.

A10.3.3 *Hydrochloric Acid*—Mix 1 part HCl (specific gravity 1.19) to 1.25 parts water.

A10.3.4 *Standard Solution, Chromium*—Dissolve 0.2828 μg of dry, primary standard grade potassium dichromate

(K<sub>2</sub>Cr<sub>2</sub>O<sub>7</sub> in distilled water and dilute to 1000 mL in a volumetric flask. This solution contains 0.1 mg Cr/mL.

A10.3.5 *Standard Solution (Blank 1.0, 2.0, and 5.0 μg Cr/mL levels)*—Pipet into four 100-mL volumetric flasks, the following amounts of the chromium standard solution (A8.3.4): First Flask, no solution; Second flask, 1.0 mL; Third flask, 2.0 mL; and Fourth flask, 5.0 mL. Add 50 mL of 1:1.25 HCl Solution to each flask. Dilute each flask to 100 mL using distilled water.

**A10.4 Apparatus**

A10.4.1 *Atomic Absorption Spectrometer*

**A10.5 Procedure**

A10.5.1 Blank disk with a standard size of 4 in.<sup>2</sup>(if a one-sided test is required, spray one side with high-temperature acrylic lacquer), or equivalent.

A10.5.2 Clean the disk with acetone.

A10.5.3 Place the disk in a 500 mL beaker. Bend the sample slightly so that it does not rest flat on the bottom of the beaker.

A10.5.4 Fill the beaker with 50 mL of the required stripping solution.

A10.5.5 Strip at 180–200°F for 2 min. Allow to cool before testing.

A10.5.6 Analyze the solution in atomic absorption spectrophotometer.

**A10.6 Calculation**

A10.6.1 Calculate the amount of chromium present on the surface as follows:

$$C = A \times B \times \frac{144 \text{ in.}^2/\text{ft}^2}{D} \quad (\text{A10.1})$$

$B$  = dilution factor, mL  
 $C$  = chromium  $\mu\text{g}/\text{ft}^2$ , and  
 $D$  = area,  $\text{in.}^2$  of surface dissolved.

where:

$A$  = concentration of Cr,  $\mu\text{g}/\text{mL}$  from the chromium calibration curve,

## A11. METHOD FOR DETERMINING DRAWING TENDENCIES OF TIN MILL PRODUCTS USING A MODUL-R DEVICE

### A11.1 Scope

A11.1.1 This method is used to assess drawing tendencies of tin mill products. These tendencies commonly are termed R-bar (normal anisotropy) and  $\Delta r$  (planar anisotropy or earing) and are indicators of a metal's performance during operations, such as can drawing. This procedure provides a method for rapidly approximating the drawing tendencies of tin mill products.

A11.1.2 The drawing tendencies of tin mill products can be determined rapidly using a device called a Modul-R. This device has been used successfully for a material thickness as low as 55 lb/bb (0.0061 in.). The test can be performed on tin plate coatings as heavy as 0.25 lb/bb without removing the tin coating. If the tin coating weight exceeds 0.25 lb/bb, then the coating should be stripped chemically.

### A11.2 Terminology

A11.2.1 *Definitions of Terms Specific to This Standard:*

*Modul-R, n*—the device used to measure the resonating frequency of a steel strip sample. The resonating frequency is used to calculate drawing properties, such as R-bar and  $\Delta r$ .

*R-bar, n*—the unitless property of a material used to describe its ability to be drawn. It is a ratio of the average properties in the plane of the sheet to those in the thickness of the sheet. It is commonly referred to as “normal anisotropy.”

*$\Delta r, n$* —the unitless property of a material used to describe the variation of properties within the plane of a sheet of material. It also signifies the degree of earing during drawing. Negative values indicate earing will occur in a direction of  $45^\circ$  to the direction of rolling. Positive values indicate earing will occur in a directions along and perpendicular to the direction of rolling. A  $\Delta r$  value of 0 is ideal.  $\Delta r$  commonly is referred to as “planar anisotropy.”

### A11.3 Summary of Method

A11.3.1 Three rectangular coupons are blanked from a flat sheet of material such that they align with the rolling direction of the material, perpendicular to the rolling direction, and at a  $45^\circ$  angle to the rolling direction. These samples then are placed into a Modul-r testing device where they are vibrated to a resonant frequency. The resultant resonant frequencies are then converted to drawing properties. Minor corrections for surface roughness and thickness effects also are taken into account. The final results are reported as an R-bar value and a  $\Delta r$  value.

### A11.4 Apparatus

A11.4.1 Modul-R testing device (illustrated in Fig. A11.1), surface roughness measurement device, and a micrometer.

### A11.5 Sample Preparation

A11.5.1 Three test samples are blanked from a material to be evaluated. The three samples must be secured such that one is parallel to the rolling direction, one is perpendicular to the rolling direction, and one is at an angle of  $45^\circ$  to the rolling direction. The samples must be sheared to dimensions of 4.12 in. long and 0.250 in. wide. The 4.12-in. dimension allows for easy calculations later in the test method in A11.6.3.1. Any burrs should be removed with light sanding using a 400-grit paper. TFS coatings or tin plate coatings less than or equal to 0.25 lb/bb need not be removed.

### A11.6 Procedure

A11.6.1 *Surface Roughness and Thickness Determination*—The surface roughness of the material must be measured to the nearest microinch using a surface roughness measurement device. Thickness of the material also must be measured to the nearest 0.0001 in. using a micrometer.

A11.6.2 *Frequency Testing of Blanked Samples*—Frequency testing is performed in accordance with the instructions provided by the vendor of the Modul-R device. For convenience they are listed as follows:

A11.6.2.1 Place the sample in the slot marked *sample* on the right side of the panel. Move the sample into the slot until it has stopped within the holder.

A11.6.2.2 Pull the sample out from the holder just enough to relieve it from the stop. In this position, the sample should have about  $\frac{1}{4}$  in. protruding from the surface of the front panel.

A11.6.2.3 Place the bias switch in the positive (+) position.

A11.6.2.4 Place the normal/phase switch in the normal position.

A11.6.2.5 Push the test switch down and note the brightness of the amber indication light marked *oscillator*, and the reading on the counter. Within a few seconds the reading should stabilize between 23.5 and 26.5 kHz with the amber light glowing.

NOTE A11.1—If the amber light does not come on, comes on very dimly, or the reading is either high, low, or rapidly fluctuating, remove the sample and reposition it in the sample slot. Turn the sample around end to end or turn it over and again try to obtain a reading. If necessary, hold the test button and gently jog the sample in the sample slot. If no reading can be obtained, return the sample to its original position in the sample slot and move the bias switch to the negative (–) position. If the light still fails to come on, reposition the sample as described above. If up to this point normal oscillation will not take place, start again with the sample in the normal position and move the normal phase switch to the phase position and repeat above steps until a reading is obtained. If no reading can be obtained after all the above steps have been performed, a micrometer should be used to check the parallel sides of the sample. Readings should



FIG. A11.1 Modul-R Device

not vary by more than 0.001 in. Sample should not be bent, and all rough edges should be sanded smooth. In some instances when readings cannot be obtained from 45° samples, punching an additional sample from the sheeting at approximately 5° from the 45° position will provide a proper reading.

A11.6.2.6 Note the reading on the meter as soon as this occurs. Record it as f0 (frequency reading for sample punched parallel to the rolling direction), f90 (frequency reading for sample punched perpendicular to the rolling direction), and f45 (frequency of reading for sample punched 45° to the rolling direction).

A11.6.3 *Calculation of Drawing Properties*—R-bar values and Δr values can be calculated or obtained from tables. The first step in the process requires converting the frequency values determined above to modulus or E values. The E values are then adjusted based on surface roughness and thickness effects. The corrected E values then are converted to E-bar and ΔE values. The E-bar and ΔE values finally are converted to R-bar and Δr values.

A11.6.3.1 If the sample length as described in Section A11.4 is 4.12 in, then E values are determined from frequency values by using the following equation:

$$E = f^2/20 \quad (A11.1)$$

where:

- E = the modulus value, and
- f = the frequency obtained from step A11.6.2.

NOTE A11.2—The E obtained from the f0 value should be noted as E0, the E from the f45 value should be noted as E45, and the E from the f90 value should be noted as E90.

NOTE A11.3—If the sample length (described in Section A11.5) is different from 4.12 in., then E values must be obtained from the following equation:

$$E = 0.0029465 l^2 f^2 \quad (A11.2)$$

where:

- E = the modulus value,
- l = the length of the sample in inches (measured to the nearest 0.01 in., and
- f = the frequency obtained from step A11.6.2.

A11.6.3.2 The E values then are corrected for the effect of surface roughness and thickness as follows:

$$E_c = E (1+2S/T) \quad (A11.3)$$

where:

- E<sub>c</sub> = the new corrected modulus value,
- E = the original modulus value,
- S = the surface roughness, in microinches (measured to the nearest microinch), and
- T = the thickness, in inches (measured to the nearest 0.0001 in.).

NOTE A11.4—The corrected E values should be distinguished by direction as indicated above, that is, E<sub>c0</sub>, E<sub>c45</sub>, and E<sub>c90</sub>.

A11.6.3.3 Calculate E-bar and ΔE values are by the following equations:

$$E\text{-bar} = (E_{c0} + E_{c90} + 2E_{c45})/4 \quad (A11.4)$$

$$\Delta E = (E_{c0} + E_{c90} - 2E_{c45})/2 \quad (A11.5)$$

A11.6.3.4 Determine R-bar by converting from E-bar to R-bar by using the following equation:

$$R\text{-bar} = 101.44/(E\text{-bar} - 38.83)^2 - 0.564 \quad (A11.6)$$

A11.6.3.5 Determine Δr by converting from ΔE by using the following equation:

$$\Delta r = 0.031 - 0.323 (\Delta E) \quad (A11.7)$$

**A11.7 Precision**

A11.7.1 *Precision*—Aside from the normal variation of the product being measured, the precision of the input variables to the above equations can effect the reported final results. The length and width of the blanked samples should not vary by more than  $\pm 0.01$  in. from the recommended blank dimensions.

The thickness of the material should be measured to the nearest 0.0001 in. The surface roughness should be measured to the nearest microinch.

**A11.8 Keywords**

A11.8.1 Modul-R; R-bar;  $\Delta r$

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## Standard Specification for Tin Mill Products, General Requirements [Metric]<sup>1</sup>

This standard is issued under the fixed designation A 623M; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon ( $\epsilon$ ) indicates an editorial change since the last revision or reapproval.

*This standard has been approved for use by agencies of the Department of Defense.*

### INTRODUCTION

This specification is the metric counterpart of Specification A 623. It is not intended to replace A 623. Users of the standard should note several very significant differences in how the product is produced and marketed.

(1) The metric product does not carry the overrun associated with tin mill products produced to customary units. Metric tin mill products are produced to ordered size.

(2) The metric product is designated in units of 100 m<sup>2</sup> called a SITA (System International Tinplate Area), rather than in base boxes.

(3) The metric product is designated by thickness in millimetres rather than by basis weight.

(4) Coating weights are given in grams per square metre, not pounds per base box.

(5) Thickness tolerances are given in absolute figures instead of a  $\pm$  percentage.

(6) Each package of metric tin mill products contains 100 sheets, not the 112 of customary unit packages.

All of the above significant differences, as well as others of lesser consequence, should be considered when switching from Specification A 623 to A 623M.

### 1. Scope

1.1 This specification covers a group of common requirements which, unless otherwise specified in the purchase order or in an individual specification, shall apply to tin mill products.

1.2 The following safety hazards caveat pertains to Annex A1 through Annex A8 of this specification: *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

NOTE 1—This metric specification is equivalent to Specification A 623 and is compatible in technical content.

### 2. Referenced Documents

#### 2.1 ASTM Standards:

A 370 Test Methods and Definitions for Mechanical Testing of Steel Products<sup>2</sup>

A 700 Practices for Packaging, Marking, and Loading Methods for Steel Products for Domestic Shipment<sup>3</sup>

A 987 Test Method for Measuring Shape Characteristics of Tin Mill Products<sup>4</sup>

E 18 Test Methods for Rockwell Hardness and Rockwell Superficial Hardness of Metallic Materials<sup>5</sup>

E 112 Test Methods for Determining the Average Grain Size<sup>5</sup>

#### 2.2 Military Standards:

MIL-STD-129 Marking for Shipment and Storage<sup>6</sup>

MIL-STD-163 Steel Mill Products, Preparation for Marking and Storage<sup>6</sup>

#### 2.3 Federal Standard:

Fed. Std. No. 123 Marking for Shipment (Civil Agencies)<sup>6</sup>

<sup>1</sup> This specification is under the jurisdiction of ASTM Committee A01 on Steel, Stainless Steel, and Related Alloys and is the direct responsibility of Subcommittee A01.20 on Tin Mill Products.

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<sup>2</sup> *Annual Book of ASTM Standards*, Vol 01.03.

<sup>3</sup> *Annual Book of ASTM Standards*, Vol 01.05.

<sup>4</sup> *Annual Book of ASTM Standards*, Vol 01.06.

<sup>5</sup> *Annual Book of ASTM Standards*, Vol 03.01.

<sup>6</sup> Available from Standardization Documents Order Desk, Bldg. 4 Section D, 700 Robbins Ave., Philadelphia, PA 19111-5094, Attn: NPODS.

### 3. Terminology

#### 3.1 Definitions:

3.1.1 *black plate, n*—light-gage, low-carbon, cold-reduced steel intended for use in the untinned state or for the production of other tin mill products. It is supplied only in a dry or oiled condition.

3.1.2 *box annealing, n*—a process involving slow heating of coils to a subcritical temperature, holding, and cooling therefrom, to recrystallize the grain, and thus, relieve stresses produced during cold reduction. It is accomplished in a sealed container. By introducing and maintaining an inert or slightly reducing atmosphere during the cycle, a relatively bright surface is obtained.

3.1.3 *bright finish, n*—a surface that has a lustrous appearance.

3.1.4 *burr, n*—metal displaced beyond the plane of the surface by slitting or shearing (see 9.1.6 and 9.2.6).

3.1.5 *camber, n*—the greatest deviation of a coil edge from a straight line. The measurement is taken on the concave side and is the perpendicular distance from a straight line to the point of maximum deviation (see 9.1.8 and 9.2.7).

3.1.6 *chemical treatment, electrolytic tin plate, n*—a passivating chemical treatment applied to the surface of electrolytic tin plate to stabilize the plate surface characteristics compatible with a specified end use (see Annex A7).

3.1.7 *chemically treated steel, n*—light-gage, low-carbon, cold-reduced steel that has a passivating or chemical treatment applied to the surface to provide rust resistance or retard underfilm corrosion, or both.

3.1.8 *cold reduction, n*—the process of reducing the thickness of the strip cold, generally accomplished by one rolling through a series of four-high mills arranged in tandem.

3.1.9 *continuous annealing, n*—a process consisting of passing the cold-reduced strip continuously and in a single thickness through a series of vertical passes within a furnace consisting of heating, soaking, and cooling zones to recrystallize the grain and thus relieve stresses produced during cold reduction. An inert or slightly reducing atmosphere is maintained in the furnace to obtain a relatively bright strip.

3.1.10 *differentially coated tin plate, n*—electrolytic tin plate with a different weight of tin coating on each surface.

3.1.11 *double-reduced plate, n*—plate given a second major cold reduction following annealing.

3.1.12 *electrolytic chromium-coated steel, n*—light-gage, low-carbon, cold-reduced steel on which chromium and chromium oxides have been electrodeposited.

3.1.13 *electrolytic tin plate, n*—light-gage, low-carbon, cold-reduced steel on which tin has been electrodeposited by an acid or alkaline process.

3.1.13.1 *J Plate, n*—electrolytic tin plate, 5.6/2.8 g/m<sup>2</sup> or heavier tin coating, with improved corrosion performance for some galvanic detinning food products as specified in 3.1.13.2 and as measured by the Special Property Tests for Pickle Lag (PL) (see Annex A2), Iron Solution Values (ISV) (see Annex A4), Tin Crystal Size (TCS) (see Annex A3). The alloy layer is normally light in color, characteristic of the acid tinning process.

3.1.13.2 *K Plate, n*—electrolytic tin plate, 5.6/2.8 g/m<sup>2</sup> or heavier tin coating, with improved corrosion performance for some galvanic detinning food products as specified in the following table and as measured by the Special Property Tests for Pickle Lag (PL) (see Annex A2), Iron Solution Value (ISV) (see Annex A4), Tin Crystal Size (TCS) (see Annex A3), Alloy Tin Couple (ATC) (see Annex A5) and Aerated Media Polarization Test (AMP) (see Annex A8).

	Special Properties Aims
Pickle Lag	10 s max
Iron Solution Value	20 µg iron max
Tin Crystal Size	ASTM No. 9 or larger
Alloy Tin Couple <sup>A</sup>	0.12 µA/cm <sup>2</sup> max

<sup>A</sup> Good mill practice has demonstrated the ability to average 0.05 µA/cm<sup>2</sup> or less over an extended period of production.

3.1.13.3 *Discussion*—The production of J Plate and K Plate require special processing and testing. In order to receive J Plate or K Plate, this requirement must be specified on the order.

3.1.14 *length dimension, n*—the longer dimension of a cut size (see 9.2.5).

3.1.15 *lot, n*—each 20 000 sheets or part thereof or the equivalent in coils, of an item in a specific shipment having the same order specifications.

3.1.16 *matte finish, n*—a surface that has an unmelted tin coating, generally on a shot-blast finish (SBF) base steel.

3.1.17 *mechanical designation, n*—an arbitrary number to designate Rockwell hardness and ultimate tensile strength characteristics for double-reduced plate (see 8.2).

3.1.18 *oiling, n*—a lubricant film applied to both surfaces of the plate.

3.1.19 *package, n*—a quantity of 100 sheets.

3.1.20 *passivating treatment, n*—a surface chemical treatment (see 3.1.6).

3.1.21 *Rockwell hardness test, n*—a test for determining hardness (see Annex A1).

3.1.22 *rolling width, n*—the dimension of the sheet perpendicular to the rolling direction.

3.1.23 *single-reduced plate, n*—plate produced with one major cold reduction.

3.1.24 *SITA, n*—100 square metres.

Formula for cut lengths:

$$\text{SITA} = \frac{\text{width (mm)}}{1000} \times \frac{\text{length (mm)}}{1000} \times \text{number of packages} \quad (1)$$

Formula for coils:

$$\text{SITA} = \frac{\frac{\text{width (mm)}}{1000} \times \text{length (m)}}{100\text{m}^2} \quad (2)$$

3.1.25 *steel Type D, n*—base-metal steel aluminum killed, sometimes required to minimize severe fluting and stretcher-strain hazards or for severe drawing applications (see Table 1).

3.1.26 *steel Type L, n*—base-metal steel, low in metalloids and residual elements, sometimes used for improved internal corrosion resistance for certain food-product containers (see Table 1).

**TABLE 1 Chemical Requirements for Tin Mill Products**

Element	Cast Composition, max %		
	Type D	Type L	Type MR
Carbon	0.12	0.13	0.13
Manganese	0.60	0.60	0.60
Phosphorous	0.020	0.015	0.020
Sulfur	0.03	0.03	0.03
Silicon <sup>A,B</sup>	0.020	0.020	0.020
Copper	0.20	0.06	0.20
Nickel	0.15	0.04	0.15
Chromium	0.10	0.06	0.10
Molybdenum	0.05	0.05	0.05
Aluminum <sup>C</sup>	0.20	0.10	0.20
Other elements, each	0.02	0.02	0.02

<sup>A</sup>When steel produced by the silicon killed method is ordered, the silicon maximum may be increased to 0.080 %.

<sup>B</sup>When strand cast steel produced by the aluminum killed method is ordered or furnished, the silicon maximum may be increased to 0.030 % when approved by the purchaser.

<sup>C</sup>Types L and MR may be supplied as non-killed or killed which would respectively be produced without and with aluminum additions. Minimum aluminum level for Type D is usually 0.02 %.

3.1.27 *steel Type MR, n*—base-metal steel, similar in metalloid content to Type L but less restrictive in residual elements, commonly used for most tin mill products (see Table 1).

3.1.28 *surface appearance, n*—visual characteristics determined primarily by the steel surface finish. For electrolytic tin plate, the appearance is also influenced by the weight of coating and by melting or not melting the tin coating.

3.1.29 *surface finishes, n*—steel surface finishes for tin mill products imparted by the finishing-mill work rolls. These may be either ground, blasted, or etched roll finishes.

3.1.30 *temper designation, n*—an arbitrary number to designate a Rockwell hardness range for single-reduced products which indicates the forming properties of the plate (see Section 8 and Table 2 and Table 3).

3.1.31 *temper mill, n*—a mill for rolling base metal steel after annealing to obtain proper temper, flatness, and surface finish. It may consist of one stand or two stands arranged in tandem.

3.1.32 *tin coating weight, n*—the weight of tin applied to the steel surface, usually stated as grams per square metre distributed evenly over both surfaces. The coating is usually referred to by designation numbers, referring separately to the nominal tin weight on each surface, but omitting the units. Thus, 2.8/2.8 designates tin plate with a coating of 2.8 g/m<sup>2</sup> on each of the two surfaces. For differential coatings the same system is applied. Thus, 1.1/2.2 has a coating of 1.1 g/m<sup>2</sup> on one surface and 2.2 g/m<sup>2</sup> on the other surface.

3.1.33 *width dimension, n*—the shorter dimension of a cut size (see 9.2.5).

#### 4. Base Metal

4.1 The steel shall be made by the open-hearth, electric furnace, or basic-oxygen process.

#### 5. Chemical Composition

5.1 The steel shall conform to the chemical composition requirements as prescribed in Table 1 except as otherwise agreed upon between the manufacturer and the purchaser.

**TABLE 2 Temper Designations and Hardness Values Single Reduces Tin Mill Products—Box Annealed**

NOTE 1—Thinner plate (0.21 mm ordered thickness and thinner) is normally tested using the Rockwell 15T scale and the results converted to the Rockwell 30T scale (see Annex A1 and Table A1.1).

Temper Designation	Rockwell Hardness Values All Thickness HR30T <sup>A</sup>		Characteristics and Typical End Uses
	Nominal	Range	
T-2 (T53)	53	49-57	moderately soft for drawing shallow parts such as can ends and pie pans
T-3 (T57)	57	53-61	Fairly stiff for parts such as can ends and bodies, closures, and crown caps
T-4 (T61)	61	57-65	Increased stiffness for can ends and bodies, crown caps, and large closures

<sup>A</sup>These ranges are based on the use of the diamond spot anvil and a 1.588 mm hardened steel ball indenter.

Test Conditions:

1. For referee purposes, samples of black plate, unreflowed ETP, and ECCS shall be aged prior to testing by holding at 200°C for 10 minutes.
2. The hardness test area on material produced with SBF or equivalent rolls shall be sanded smooth on both surfaces.
3. To avoid incorrect results due to the cantilever effect, samples shall have an area no longer than 2500 mm<sup>2</sup> and the point of testing shall be no more than 13 mm off the center of the samples.

#### 6. Cast or Heat Analysis

6.1 For Type D, MR, and L an analysis of each heat of steel shall be made by the supplier to determine the percentage of carbon, manganese, phosphorus, sulfur, silicon, and residual elements shown in Table 1. Other elements, unless agreed upon between the manufacturer and the purchaser, individually shall not exceed 0.02 %, maximum and while not necessarily analyzed are dependent on the suppliers' practices and controls.

#### 7. Product Analysis

7.1 Rimmed or capped steels are characterized by a lack of uniformity in their chemical composition, and for this reason, product analysis is not technologically appropriate unless misapplication is clearly indicated.

#### 8. Mechanical Requirements

8.1 *Single-Reduced Tin Mill Products, Temper*—The term *temper* when applied to single-reduced tin mill products summarizes a combination of interrelated mechanical properties. No single mechanical test can measure all the various factors that contribute to the fabrication characteristics of the material. The Rockwell 30T hardness value is a quick test which serves as a guide to the properties of the plate. This test forms the basis for a system of temper designations as shown in Table 2 and Table 3. A given temper shall have hardness values meeting the limits shown. The mechanical properties of continuously annealed plate and batch annealed plate of the same Rockwell 30T temper designation are not identical. It is

**TABLE 3 Temper Designations and Hardness Values Single-Reduced Tin Mill Products—Continuously Annealed**

NOTE 1—Thinner plate (0.21-mm ordered thickness and thinner) is normally tested using the Rockwell 15T and the results converted to the Rockwell 30T scale (see Annex A1 and Table A1.1).

Temper Designation	Rockwell Hardness Value All Thicknesses HR30T <sup>A</sup>		Characteristics and Typical End Uses
	Nominal	Range	
T-1 (T49)	49	45–53	soft for drawing parts such as nozzles, spouts, and oil filter shells
T-2 (T53)	53	49–57	moderately soft for drawing shallow parts such as rings, plugs, and pie pans
T-3 (T57)	57	53–61	moderate stiffness for parts such as can ends and bodies, drawn and ironed can bodies closures, and crown caps
T-4 (T61)	61	57–65	increased stiffness for can ends, drawn (and ironed) can bodies, and large closure
T-5 (T65)	65	61–69	moderately high stiffness for can ends and bodies

<sup>A</sup>These ranges are based on the use of the diamond spot anvil and a 1.588 mm hardened steel ball indenter.

Test Conditions:

1. For referee purposes, samples of black plate, unreflowed ETP, and ECCS shall be aged prior to testing by holding at 200°C for 10 minutes.
2. The hardness test area on material produced with SBF or equivalent rolls shall be sanded smooth on both surfaces.
3. To avoid incorrect results due to the cantilever effect, samples shall have an area no longer than 2500 mm<sup>2</sup> and the point of testing shall be no more than 13 mm off the center of the samples.

important to keep in mind, that the Rockwell 30T test does not measure all the various factors which contribute to the fabrication characteristics of the plate.

**8.2 Double-Reduced Tin Mill Products, Mechanical Characteristics**—No test or group of tests have been developed that adequately predict the fabricating performance of double-reduced tin mill products. Designations for mechanical properties showing typical applications are arranged in generally ascending level of strength as shown in Table 4.

**TABLE 4 Mechanical Designations Double-Reduced Tin Mill Products**

NOTE 1—Thinner plate (0.21-mm ordered thickness and thinner) is normally tested using Rockwell 15T scale and the results converted to the Rockwell 30T scale (see Annex A1 and Table A1.1).

Designation	Nominal Longitudinal (L) Ultimate Tensile Strength, MPa	Nominal Rockwell Hardness HR30-T <sup>A</sup>	Examples of Usage
DR-7.5	520	71	can bodies
DR-8	550	72	can bodies and ends
DR-8.5	580	73	can bodies and ends
DR-9	620	75	can bodies and ends
DR-9.5	660	76	can ends

<sup>A</sup>These values are based on the use of the diamond spot anvil and a 1.588 mm steel ball indenter. Testing will be in accordance with Test Methods and Definitions A 370. Rockwell values are too varied to permit establishment of ranges. For details see *AISI Contributions to the Metallurgy of Steel*, "Survey of Mechanical Properties of Double Reduced Tin Plate," January 1966.

8.3 Rockwell testing shall be in accordance with the latest revision of Test Methods and Definitions A 370 (see Annex A1) and Test Methods E 18.

## 9. Permissible Variation in Dimensions

### 9.1 Dimensional Characteristics, Coils:

9.1.1 **Thickness, Method for Determination**—When the purchaser wishes to make tests to ascertain compliance with the requirements of this specification for thickness of an item in a specific shipment of tin mill products in coils having the same order specification, the following procedure shall be used: Random and representative measurements using a hand micrometer must be made throughout the coil length. Measurements may be made at any location across the coil width except 10 mm from the mill-trimmed edge. The hand micrometers are assumed to be accurate to  $\pm 0.003$  mm. No measurements are to be made within 1.0 m of a weld.

9.1.2 **Thickness Tolerances** shall conform to those prescribed in Table 5 (also see Table 6).

9.1.3 **Feather Edge** is a measure of the thickness deviation across the strip width. It is measured at a location 6 mm from the mill-trimmed edge and is generally less than the thickness at positions 25 mm or more from the mill-trimmed edge. Maximum feather edge deviation shall not be more than 15 % under the specified thickness.

9.1.4 **Crown** is the difference in strip thickness from the center of roll width and the location 10 mm in from the mill-trimmed edge.

9.1.5 **Width**—Coils are trimmed to ordered width. The slit dimension shall not vary by more than  $-0, +3$  mm.

**TABLE 5 Thickness Tolerances**

NOTE 1—When weld-free coils are specified, this does not afford the supplier the opportunity to discard off-gage product, and for that reason the above thickness tolerances are not applicable.

Lot Size, Mg (metric tons)	Tolerance
0 to 5.5	95 % of the product of the coils shall be within the tolerances slated in Table 6.
Over 5.5 to 13.6	97.5 % of the product of the coils shall be within the tolerances stated in Table 6.
Over 13.6 to 68.0	99.0 % of the product of the coils shall be within the tolerances stated in Table 6.
Over 68.0	99.5 % of the product of the coils shall be within the tolerances stated in Table 6.

**TABLE 6 Ordered Thickness and Thickness Tolerances**

NOTE 1—Thickness tolerances are +5 % and -8 % from the ordered thickness

Ordered Thickness, mm	Thickness Tolerance, Over, mm	Thickness Tolerance, Under, mm
0.140	0.007	0.011
0.150	0.008	0.012
0.160	0.008	0.013
0.170	0.008	0.014
0.180	0.009	0.014
0.190	0.010	0.015
0.200	0.010	0.016
0.210	0.010	0.017
0.220	0.011	0.018
0.230	0.012	0.018
0.240	0.012	0.019
0.250	0.012	0.020
0.260	0.013	0.021
0.270	0.014	0.022
0.280	0.014	0.022
0.290	0.014	0.023
0.300	0.015	0.024
0.310	0.016	0.025
0.320	0.016	0.026
0.330	0.016	0.026
0.340	0.017	0.027
0.350	0.018	0.028
0.360	0.018	0.029
0.370	0.018	0.030
0.380	0.019	0.030

9.1.6 *Burr*—A maximum of 0.05 mm is permissible.

9.1.7 *Coil Length*—Variation between the measured length by the purchaser versus the supplier’s billed length shall not exceed the limits prescribed in Table 7.

9.1.7.1 Since it is a common practice for each consumer’s shearing operation to keep a running measurement of their supplier’s coil shipments, any length variation in small lots (1 to 5 coils) for a given period will automatically be included in this summary. Before concluding there is a length variation in these small lots the total length received from the supplier, regardless of thickness, over periods of one month or one quarter, or both should be checked.

**TABLE 7 Coil Length Variation**

No. of Coils	Variation, ±, %
1	3
100	0.1

9.1.8 *Camber* is limited to a maximum of 6 mm in 6 m or fraction thereof of length, in accordance with the latest version of measuring methods and definitions in Test Method A 987.

9.1.9 *Inside Coil Diameters*—The standard inside diameter produced is approximately 410 mm.

9.2 *Dimensional Characteristics, Cut Sizes:*

9.2.1 *Thickness, Method for Determination*—Random measurements must be made at least 10 mm from the slit edge of the sheet using a hand micrometer. The hand micrometers are assumed to be accurate to ±0.003 mm.

9.2.2 *Thickness Tolerances*—Tin mill products in cut sizes are produced within thickness tolerances of +5 %, -8 % of the ordered thickness, see (Table 6). Any sheets not meeting this requirement are subject to rejection.

9.2.3 *Feather Edge* is a measure of the thickness deviation across the strip width. It is measured at a location 6 mm from the mill-trimmed edge and is generally less than the thickness at positions 25 mm or more from the mill-trimmed edge. Maximum feather edge deviation shall not be more than 15 % under the specified thickness.

9.2.4 *Crown* is the difference in strip thickness from the center of roll width and the location 10 mm in from the mill-trimmed edge.

9.2.5 *Shearing Practice*—Tin mill products are generally ordered to even-numbered millimetres and sheared to ordered size. The greater dimension is considered length. The slit dimension shall not vary by more than -0, +3 mm and the drumcut dimension shall not vary by more than -0, +6 mm.

9.2.6 *Burr*—A maximum of 0.05 mm is permissible.

9.2.7 *Camber*—The maximum permissible deviation is 1.3 mm for each 1 m of length or fraction thereof, in accordance with the latest version of measuring methods and definitions in Test Method A 987.

9.2.8 *Out-of-Square* is the deviation of an end edge from a straight line which is placed at a right angle to the side of the plate, touching one corner and extending to the opposite side. The amount of deviation is customarily limited to 1.5 mm for any edge measurement, except that a multiple-package lift may contain a maximum of four sheets with a deviation up to 3 mm.

## 10. Special Requirements

10.1 *Welds*—Coils may contain lap or mesh welds, the locations of which are marked. A hole may be punched adjacent to the weld for automatic rejection of the weld during shearing. The leading ends of lap welds shall not exceed 25 mm.

10.2 *Cores*—If coil centers must be supported to minimize damage, this requirement should be so stated on the order as a special requirement.

## 11. Sheet Count—Cut Sizes

11.1 Small variations in sheet count of a multiple-package lift should average out to at least the proper exact count in quantities of 450 packages or more.

## 12. Retest Procedure

12.1 In the event the material fails to meet the specified requirements, two further series of samples are to be selected

by the purchaser in accordance with the applicable procedures. Both retests must meet the specification limits to qualify as meeting the requirements.

### 13. Conditions of Manufacture

13.1 The purchaser should be informed of any alterations in the method of manufacture which will significantly affect the properties of the purchased product. Similarly, the purchaser should inform the manufacturer of modifications in their fabrication methods which will significantly affect the way in which the purchased product is used.

### 14. Inspection

14.1 The inspector representing the purchaser shall have entry, at all times while work on the contract of the purchaser is being performed, to all parts of the manufacturer's works that concern the manufacture of the material ordered. The supplier shall afford the inspector all reasonable facilities to satisfy him that the material is being furnished in accordance with this specification. Unless otherwise specified, all inspection and tests shall be made prior to shipment at the supplier's works and such inspection or sampling shall be made in conjunction with and to the extent of the manufacturer's regular inspection operations.

### 15. Rejection

15.1 Material that shows excessive number of injurious imperfections subsequent to its acceptance at the manufactur-

er's works, except as noted in the basis of purchase of the applicable specification, shall be rejected and the supplier notified.

### 16. Packaging

16.1 Unless otherwise specified, the tinplate shall be packaged and loaded in accordance with Practices A 700.

16.2 When specified in the contract or order, and for direct procurement by or direct shipment to the government, when Level A is specified, preservation, packaging, and packing shall be in accordance with the Level A requirements of MIL-STD-163.

16.3 The standard method of shipping coils is with the eye of the coil vertical.

### 17. Marking

17.1 As a minimum requirement, the material shall be identified by having the manufacturer's name, ASTM designation, weight, purchaser's order number, and material identification legibly stenciled on top of each lift or shown on a tag attached to each coil or shipping unit.

17.2 When specified in the contract or order, and for direct procurement by or direct shipment to the government, marking for shipment, in addition to requirements specified in the contract or order, shall be in accordance with MIL-STD-129 for military agencies and in accordance with Federal Std. No. 123 for civil agencies.

## ANNEXES

### (Mandatory Information)

#### A1. ROCKWELL HARDNESS TESTING OF TIN MILL PRODUCTS

##### A1.1 Scope

A1.1.1 This annex covers the application to tin mill products of Rockwell superficial hardness tests using the 15T and 30T scales. Tests shall be made in accordance with the methods outlined in Test Methods E 18 and Test Methods and Definitions A 370 with the exceptions given in the following sections.

##### A1.2 Anvil

A1.2.1 All tests shall be made using the diamond spot anvil and a 1.588 mm hardened steel ball indenter.

##### A1.3 Specimens

A1.3.1 *Thickness*—The recommendations given in Table 12 of Test Methods E 18 shall not apply to tests on tin mill products. The Rockwell superficial scale to be used shall be determined from the nominal thickness of the material as given in the following table:

Nominal Sheet Thickness, mm	Rockwell Superficial Scale	Major Load, kgf
0.212 and less	15T	15
0.547–0.213	30T	30

A1.3.2 *Surface Finish*—The surface of the specimen in contact with the diamond spot anvil shall be flat, smooth, and free from dirt or surface irregularities. When necessary the surface shall be finished with fine emery paper. Unless otherwise agreed upon, the tin coating shall not be removed from the surface on which the indentation is made.

##### A1.4 Reports

A1.4.1 *Number of Tests*—The Rockwell scale value to be reported shall be the average of at least three impressions.

A1.4.2 *Conversion*—Hardness tests made on the 15T scale may be converted to the 30T scale by the use of Table A1.1. It is recognized that such conversions are for convenience in reporting and that conversion, particularly from tests on thin and soft materials, is not an accurate process.

**TABLE A1.1 Conversion Table (Approximation) Rockwell  
Hardness Testing**

HR30T	HR15T	HR30T	HR15T
82.0	93.0	65.0	84.0
81.5	92.5	64.0	...
81.0	...	63.5	83.5
80.5	92.0	62.5	83.0
80.0	...	62.0	...
79.0	91.5	61.5	82.5
78.5	...	60.5	82.0
78.0	91.0	60.0	...
77.5	90.5	59.5	81.5
77.0	...	58.5	81.0
76.0	90.0	58.0	...
75.5	89.5	57.0	80.5
75.0	...	56.5	...
74.5	89.0	56.0	80.0
74.0	88.5	55.0	79.5
73.5	...	54.5	...
73.0	88.0	54.0	79.0
72.0	87.5	53.0	78.5
71.5	...	52.5	...
71.0	87.0	51.5	78.0
70.0	86.5	51.0	77.5
69.5	...	50.5	...
69.0	86.0	49.5	77.0
68.0	85.5	49.0	76.5
67.5	...	48.5	...
67.0	85.0	47.5	76.0
66.0	...	47.0	75.5
65.5	84.5	46.0	...

## A2. METHOD FOR DETERMINATION OF PICKLE LAG ON STEEL FOR ELECTROLYTIC TIN PLATE

### INTRODUCTION

It is not intended that variations in apparatus, sample preparation, or procedures from those described in this standard method be precluded. Suppliers or consumers may employ such variations for control purposes provided test results agree with results obtained by the standard method.

#### A2.1 Scope

A2.1.1 The rate of pickling test,<sup>7</sup> also called the pickle lag test, is one of four special property tests used to measure certain characteristics of electrolytic tin plate which affect internal corrosion resistance. The test is applicable to nominal tin coating and heavier electrolytic tin plate (For K-plate, see 3.1.13.2 and J-plate, see 3.1.13.1). It is not applicable to 2.8/2.8 and lighter electrolytic tin plate.

#### A2.2 Summary of Method

A2.2.1 The time lag for a piece of steel to attain constant dissolution rate in acid under controlled conditions is determined. The change in pressure in a closed system caused by hydrogen evolution from the steel is continuously plotted on a chart through use of an electro-mechanical linkage and mercury manometer.

#### A2.3 Apparatus

A2.3.1 *Reaction Vessel*,<sup>8</sup> consisting of a specially modified 125-mL Erlenmeyer flask. The flask shall have a 10-mm bore stopcock, glass sealed to the mouth and a small-diameter glass tube side arm sealed in the side just below the mouth of the original flask. The bottom of the flask shall be rounded out. A mercury switch shall be attached to the stop-cock plug with a metal band.

A2.3.2 *Constant-Temperature Water Bath*, large enough to accommodate the reaction vessel and maintain a temperature of  $90 \pm 0.5^\circ\text{C}$ .

A2.3.3 *Recording Mercury Manometer*,<sup>9</sup> to measure the rate of increase in pressure in the vessel generated by hydrogen. Initial setup of the recorder is described in Section 9.

A2.3.4 A 381 by 3.17-mm magnetized steel rod for removal of test specimen. (A one-hole rubber stopper may be positioned

<sup>7</sup> Willey, A. R., Krickl, J. L., and Hartwell, R. R., "Steel Surface Properties Affect Internal Corrosion Performance of Tin Plate Containers," *Corrosion*, Vol 12, No. 9, 1956, p. 433.

<sup>8</sup> Available from Wilkens-Anderson Co., 5626 W. Division St., Chicago, IL 60651. Such apparatus or its equivalent has been found satisfactory.

<sup>9</sup> Manufactured by Thwing-Albert Instrument Co., 10960 Dutton Rd., Philadelphia, PA 19154. Such apparatus or its equivalent has been found satisfactory.

near the upper end to prevent the bottom of the rod from striking the bottom of the reaction flask.)

A2.3.5 *Coordinate Paper*, 101 by 279 mm, with either 10 or 20 gradations, each 25.4 mm.

#### A2.4 Reagents and Materials

A2.4.1 *Purity of Reagents*—Reagent grade chemicals shall be used in all tests. Unless otherwise indicated, it is intended that all reagents shall conform to the specifications of the Committee on Analytical Reagents of the American Chemical Society, where such specifications are available.<sup>10</sup> Other grades may be used, provided it is first ascertained that the reagent is of sufficiently high purity to permit its use without lessening the accuracy of the determination.

A2.4.2 *Purity of Water*—Unless otherwise indicated, references to water shall be understood to mean distilled water or water of equal purity.

A2.4.3 *For Rate of Pickling Test:*

A2.4.3.1 *Hydrochloric Acid (HCl)*, (6 N).

A2.4.4 *For Sample Preparation:*

A2.4.4.1 *Acetone*.

A2.4.4.2 *Antimony Trichloride Solution* (120 g/L)—Dissolve 120 g of antimony trichloride (SbCl<sub>3</sub>) in 1 L of concentrated HCl.

A2.4.4.3 *Sodium Carbonate Solution* (Na<sub>2</sub>CO<sub>3</sub>) (0.5%).

A2.4.4.4 *Sodium Hydroxide Solution* (NaOH) (10 %).

A2.4.4.5 *Sodium Peroxide* (Na<sub>2</sub>O<sub>2</sub>), *granulated*.

A2.4.5 *For Water Bath:*

A2.4.5.1 *Paraffin Oil*.

#### A2.5 Test Specimen Preparation

A2.5.1 *Test Specimen*—A piece of steel 8 by 65 mm with the long dimension perpendicular to the rolling direction of the steel.

A2.5.1.1 Cut a piece of metal 8 by 100 mm or longer. The added length above the 65 mm serves as a handle during preparation.

A2.5.1.2 Remove surface oil and grease by dipping the specimen in acetone and wiping with a cloth or paper towel.

A2.5.1.3 Cathodically clean the specimen in 0.5 % solution of Na<sub>2</sub>CO<sub>3</sub>, rinse in water, and dry.

A2.5.1.4 Detin the specimen by immersing in SbCl<sub>3</sub>-HCl solution at room temperature. Allow the specimen to remain in solution 10 to 20 s after bubbling ceases.

A2.5.1.5 Remove the specimen, rinse in tap water, and wipe surface clean of antimony. (A wet cellulose sponge with a little non-ionic detergent has been found effective.)

A2.5.1.6 Immerse specimen in 10 % NaOH solution held at 90°C for approximately 1 min. During this time add granulated Na<sub>2</sub>O<sub>2</sub> slowly to keep solution bubbling freely. This treatment removes the last traces of antimony and any iron-tin alloy not removed during detinning. More than one specimen may be treated at one time. A stainless steel beaker with specimens

contacting the beaker appears to facilitate removal of the antimony and iron-tin alloy.

A2.5.1.7 Rinse specimen successively in tap water, distilled or deionized water and acetone. Alternatively rinse specimen in tap water and wipe dry with a clean towel.

A2.5.1.8 Trim specimen to 8 by 65 mm.

A2.5.1.9 Handle the specimen with forceps as touching with the fingers may produce erratic test results.

#### A2.6 Procedure

A2.6.1 Bring the constant-temperature water bath to 90 ± 0.5°C, making certain the 6 N HCl in the reaction vessel has also reached 90°C, if it has been freshly transferred.

A2.6.2 Start recorder and place the pen against the graph paper near the bottom.

A2.6.3 Drop the specimen into the reaction vessel and immediately close the stopcock. The mercury switch will start the recorder drum turning. The pressure generated by reaction of the acid on the specimen will cause the pen to rise.

A2.6.4 Allow approximately 51 to 635 mm of vertical pen travel. Remove pen from paper and immediately open stopcock.

A2.6.5 Remove the specimen with a magnetized rod.

A2.6.6 Reposition the pen for the next determination and repeat the procedure.

A2.6.7 Change acid after every ten specimens.

#### A2.7 Calculation

A2.7.1 Extrapolate the upper straight-line portion of the curve to the horizontal base line.

A2.7.2 Measure the time in seconds along the horizontal base line between the origin of the curve and the point where the extrapolation intersects the base line. This time in seconds is defined as the *pickle lag*. A typical curve is shown in Fig. A2.1.

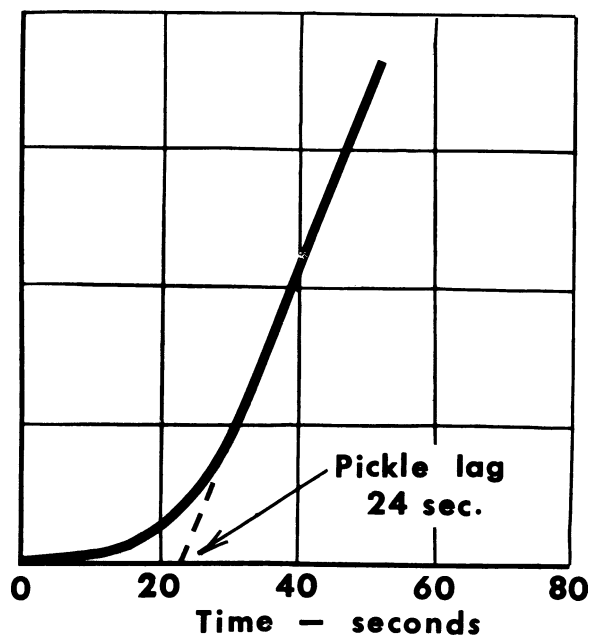


FIG. A2.1 Pickle Lag

<sup>10</sup> "Reagent Chemicals, American Chemical Society Specifications," Am. Chemical Soc., Washington, DC. For suggestions on the testing of reagents not listed by the American Chemical Society, see "Analar Standards for Laboratory U.K. Chemicals," BDH Ltd., Poole, Dorset, and the "United States Pharmacopeia."



## A2.8 Interferences

A2.8.1 Do not use rubber stoppers and tubing in contact with the acid. Some substance is extracted from the rubber which acts as an inhibitor and increases lag time.

A2.8.2 Headspace in the vessel affects the slope of the corrosion–time curve. The total volume of headspace in the reaction vessel between the liquid level and the plug of the stopcock should be approximately 40 mL including the volume of the side arm to the manometer. Lag time is not affected by small variation in headspace volume.

A2.8.3 It is essential that the system be gas-tight. A periodic test to check the system is recommended. Attach an aspirator bulb to the reaction vessel inlet. Raise pressure to about 7 kPa. Close the stopcock and start the recording drum and holding pressure in system. If the system is gas-tight, the recording pen will draw a straight horizontal line.

## A2.9 Assembly and Preparation of Apparatus

A2.9.1 It has been found convenient to alter the manometer (see A2.3.3) furnished with the equipment to avoid occasional problems of air entrapment in the mercury reservoir. The reservoir may be replaced with a stainless steel U-tube and connected to the two glass tubes with rubber tubing.

A2.9.2 Remove the front panel and the circular plate on top of the recorder (see Annex A2.3.3) to install the mercury manometer. Make an electrical connection from the mercury reservoir or the stainless steel U-tube to the electrical relay. With the traveling rack about 6.35 mm from its bottom position insert the moving electrical contact in the manometer arm with the reservoir trap at top and attach it to the top of the rack. Add

mercury to the trap to bring the level up to the bottom of the moving contact. Add a drop of 6 *N* HCl to the straight manometer arm to keep the wall clean. The arm should be cleaned or replaced when it becomes coated with mercury compounds.

A2.9.3 Connect the straight manometer arm to the reaction vessel with a 457-mm length of rubber or vinyl tubing, 4.76-mm inside diameter.

A2.9.4 Connect the mercury switch in series with the motor drive for the recorder drum. The switch is adjusted so the motor turns on when the stopcock of the reaction vessel is in the closed position. The rack should oscillate vertically when the switch on the top of the recorder is turned to the *on* position.

A2.9.5 Add a layer of paraffin oil approximately 6.35 mm thick to the water bath in order to minimize evaporation.

A2.9.6 Mount the reaction vessel in the constant-temperature water bath using a corrosion-resistant buret holder so that the side arm is 12.7 mm below the level of the bath. Stopcock grease or equivalent is used to lubricate the stopcock which is firmly held in place by a 12.7-mm wide rubber band or other means.

A2.9.7 Fill the reaction vessel with 6 *N* HCl to the stopcock. Remove enough acid to provide a constant headspace of 40 mL in the reaction vessel and side arm. This is readily accomplished by lowering a glass tube of convenient bore to a predetermined depth (the glass tube should be marked for this purpose) and connecting it to a water aspirator. Any acid in the side arm should be expelled by squeezing the tubing connected to the side arm.

## A3. METHODS FOR TIN CRYSTAL SIZE TEST FOR ELECTROLYTIC TIN PLATE

### INTRODUCTION

The three methods described in this annex for estimating tin crystal size on electrolytic tin plate are typical of several possible methods to obtain the same result. Publication of these methods is not intended to preclude any other method that produces the same result.

### A3.1 Scope

A3.1.1 The tin crystal size test is one of four special property tests used to measure certain characteristics of electrolytic tin plate which affect internal corrosion resistance. The test is applicable to nominal tin coating weights 5.6/2.8 g/m<sup>2</sup> and heavier electrolytic tin plate (for K-plate, see 3.1.13.2 and J-plate, see 3.1.13.1). It is not applicable to 2.8/2.8 g/m<sup>2</sup> and lighter electrolytic tin plate.

### A3.2 Summary of Method

A3.2.1 The surface of a piece of electrolytic tin plate is chemically etched or examined under polarized light to reveal the tin crystal pattern. The size of the tin crystals is estimated by comparison with ASTM macro-grain size number standards.

### A3.3 Apparatus (Required Only for Method No. 3)

A3.3.1 *Polarized Light Source and Analyzer*.<sup>8</sup>

### A3.4 Reagents and Materials (Required Only for Method No. 1)

A3.4.1 *Purity of Reagents*—Reagent grade chemicals shall be used in all tests. Unless otherwise indicated, it is intended that all reagents shall conform to the specifications of the Committee on Analytical Reagents of the American Chemical Society, where such specifications are available.<sup>10</sup> Other grades may be used, provided it is first ascertained that the reagent is of sufficiently high purity to permit its use without lessening the accuracy of the determination.

A3.4.2 *Purity of Water*—Unless otherwise indicated, references to water shall be understood to mean distilled water or water of equal purity.

A3.4.3 *Cotton or Soft Cloth*.

A3.4.4 *Ferric Chloride* (FeCl<sub>3</sub>·6H<sub>2</sub>O)—Chemically pure grade.

A3.4.5 *Hydrochloric Acid* (HCl) (1*N*)—Chemically pure grade.

A3.4.6 *Sodium Sulfide* ( $\text{Na}_2\text{S}\cdot 9\text{H}_2\text{O}$ ) or *Sodium Bisulfate* ( $\text{NaHSO}_3\cdot \text{H}_2\text{O}$ )—Chemically pure grade.

### A3.5 Test Specimen

A3.5.1 The sample consists of any convenient size piece of fused electrolytic tin plate 25.8 cm<sup>2</sup> or larger.

### A3.6 Procedure

A3.6.1 *Method No. 1*—Ferric chloride etch.

A3.6.1.1 Prepare etching solution by dissolving 100 g of  $\text{FeCl}_3\cdot 6\text{H}_2\text{O}$  and 1 g of  $\text{Na}_2\text{S}\cdot 9\text{H}_2\text{O}$  or  $\text{NaHSO}_3\cdot \text{H}_2\text{O}$  in 1000 mL of 1 N HCl. Solution is reusable but should be replaced when etching of specimen takes longer than 30 s.

A3.6.1.2 Buff surface of specimen vigorously but with light pressure with cotton or soft cloth. This disrupts the passive film and permits the etching solution to attack the tin readily.

A3.6.1.3 As an alternative to A3.6.1.2 and, if the equipment is available, cathodically clean specimen in 0.5 % sodium carbonate ( $\text{Na}_2\text{CO}_3$ ) solution for 30 s. Reversing the polarity of the current for 1 s near the beginning of the cleaning cycle assists in removal of the passive layer. Rinse in tap water.

A3.6.1.4 Immerse specimen in etching solution for 5 to 15 s or until a crystal pattern develops. Remove, rinse in tap water, and dry. (Do not allow the specimen to remain in the etching solution too long as complete detinning will occur.)

A3.6.1.5 Estimate the tin crystal size number by comparing the specimen with ASTM macro-grain size number standards. (See Test Methods E 112.) For routine testing, it is convenient to use a set of secondary standards consisting of actual tin plate specimens or photographs thereof at 1 × magnification.

A3.6.2 *Method No. 2*—Iron solution value disk.

A3.6.2.1 Examine the specimen after completion of the ISV test (see Annex A4) as it will already be suitably etched.

A3.6.2.2 Estimate tin crystal size same as in Method No. 1.

A3.6.3 *Method No. 3*—Polarized light.

A3.6.3.1 This is a rapid nondestructive method.

A3.6.3.2 Place the specimen in a beam of polarized light so the beam strikes the surface obliquely.

A3.6.3.3 Examine the reflected light beam through an analyzer. Rotate the analyzer to obtain best definition of tin crystal pattern.

A3.6.3.4 Estimate tin crystal size same as in Method No. 1.

## A4. METHOD FOR DETERMINATION OF IRON SOLUTION VALUE ON ELECTROLYTIC PLATE

### INTRODUCTION

It is not intended that variations in apparatus, sample preparation, or procedures from those described in this standard method be precluded. Suppliers or consumers may employ such variations for control purposes provided results agree with those obtained by the standard method.

### A4.1 Scope

A4.1.1 The iron solution test,<sup>7</sup> also called the ISV test, is one of four special property tests used to measure certain characteristics of electrolytic tin plate which affect internal corrosion resistance. The test is applicable to nominal tin coating weights 5.6/2.8 g/m<sup>2</sup>, and heavier electrolytic tin plate (for K-plate, see 3.1.13.2 and J-plate, see 3.1.13.1). It is not applicable to 2.8/2.8 and lighter electrolytic tin plate.

### A4.2 Summary of Method

A4.2.1 The iron solution test involves the colorimetric determination of the total amount of iron dissolved when 20.3 cm<sup>2</sup> of tin plate surface area are exposed for 2 h at  $27 \pm 0.5^\circ\text{C}$  to 50 mL of a mixture of dilute sulfuric acid ( $\text{H}_2\text{SO}_4$ ), hydrogen peroxide ( $\text{H}_2\text{O}_2$ ), and ammonium thiocyanate ( $\text{NH}_4\text{SCN}$ ). The amount of iron dissolved expressed as micrograms is arbitrarily called the *iron solution value* (ISV).

### A4.3 Apparatus<sup>8</sup>

A4.3.1 *Cabinet, Room, or Other Means* of maintaining  $27 \pm 0.5^\circ\text{C}$  during the test run.

A4.3.2 *Test Vessels*, round, tall-form, wide-mouth, approximately 236-mL glass bottles with 63-mm diameter plastic caps.

A4.3.3 *Gaskets* made from 1.59-mm thick vinyl sheeting. Gaskets have 51-mm inside diameter (ID) and 61.5-mm outside diameter (OD).

A4.3.4 *Burets*—Two 25-mL automatic filling rapid dispensing burets.

A4.3.5 *Equipment for Cathodically Cleaning Test Specimens*—The power source should be capable of supplying 1 to 1½ A per test specimen (26-cm<sup>2</sup> disk). A stainless steel beaker or tank is recommended as the cleaning vessel as it may also serve as the anode.

A4.3.6 *Spectrophotometer and Cuvettes*.

### A4.4 Reagents and Materials

A4.4.1 *Purity of Reagents*—Reagent grade chemicals shall be used in all tests. Unless otherwise indicated, it is intended that all reagents shall conform to the specifications of the Committee on Analytical Reagents of the American Chemical Society, where such specifications are available.<sup>10</sup> Other grades may be used, provided it is first ascertained that the reagent is of sufficiently high purity to permit its use without lessening the accuracy of the determination.

A4.4.2 *Purity of Water*—Unless otherwise indicated, references to water shall be understood to mean distilled water or water of equal purity.

A4.4.3 *For Cleaning Test Specimen:*

A4.4.3.1 *Acetone*.

A4.4.3.2 *Sodium Carbonate Solution* ( $\text{Na}_2\text{CO}_3$ ) (0.5 %).

A4.4.4 *For Iron Solution Test:*

A4.4.4.1 *Ammonium Thiocyanate Solution (Iron-Free)* ( $\text{NH}_4\text{SCN}$ ).

A4.4.4.2 Hydrogen Peroxide Solution (H<sub>2</sub>O<sub>2</sub>) (30 %).

A4.4.4.3 Sulfuric Acid (H<sub>2</sub>SO<sub>4</sub>) (2.18 N).

A4.4.5 For Calibration:

A4.4.5.1 Iron Wire, Analytical.

A4.4.5.2 Sulfuric Acid (H<sub>2</sub>SO<sub>4</sub>) (10 N).

## A4.5 Procedure

A4.5.1 Test Solutions:

A4.5.1.1 Prepare a 3 % solution of H<sub>2</sub>O<sub>2</sub> by dilution of the 30 % grade.

A4.5.1.2 Prepare acid-peroxide stock solution by mixing in following proportions: 23 mL of H<sub>2</sub>SO<sub>4</sub>(2.18 N) to 2 mL of H<sub>2</sub>O<sub>2</sub>(3 %). (This mixture remains stable for several weeks.) Connect acid-peroxide stock solution bottle to one of the 25-mL automatic filling rapid-dispensing burets.

A4.5.1.3 Prepare a stock solution of NH<sub>4</sub>SCN (40 g/L) and connect the stock bottle to the other buret.

A4.5.2 Sample Preparation:

A4.5.2.1 The specimen consists of a flat-circular piece of tin plate  $57.33 \pm 0.03$  mm in diameter. This is equivalent to 25.8 cm<sup>2</sup>. The specimen must be typical of the plate being tested and free of incidental deep scratches and surface conditions that are not representative of the tin plate under test.

A4.5.2.2 Cathodically clean the specimen in 0.5 % Na<sub>2</sub>CO<sub>3</sub> solution for 30 s. Near the beginning of the cleaning cycle reverse the polarity of the current for 1 s. This 1-s anodic flash assists in removal of the oxides on the surface.

A4.5.2.3 Rinse the specimen successively in tap water and distilled or deionized water. Dry in acetone vapors. Do not touch the test surface.

A4.5.3 Iron Solution Test:

A4.5.3.1 Place the cleaned specimen, test surface up, in the plastic cap. (Paper liner should previously have been removed. To facilitate seating of gasket, the last 1.59 mm of cap thread may be removed by machining on a lathe.)

A4.5.3.2 Place the vinyl gasket over the specimen, seating it so that the gasket lies flat and holds the specimen firmly in place.

A4.5.3.3 Add 25 mL of the H<sub>2</sub>SO<sub>4</sub>-H<sub>2</sub>O<sub>2</sub> stock solution and 25 mL of the NH<sub>4</sub>SCN solution to the test vessel. Swirl to assure thorough mixing.

A4.5.3.4 Affix the cap with specimen and gasket to the test vessel. Secure tightly. Invert the vessel immediately and let stand for 2 h at 27°C without agitation or vibration.

A4.5.3.5 Provide one extra test vessel for each run. Add 25 mL each of the two stock solutions, cover with a plastic cap, but do not invert. This mixture will act as a blank during the calculation of the iron solution value.

A4.5.3.6 After 2 h, swirl the liquid once, turn the vessel upright, and remove cap, gasket, and specimen immediately. Repeat for all test vessels in the run. Remove cap from the blank.

NOTE A4.1—**Caution:** A small amount of hydrogen cyanide gas may be liberated during test run. Be sure the vessels are opened in a well-ventilated room or preferably under a hood.

A4.5.3.7 Add 1 mL of 3 % H<sub>2</sub>O<sub>2</sub> to each test vessel including the blank. Add the peroxide just before transferring the liquid in each test vessel to the cuvette. (See A4.8)

A4.5.3.8 Set the spectrophotometer at 485 nm. Zero the instrument by setting the scale for 100 % transmission on distilled or deionized water.

A4.5.3.9 Transfer a portion of the liquid to a cuvette and record the optical density or percent transmission, depending on the original calibration. If the instrument has been fitted with an *ISV* scale, read the *ISV* directly.

A4.5.3.10 Rinse the vessels successively with tap water and distilled or deionized water as soon after test as possible. Quick rinsing minimizes the buildup of a yellow sulfur deposit. Periodically the vessels should be cleaned with sulfuric acid-dichromate cleaning solution to remove the deposit.

A4.5.3.11 Soak gaskets for a few minutes in dilute H<sub>2</sub>SO<sub>4</sub>, rinse with distilled or deionized water and hang on a glass rod to dry. (Heating the H<sub>2</sub>SO<sub>4</sub> to around 66°C during the soaking of the gaskets assists in removal of any iron compounds and helps retain resiliency of the gaskets.)

## A4.6 Calibration

A4.6.1 The spectrophotometer and cuvettes should be calibrated with standard solutions containing known amounts of iron. A typical calibration might proceed as follows:

A4.6.1.1 Prepare standard iron solution by dissolving 0.100 g of iron wire in 100 mL of 10 N H<sub>2</sub>SO<sub>4</sub>. Dilute with distilled water to 1000 mL in a volumetric flask.

A4.6.1.2 Using aliquots, also prepare 10+1 and 100+1 dilutions of this solution. These three will give standard iron solutions containing 0.1, 0.01, and 0.001 mg Fe/mL, respectively.

A4.6.1.3 Mix 25 mL of the H<sub>2</sub>SO<sub>4</sub>-H<sub>2</sub>O<sub>2</sub> and 25 mL of the NH<sub>4</sub>SCN stock solutions as in A4.5.3.3. Add 1 mL of the standard iron solution containing 0.1 mg Fe/mL. Repeat using the 0.01 and 0.001 mg Fe/mL standard iron solutions. The three mixtures will give iron solution values (*ISV*) of 100, 10, and 1, respectively.

A4.6.1.4 Measure the optical densities at a wavelength of 485 nm in a spectrophotometer and plot these against the *ISV*'s. The *ISV* is directly proportional to optical density. A typical calibration curve using a Coleman Model 6A Junior spectrophotometer<sup>11</sup> and 19 by 150-mm round cuvettes is shown in Fig. A4.1. A full logarithmic plot is used to enhance the definition at the low end of the *ISV* scale where most readings occur. Once the calibration is established the simplest procedure is to make and attach a scale to the spectrophotometer which reads directly in *ISV*.

## A4.7 Calculation

A4.7.1 If the spectrophotometer does not have an *ISV* scale, determine the *ISV* from the calibration curve for each sample including the blank.

A4.7.2 Subtract the blank *ISV* from each of the scale *ISV* readings or from the *ISV*'s obtained in A4.7.1. This is the true *ISV*.

## A4.8 Interferences

A4.8.1 *Leakers*—Sometimes leaks will occur. These are generally discovered when the vessels are opened at the end of

<sup>11</sup> Such an instrument or its equivalent has been found satisfactory.

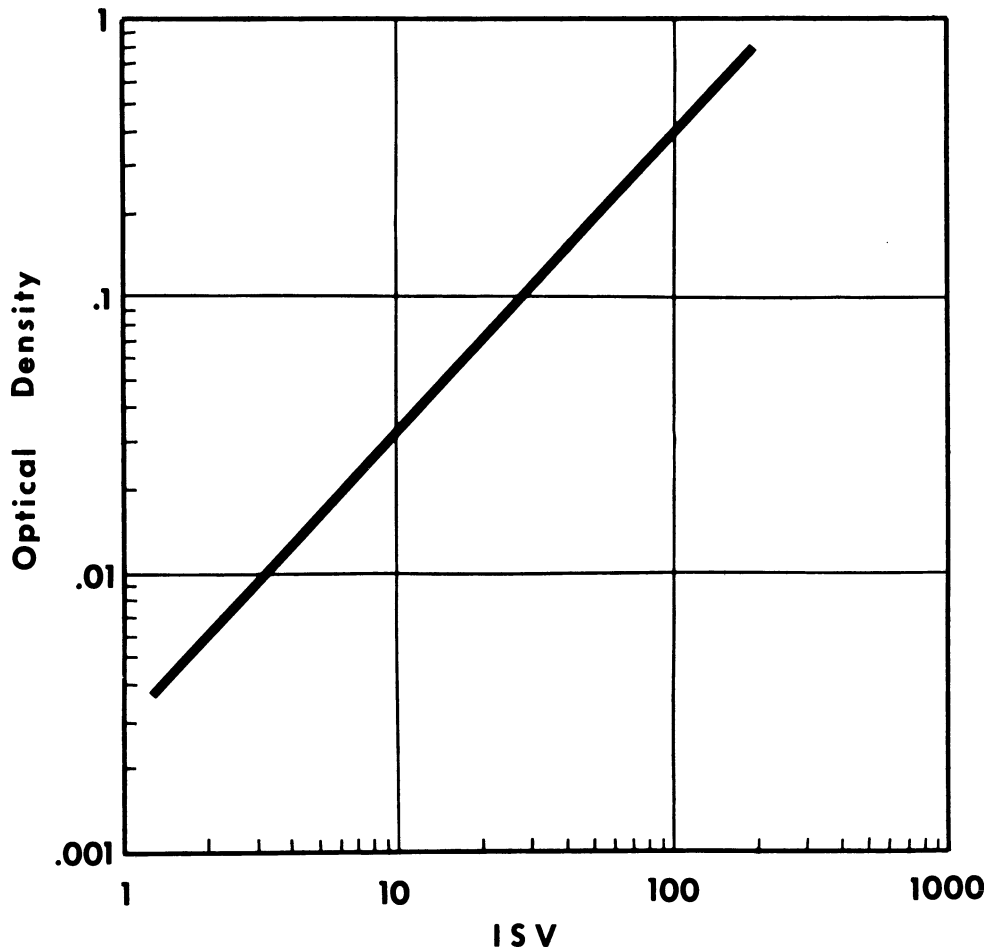


FIG. A4.1 Typical Iron Solution Value Calibration Curve

the test. If a leak has occurred, a local spot of iron-tin alloy or bare steel will show near the edge of the specimen or etching may be seen on the reverse side of the disk, or both. Sometimes the leak will not affect the ISV; at other times it may cause an extremely high ISV. Any test showing a leak or other irregularity should be discarded and a retest made.

A4.8.2 Detinning or etching of the tin plate disk by any other cause than the normal exposure to the reagents may cause erroneously high results. Such detinning or etching could be caused by, (1) inadvertent too long anodic flash or too long exposure to Na<sub>2</sub>CO<sub>3</sub> in sample preparation (see A4.5.2.1), (2) agitation, swirling, or vibration of test vessel during 2-h test time, (3) leakers, and (4) rise in temperature.

A4.8.3 Fading of the red ferric thiocyanate complex color may occur due to decomposition of the complex by excess peroxide. Delay between the adding of the peroxide at the end of the test and the reading of the optical density should be avoided. Also care should be exercised not to add more than the 1 mL of peroxide.

**A4.9 Precision**

A4.9.1 The principal source of error in reproducibility of test results is variation in the tin plate itself. Variation may

occur across the rolling width and along different portions of the same coil of tin plate. Generally plate with low ISV has much less variation than plate with high ISV. Plate Lots B, D, E, and F as follows show the type of variation that can occur when replicates of a given plate lot with all specimens closely adjacent to each other are run at one time. Plate Lots A and C show the type of variation that can occur when replicates of a given plate lot are run singly in tests over a long period of time.

Plate Lot	Iron Solution Values, mg Iron			Number of Samples
	Average	Range	Standard Deviation	
A	4.4	2-8	1.6	56
B	9.4	8-19 <sup>A</sup>	1.9	36
C	34	19-55	7.2	47
D	36	25-42	5.8	8
E	87	72-95	6.5	8
F	97	74-120	14	8

<sup>A</sup>35 of 36 samples in range from 8 to 12.

A4.9.2 It is recommended that at least one specimen from a lot of plate with known ISV be included in each test run as a control. Preferably two controls should be used; one with low ISV (2-10) and one with a higher ISV (20-40).

## A5. METHOD FOR ALLOY-TIN COUPLE TEST FOR ELECTROLYTIC TIN PLATE

### INTRODUCTION

The method described in this specification for conducting the alloy-tin couple test is one of several possible methods to obtain the same test result. It is not intended that other methods or variants of this method be precluded. Variation in apparatus, reagents, test media, and procedure from those specified may be employed for control purposes by the consumer or the supplier provided satisfactory results are obtained which correlate with the specified method.

#### A5.1 Scope

A5.1.1 The alloy-tin couple test,<sup>12</sup> also called the *ATC* test, is one of four special property tests used to measure certain characteristics of electrolytic tin plate which affect internal corrosion resistance. The test is applicable to nominal tin coating weights 5.6/2.8 g/m<sup>2</sup> and heavier electrolytic tin plate (for K-plate, see 3.1.13.2). It is not applicable to 2.8/2.8 g/m<sup>2</sup> and lighter electrolytic tin plate.

#### A5.2 Summary of Method

A5.2.1 The *ATC* test is an electrochemical procedure which involves measuring the current flowing between a pure tin electrode and an electrode consisting of a piece of tin plate from which the free (unalloyed) tin has been removed to expose the iron-tin alloy. The measurement is made after 20-h exposure of the electrodes in a medium consisting essentially of deaerated aged grapefruit juice.

#### A5.3 Apparatus

A5.3.1 *Constant-Temperature Cabinet or Room* (27 ± 0.5°C).

A5.3.2 *Test Cell* (Fig. A5.1):

A5.3.2.1 *Borosilicate Glass Test Cell*, approximately 1.5 L capacity.

A5.3.2.2 *Poly(Methyl Methacrylate) Plastic Cover* for test cell approximately 12.7 mm thick drilled with 15.9-mm diameter holes to accommodate cell elements.

A5.3.2.3 *Polychloroprene or Similar Synthetic Rubber O-Ring Gasket* to effect seal between glass vessel and plastic cover or equivalent method to effect gas-tight seal.

A5.3.2.4 *Silicone Rubber 6.35-mm Thick Grommets* to act as gas-tight holders for cell elements inserted through the plastic cover.

A5.3.3 *Magnetic Stirrer*.

A5.3.4 *Low-Resistance, High-Sensitivity Galvanometer*.<sup>13</sup>

A5.3.5 *Potentiometer* to measure the tin electrode potential. Any high-impedance voltage-measuring device such as a pH meter with a 0 to 1300-mV scale is satisfactory.

A5.3.6 *Calomel Reference Electrode* (Either saturated or 0.1 *N* is satisfactory).

A5.3.7 *Power Source* capable of supplying variable d-c voltage for use in sample preparation (cathodic cleaning 10-V dc and tin stripping 0.4-V dc reducible to 0.2 V).

A5.3.8 *Various Electrical Components* such as plugs, jacks, switches, and resistors to permit construction of circuit depicted in schematic diagram (Fig. A5.2).

A5.3.9 (*Optional*) *Special Die* for applying microcrystalline wax to mask off known areas on test specimen.<sup>8</sup>

#### A5.4 Reagents and Materials

A5.4.1 *Purity of Reagents*—Reagent grade chemicals shall be used in all tests. Unless otherwise indicated, it is intended that all reagents shall conform to the specifications of the Committee on Analytical Reagents of the American Chemical Society, where such specifications are available.<sup>10</sup> Other grades may be used, provided it is first ascertained that the reagent is of sufficiently high purity to permit its use without lessening the accuracy of the determination.

A5.4.2 *Purity of Water*—Unless otherwise indicated, references to water shall be understood to mean distilled water or water of equal purity.

A5.4.3 *Test Medium*:

A5.4.3.1 *Distilled Water or Deionized Water* of equal purity.

A5.4.3.2 *Ethanol, Denatured* (70 % volume).

A5.4.3.3 *Frozen Concentrated Grapefruit Juice*.<sup>14</sup>

A5.4.3.4 *Nitrogen Gas (High-Purity Oxygen-Free Dry Tank Nitrogen)*.

A5.4.3.5 *Potassium Sorbate*.

A5.4.3.6 *Pure Tin Wire* (approximately 3.18-mm diameter).

A5.4.3.7 *Sodium Hydroxide Solution* (NaOH) (10 %).

A5.4.3.8 *Stannous Chloride Solution* (SnCl<sub>2</sub>·2 H<sub>2</sub>O).

A5.4.4 *Sample Preparation*:

A5.4.4.1 *Acetone*.

A5.4.4.2 *Microcrystalline Wax* (140 to 145°F melting point).

A5.4.4.3 *Poly(Methyl Methacrylate) Plastic Strips* 1.59 by 14.3 by 82.6 mm.

A5.4.4.4 *Sodium Carbonate Solution* (Na<sub>2</sub>CO<sub>3</sub>) (0.5 %).

A5.4.4.5 *Sodium Hydroxide Solution* (NaOH) (5 %).

#### A5.5 Test Specimen

A5.5.1 The specimen consists of a piece of tin plate cut 12.7 by 114.3 mm with the long dimension transverse to the rolling direction.

<sup>12</sup> Kamm, G. G., Willey, A. R., Beese, R. E., and Krickl, J. L., "Corrosion Resistance of Electrolytic Tin Plate, Part 2, The Alloy-Tin Couple Test—A New Research Tool," *Corrosion*, Vol 17, 1961, p. 84.

<sup>13</sup> A Leeds and Northrup Model 2430-C, 25-Ω galvanometer with 0.003- μA/mm sensitivity or equivalent has been found satisfactory.

<sup>14</sup> Minute Maid brand frozen sweetened concentrate or its equivalent has been found satisfactory.

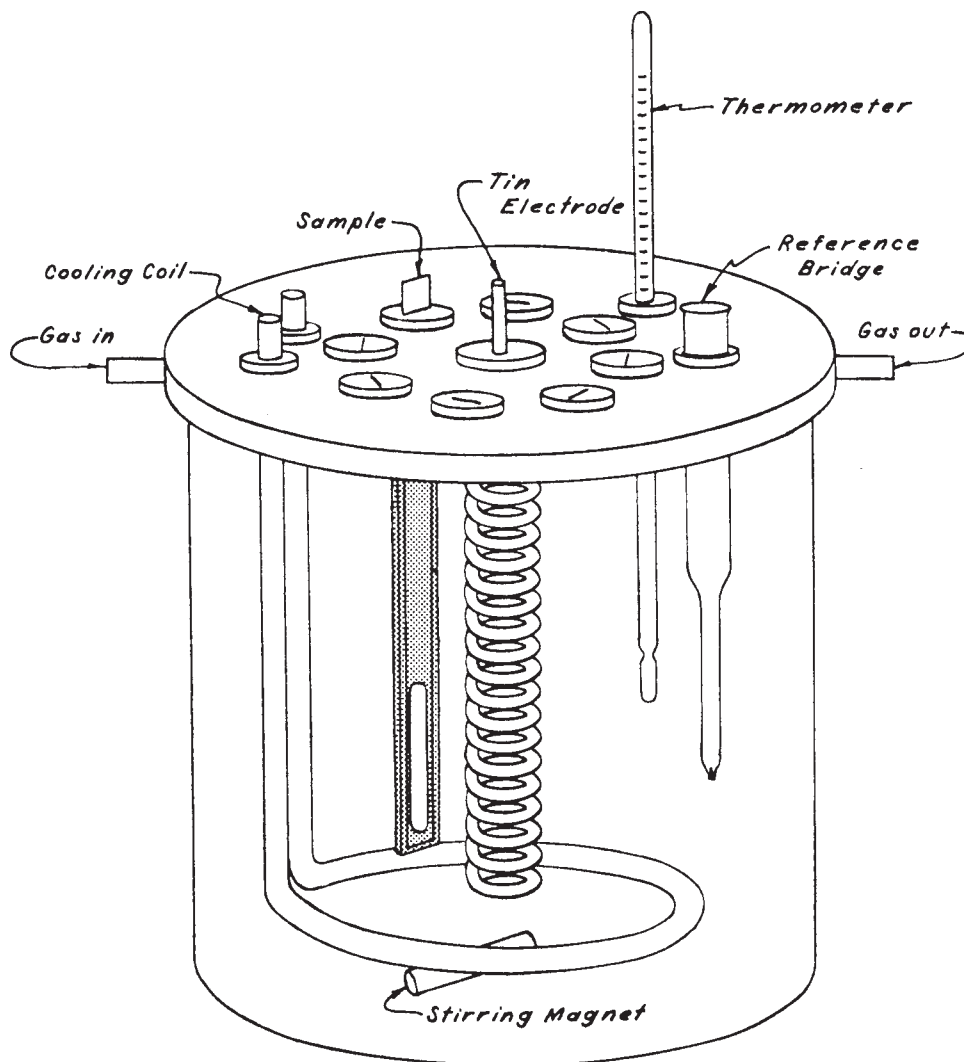


FIG. A5.1 Test Cell Used in the ATC Test

A5.5.2 Eight test specimens can be accommodated at one time in the apparatus described above. Only the number of specimens to be included in one run should be prepared at one time.

A5.5.3 Details of sample preparation are given in A5.7.

#### A5.6 Preparation of Apparatus (Fig. A5.2)

A5.6.1 Drill 15.9-mm diameter holes in 12.7-mm thick plastic cover to accommodate eight test specimens, the pure tin anode, a thermometer, and cooling coil. The reference electrode bridge can be inserted through one of the test specimen openings during potential measurement. Drill smaller diameter holes into the cover to accommodate gas inlet and outlet tubes.

A5.6.2 Cut stoppers or grommets from 6.35-mm thick silicone rubber to fit snugly in 15.9-mm diameter openings. Cut holes or slits in stoppers and grommets to hold various cell elements. Boil all rubber parts including O-ring gasket in 10 % NaOH solution for 5 min and rinse thoroughly before use in distilled or deionized water.

A5.6.3 Thoroughly clean test cell and its components and finally rinse them in ethanol just prior to use to guard against mold and yeast growth in test medium.

A5.6.4 Fit silicone rubber parts, cooling coil, thermometer, and gas tubes into the cover. Do not insert pure tin anode or test specimens at this time.

A5.6.5 Form 3.18-mm diameter pure tin wire into a loosely wound coil to give a total surface area of approximately 100 cm<sup>2</sup>. Cathodically clean in 0.5 % Na<sub>2</sub>CO<sub>3</sub> solution, rinse in tap water and in acetone.

#### A5.7 Procedure

##### A5.7.1 Test Medium:

A5.7.1.1 Place a polytetrafluoroethylene-covered magnetic stirring bar in the bottom of the test cell.

A5.7.1.2 In a separate vessel, dilute frozen concentrated grapefruit juice 3+1 with distilled or deionized water, add preservative potassium sorbate to give concentration of 0.5 g/L, deaerate by heating to boiling, and transfer to the test cell

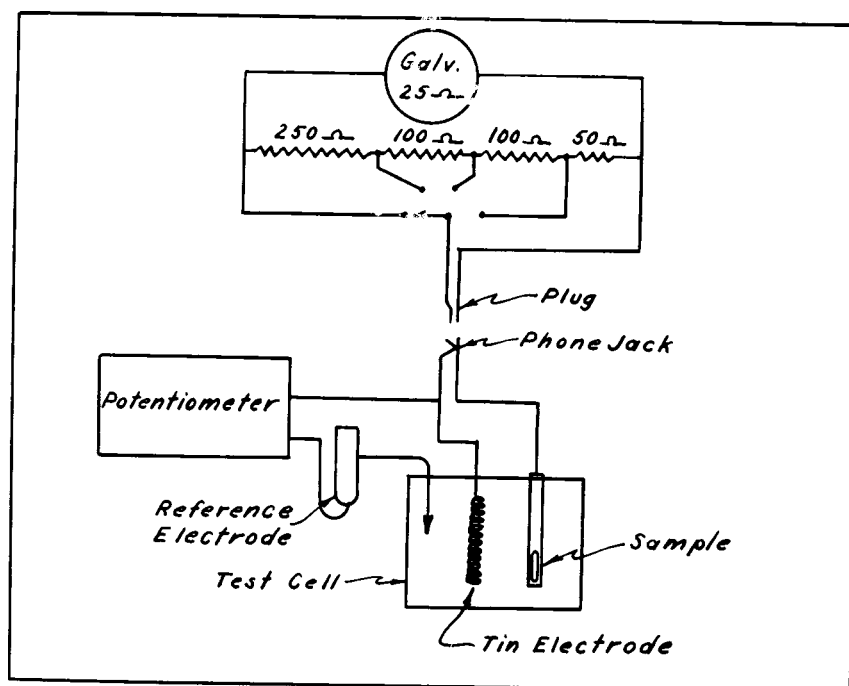


FIG. A5.2 Schematic Diagram of ATC Test Circuit

and age for not less than two days. Leave approximately 6.35-mm headspace. Turn on the magnetic stirrer.

A5.7.1.3 Assemble the plastic cover to the test cell with an O-ring or by other leak-proof seal. Begin the flow of nitrogen through the headspace. Bubble nitrogen through distilled or deionized water before entering the test cell in order to minimize evaporation of test medium. Maintain a slight positive pressure in the cell during actual test run by bubbling nitrogen from the gas outlet tube through 25.4 or 50.8 mm of water or 12.7 mm of dibutyl phthalate.

A5.7.1.4 Allow the transferred hot juice to cool for 5 min; then start cold water through the cooling coil. This minimizes settling of the pulp. Continue cooling until the test medium reaches 27°C.

A5.7.1.5 Insert the cleaned pure tin anode into the test cell.

A5.7.1.6 Add  $\text{SnCl}_2 \cdot 2\text{H}_2\text{O}$  to produce a concentration of 0.190 g/L. This yields a  $\text{Sn}^{++}$  concentration of 100 ppm. Continue stirring for 5 or 10 min to make sure the  $\text{SnCl}_2 \cdot 2\text{H}_2\text{O}$  has been dissolved.

A5.7.1.7 Discontinue stirring.

A5.7.1.8 Measure the potential of the tin electrode with a high-impedance device such as a pH meter, using calomel reference electrode. The potential of the tin anode should be -615 mV against a saturated calomel electrode or -705 mV against a 0.1 N calomel electrode.

A5.7.2 Test Specimen:

A5.7.2.1 Degrease the specimen in acetone and allow to dry.

A5.7.2.2 Clean the specimen cathodically in 0.5 %  $\text{Na}_2\text{CO}_3$  solution (carbon anode) using a current density of approximately 25 mA/cm<sup>2</sup>. A 10-V dc power source with a polarity reversing switch and the following sequence of test specimen polarity is suggested: 2 s cathodic, 0.1 s anodic, 2 s cathodic, 0.1 s anodic, 2 s cathodic. The two short anodic flash

treatments enhance the ability of the cathodic treatments to remove oxides and impurities from the surface and secure absence of water break on the test specimen. Rinse the specimen in tap water, distilled water, and acetone and allow to dry.

A5.7.2.3 Detin the specimen electrolytically in a 5 % NaOH solution at room temperature. The specimen is the anode and a piece of stainless steel is the cathode. The area of the stainless steel cathode should be 5 to 10 times as large as the area being detinned in order to give a high anode current density and hence rapid detinning. Carry out the detinning at a constant 0.40-V dc maximum (in this method a 0.1-Ω resistor is placed in parallel with the detinning circuit to assure constant voltage). As detinning nears completion, it is possible a small area or a few isolated spots will be slow to detin. Reducing the voltage to 0.20 V speeds up the detinning of these last few spots. For convenience, detin several specimens simultaneously all connected in parallel to the power source. When this is done it is usually necessary to reduce the voltage to 0.20 V only for the last sample remaining in the detinning set up. Remove the specimen from the detinning solution with the power on to prevent reversal of the current and replating of tin as a result of the primary cell effect. Do not leave the detinned specimen in the detinning bath longer than 5 min. The electrolyte and the detinning procedure have been so chosen to remove completely all the free (unalloyed) tin and to prevent any attack whatever on the iron-tin alloy layer. Rinse specimen sequentially in tap water, distilled water, and acetone and allow to dry.

A5.7.2.4 Mask the specimen with hot microcrystalline wax to expose a given test area. This may be done by hand brushing or by mechanical means provided the test surface is not damaged or contaminated in the process. Area variations

between 0.5 and 4.0 cm<sup>2</sup> do not affect the *ATC* measurement. It is strongly recommended that an area of 2.3 cm<sup>2</sup> be used in the test. A die that produces an outline of wax exposing 2.3 cm<sup>2</sup> is available (A5.3.9). After the test area has been outlined, manually wax the specimen to a thin plastic backing (A5.4.4.3) making certain all edges and surfaces other than the test area are covered.

#### A5.7.3 Current Measurement:

A5.7.3.1 Connect the test specimen to the tin anode electrically before inserting the specimen in the test cell to assure continuous galvanic protection of the alloy surface (for the same reason, refer to Fig. A5.2 and note that the phone jacks are the *shorting* type). All test specimens are coupled to the single tin anode.

A5.7.3.2 After 20 h, measure the current flowing between the tin anode and each individual specimen with a low-resistance, high-sensitivity galvanometer (A5.3.4). The test cell must be free from vibration during the time the specimens are in the cell.

A5.7.3.3 Include at least one test specimen with known *ATC* value in each run in each cell to act as a control for that run. Preferably two controls should be used: one with a known low *ATC* value and one with a known high *ATC* value.

A5.7.3.4 Use a given batch of aged juice for repeated test runs for a period of about 3 to 4 weeks. Make a fresh batch sooner if there are signs of mold growth or fermentation.

### A5.8 Calculation

A5.8.1 Divide the current flowing between the electrodes by the area of the exposed alloy on the test specimen measured in square centimetres. Report the *ATC* in microamperes per square centimetre.

### A5.9 Hazards

A5.9.1 It is important to maintain oxygen-free conditions in the cell. During insertion and removal of the test specimen in the cell increase the nitrogen flow somewhat to prevent entry of air. Air causes increased *ATC* values and reduces differences between good and poor plate.

A5.9.2 Take care to avoid vibration during the test run. Do not bump or disturb the electrodes before taking current measurements.

A5.9.3 Different batches of juice will vary slightly in corrosivity or pH or both. This could affect the potential of the tin anode. Regardless of the original potential in a given batch of juice, the addition of 100 ppm Sn<sup>++</sup> shifts the potential approximately 50 mV in the cathodic (positive) direction.

A5.9.4 Temperature of microcrystalline wax during masking should be sufficiently high to assure good adhesion to the test specimen but not so high as to run and distort the test area.

A5.9.5 Reliable *ATC* data depend to a large extent on proper test specimen preparation. Once preparation has begun the test area should not be touched, scratched, or otherwise contaminated in any way.

## A6. METHODS FOR DETERMINATION OF TOTAL SURFACE OIL ON TIN MILL PRODUCTS

### A6.1 Scope

A6.1.1 This method covers the determination of the total extracted oil on the surface of tin mill products.

### A6.2 Summary of Method

A6.2.1 The oil on the surface of the strips of plate is removed with boiling chloroform or equivalent. The chloroform or equivalent is evaporated to dryness and the residue is weighed.

### A6.3 Significance and Use

A6.3.1 The amount of surface lubricating oil on the surfaces of tin mill products is critical and can be cause for users complaint. Insufficient lubricant can contribute to poor sheet mobility and poor lithography; excessive lubricant can contribute to eyeholing or dewetting of certain organic coatings.

### A6.4 Apparatus

A6.4.1 *Slotted Mandrel* with handle for coiling the strips.

A6.4.1.1 A 12.7-mm diameter slotted mandrel is used for high-temper materials and a 25.4-mm diameter slotted mandrel is used for low-temper plate.

### A6.5 Reagents

A6.5.1 *Chloroform* (CHCl<sub>3</sub>), distilled reagent grade or equivalent.

### A6.6 Hazards

A6.6.1 **Caution**—Chloroform vapors present a potential health hazard. The cleaning of equipment, extraction, and evaporation of the chloroform should be done in an exhaust hood.

### A6.7 Test Specimen

A6.7.1 The samples are generally sheets of plate such as used for can making. The sample sheets should be transported between two protection sheets and the edges covered with masking or equivalent tape. The four edges of the test sheets should be trimmed to remove possible contaminant of the tape adhesive.

### A6.8 Preparation of Apparatus

A6.8.1 Clean the shears for cutting the plate into strips, coiling mandrel, pliers, and forceps with chloroform or equivalent.

A6.8.2 The glassware must be rinsed with boiling chloroform or equivalent.

A6.8.3 Wear clean white cloth gloves when handling plate.

### A6.9 Procedure

A6.9.1 Cut the sample of plate at least 3225 cm<sup>2</sup>(preferably 6450 cm<sup>2</sup>) into 50.8-mm wide strips.

A6.9.2 Determine the exact area of plate (length by width by number of strips).



A6.9.3 Coil strips using the coiling mandrel by holding one end of the strip with pliers. Insert the other end in the slot of the mandrel. Coil the strips around the mandrel tightly using the pliers to maintain tension.

A6.9.4 Heat two 250-mL beakers of chloroform or equivalent to boiling. Using forceps dip the coils 4 or 5 times in one beaker and then rinse similarly in the second beaker. After all the coils have been extracted, filter the chloroform or equivalent, while hot, through filter paper into a 500-mL Erlenmeyer flask. Boil off the chloroform or equivalent to a volume of approximately 10 mL. Transfer this to a previously cleaned, dried, and weighed 10-mL beaker. While the chloroform or equivalent is boiling from the small beaker, rinse the Erlenmeyer flask two or three times with small portions of chloroform or equivalent and add each rinsing to the 10-mL beaker. When

nearly all the chloroform or equivalent has evaporated from the 10-mL beaker, place the beaker in an oven at 105°C for 10 min, cool in a desiccator, and reweigh. Make a blank determination using a similar volume of chloroform or equivalent. The blank should not exceed 0.0002 g.

### A6.10 Calculation

A6.10.1 Calculate the weight of oil per square metre as follows:

$$\text{mg/m}^2 = \frac{W \times 10\,000}{A}$$

where:

$W$  = weight of extracted oil, mg, and

$A$  = area of sample, cm<sup>2</sup>.

To convert to g/SITA: divide mg/m<sup>2</sup> by 10.

## A7. DETERMINATION OF CHROMIUM ON TIN PLATE BY THE DIPHENYL CARBAZIDE METHOD

### A7.1 Scope

A7.1.1 This method<sup>15</sup> covers the determination of chromium on tin plate with the use of diphenylcarbazide.

### A7.2 Reagents

A7.2.1 *Purity of Reagents*—Reagent grade chemicals shall be used in all tests. Unless otherwise indicated, it is intended that all reagents shall conform to the specifications of the Committee on Analytical Reagents of the American Chemical Society, where such specifications are available.<sup>10</sup> Other grades may be used, provided it is first ascertained that the reagent is of sufficiently high purity to permit its use without lessening the accuracy of the determination.

A7.2.2 *Purity of Water*—Unless otherwise indicated, references to water shall be understood to mean distilled water or water of equal purity.

A7.2.3 *Chromate, Standard Solution A* (1 mL = 0.5 mg Cr)—Dissolve 1.410 g of K<sub>2</sub>Cr<sub>2</sub>O<sub>7</sub> in water and dilute to 1.0 L.

A7.2.4 *Chromate, Standard Solution B* (1 mL = 10.0 µg Cr)—Pipet 20 mL of the chromate Standard Solution A into a 1.0-L volumetric flask and add water to 1.0 L.

A7.2.5 *Diphenylcarbazide Reagent*—Add 10.0 mL of acetone, 10.0 mL of 95 % ethyl alcohol, and 20.0 mL of H<sub>3</sub>PO<sub>4</sub>(85 % acid diluted with an equal volume of water).

A7.2.6 *Hydrochloric Acid* (HCl) (sp gr 1.19).

A7.2.7 *Potassium Permanganate Saturated Solution* (KMnO<sub>4</sub>).

A7.2.8 *Sodium Hydroxide* (1.0 N)—*Trisodium Phosphate* (5 %) *Solution*—Dissolve 40.0 g of NaOH and 50.0 g of Na<sub>3</sub>PO<sub>4</sub> in water and dilute to 1.0 L.

A7.2.9 *Sulfuric Acid* (1+3)—Add 100 mL of H<sub>2</sub>SO<sub>4</sub>(sp gr 1.84) slowly and with stirring to 300 mL of water.

### A7.3 Procedure

A7.3.1 Use for analysis a sample having 52 cm<sup>2</sup> of surface area (one 26-cm<sup>2</sup> disk). If both sides of the sample are to be

stripped, slightly bend the disk through the center so it will not lie entirely flat. If only one side of the sample is to be stripped, hold the disk tightly against a rubber stopper. The stopper should be slightly larger in diameter than the disk and grooved to allow vacuum from a tube in the center to be applied to most of the surface of the disk. Leave intact a band approximately 3.2 mm wide at the perimeter of the stopper.

A7.3.2 Place the sample in a 250-mL beaker, add 25 mL of NaOH-Na<sub>3</sub>PO<sub>4</sub> solution, and heat to boiling. Boil for 1½ min. Transfer the solution to another 250-mL beaker, washing disk and beaker once with water. Add 25 mL of H<sub>2</sub>SO<sub>4</sub>(1+3) to the original beaker and sample, heat to boiling, and boil 1 min. Transfer the acid solution to the beaker containing the alkaline stripping solution, washing sample and beaker with two small portions of water. If both sides of the disk are being stripped, it is necessary to swirl the beaker continually over the flame while the H<sub>2</sub>SO<sub>4</sub> is boiling. This is necessary to keep the surface completely wetted and strip all of the chromium from the surface of the tin plate.

A7.3.3 Heat the sample solution to boiling and add 1 to 2 drops of saturated KMnO<sub>4</sub> solution. This amount is usually sufficient to maintain a pink color. Boil 3 to 4 min for complete oxidation of chrome. Add 5 drops of HCl (sp gr 1.19) to the sample and continue to boil until all pink color is dispelled. More acid may be used if needed. The beaker should be covered when boiling to avoid any loss that may be caused by spattering.

A7.3.4 Transfer to a 100-mL volumetric flask and cool to approximately 70°F (21°C) in a water bath. Add 3.0 mL of diphenylcarbazide reagent, make to mark with distilled water, and mix.

A7.3.5 Determine optical density, within 30 min after the addition of diphenylcarbazide reagent to the sample, at 540 nm.<sup>16</sup>

<sup>15</sup> Furman, N. H., "Chromium in Acid Solution with Diphenylcarbazide," *Scott's Standard Methods of Chemical Analysis*, Vol 1, 1962, pp. 357–359.

<sup>16</sup> The Coleman Spectrophotometer with 1.5-cm cell is a suitable instrument.

A7.3.6 A reagent blank and a standard including all solutions used in treating a sample should be carried along with each set of samples.

#### A7.4 Calibration of Spectrophotometer

A7.4.1 Add to 250-mL beakers duplicate 0.5, 1.0, 1.5, 2.0, 2.5, and 3.0-mL aliquots of the chromate Standard Solution B and carry through the entire procedure for a sample. Also run reagent blanks in duplicate.

A7.4.2 Calculate a constant,  $K$ , for the instrument as follows:

$$K = (\mu\text{g Cr}) / (\text{O.D.}_1 - \text{O.D.}_2)$$

where:

$\text{O.D.}_1$  = optical density for the standard, and  
 $\text{O.D.}_2$  = optical density for the blank.

#### A7.5 Calculation of Chromium on Tin Plate

A7.5.1 Report chromium on tin plate as micrograms of chromium per square foot of surface area, as follows:

$$\text{Cr, } \mu\text{g/ft}^2 = [144 K (\text{O.D.}_1 - \text{O.D.}_2)] / A$$

where:

$K$  = constant for spectrophotometer and cell used to determine optical density,  
 $\text{O.D.}_1$  = optical density of sample,  
 $\text{O.D.}_2$  = optical density of reagent blank, and  
 $A$  = area of sample used.

### A8. METHOD FOR AERATED MEDIA POLARIZATION TEST FOR ELECTROLYTIC TIN PLATE

#### INTRODUCTION

The Aerated Media Polarization (AMP) test was originally developed at Weirton Steel Corporation by James A. Bray and J. Robert Smith (see U.S. Patent No. 3,479,256) as a quick, accurate replacement for the Alloy Tin Couple (ATC) test developed by G. Kamm at American Can Company. The AMP test results are obtained in a few minutes as compared to a minimum 20 h for ATC results. This has proven invaluable to tinplate producers who then can make adjustments during actual production.

#### A8.1 Scope

A8.1.1 The AMP test is one of four special property tests used to measure certain characteristics of electrolytic tin plate that affect internal corrosion resistance. The test is applicable to No. 50 (5.6), No. 50/25 (5.6/2.8), and heavier electrolytic tin plate, used for K-plate.

#### A8.2 Summary of Method

A8.2.1 This method is an electrochemical procedure that involves measuring the current flowing between a pure tin electrode and an electrode consisting of a piece of tin plate from which the free (unalloyed) tin has been removed to expose the iron-tin alloy. Both electrodes are immersed in grapefruit juice concentrate (GFJ) or its equivalent.

#### A8.3 Apparatus

A8.3.1 *Test Cell* (see Fig. A8.1).

A8.3.2 *AMP Analyzer* (see Fig. A8.2).

A8.3.3 *dc Power Supply*, capable of supplying 3 to 4 A at 10 to 12 V and means of reversing polarity.

A8.3.4 *Three Laboratory Hot Plates*—Thermolyne-type P 100, Model HP-A1915B, or equivalent.

A8.3.5 *Crystallizing Dish*, 150-mm diameter, 25-mm depth.

A8.3.6 *Watch Glass*, 115-mm diameter.

A8.3.7 *Two 250-mL Beakers*—Griffin low form.

A8.3.8 *Two Watch Glasses*, for the 400-mL beakers.

A8.3.9 *Three 400-mL Beakers*—Berzelius (tall form without pouring spout).

A8.3.10 *Timer or Stopwatch*, capable of reading to the nearest second.

A8.3.11 *400-mL Beaker*, stainless steel.

A8.3.12 *Levelling Funnel*.

A8.3.13 *22.2-mm Inside Diameter O-Ring*—387 mm<sup>2</sup>.

#### A8.4 Reagents and Materials

A8.4.1 *Purity of Reagents*—Reagent grade chemicals shall be used in all tests. Unless otherwise indicated, it is intended that all reagents shall conform to the specifications of the Committee on Analytical Reagents of the American Chemical Society, where such specifications are available.<sup>10</sup> Other grades may be used, provided it is first ascertained that the reagent is of sufficiently high purity to permit its use without lessening the accuracy of the determination.

A8.4.2 *Purity of Water*—Unless otherwise indicated, references to water shall be understood to mean distilled water or water of equal purity.

A8.4.3 *Anhydrous Acetone*.

A8.4.4 *Stripping Solution*.

A8.4.4.1 *5.0 % (by weight) sodium hydroxide, (NaOH)*, in distilled water.

A8.4.4.2 *1.0 % (by weight) potassium iodate (KIO<sub>3</sub>)*, in distilled water.

A8.4.5 *0.5 M Citric Acid*—9.1 g anhydrous citric acid per 1 L distilled water.

A8.4.6 *Potassium Sorbate*.

A8.4.7 *Frozen Sweetened Grapefruit Juice Concentrate (GFJ)*.

A8.4.8 *Equivalent to GFJ*, when dissolved in 500 mL of distilled water:

A8.4.8.1 5 g citric acid,

A8.4.8.2 2.5 g sodium citrate,

A8.4.8.3 17.5 g fructose,

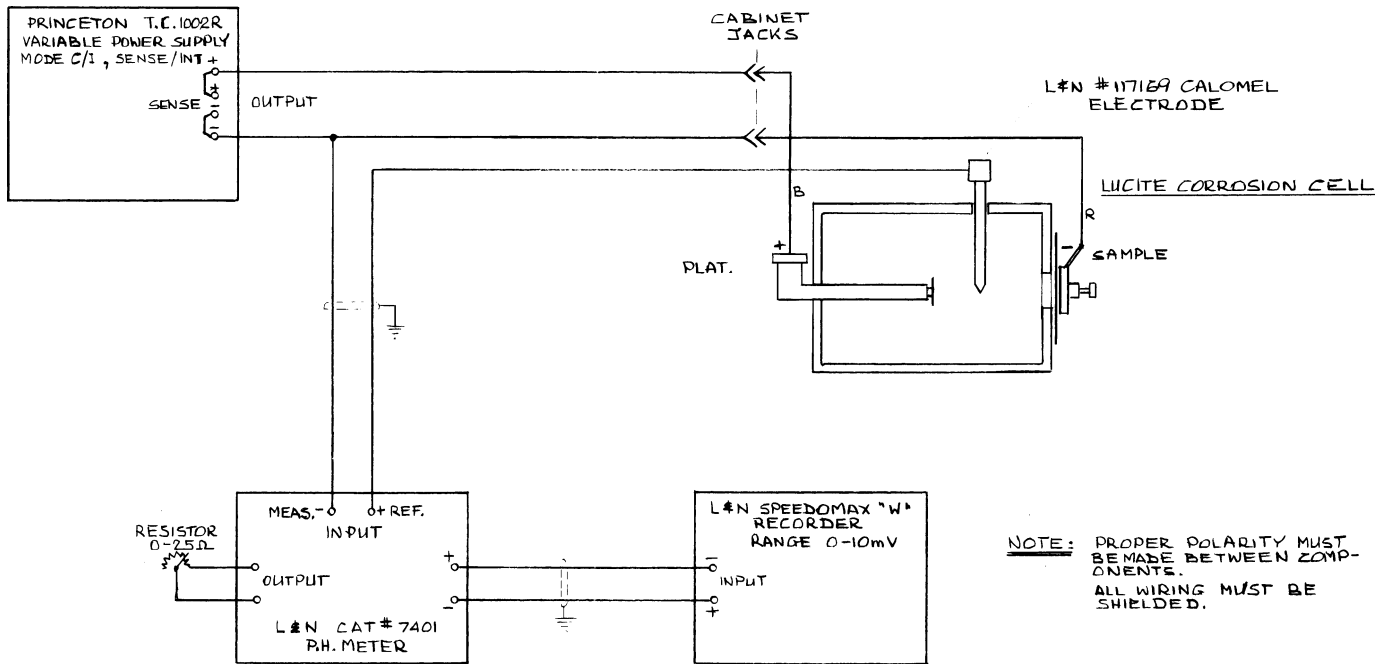


FIG. A8.1 Wiring Schematic for AMP Test

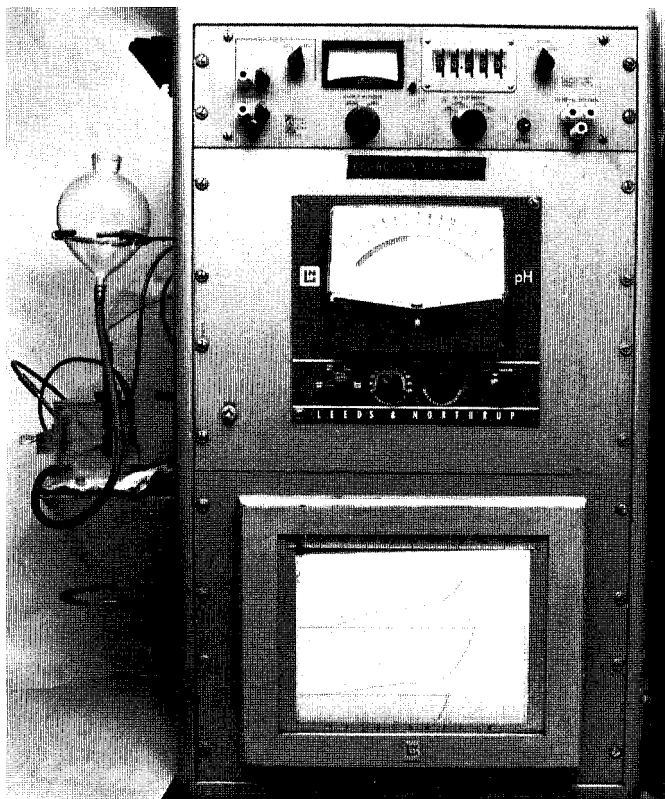


FIG. A8.2 Corrosion Analyzer (AMP)

### A8.5 Test Media

A8.5.1 The 575-mL size cans of grapefruit juice concentrate are thawed, opened, and diluted with 510 mL of distilled water per can. The resulting single strength GFJ is filtered under vacuum through silica sand to remove most of the pulpy material.

A8.5.2 To retard spoilage, 0.5 g of potassium sorbate per can is added to the GFJ. It has been found convenient to prepare the GFJ in five can batches and keep it refrigerated until needed. The GFJ must be prepared at least 24 h prior to usage to allow it to stabilize.

A8.5.3 Enough GFJ to fill the cell, 400 mL, is brought to room temperature, 22 to 23°C, and poured into the levelling funnel.

A8.5.4 Under normal conditions, this 400-mL aliquot of juice will yield about 200 results before it need be discarded. Worn-out juice is indicated by a marked decrease or offset, or both, in the slope of the standard curve.

### A8.6 Test Specimen

A8.6.1 Samples, 3.81 cm wide by any convenient length, 12.7 to 25.4 cm are cut from the tin plate area to be tested. The sample identification is scribed across the top side (or heavy-coated side) of the test piece. The following procedure is recommended for cathodic cleaning to remove the oil film and chemical treatment films without opening pores in the free tin and alloy layers.

### A8.7 Sample Preparation

A8.7.1 In a 1 % solution of  $\text{Na}_2\text{CO}_3$  at room temperature, using mild steel anodes, make the sample cathodic for 3 s, then anodic for 3 s, and finally cathodic for 3 s. Current densities of 222 to 223  $\text{A/m}^2$  are satisfactory. Rinse the sample thoroughly in distilled water dip in hot acetone and dry in air.

A8.4.8.4 25 g sucrose, or

A8.4.8.5 0.25 g potassium sorbate.

A8.4.8.6 Prepare fresh for each occasion of testing.

A8.4.9 *Cleaning Solution*—1 % (by weight) sodium carbonate in 1500 mL of distilled water.

NOTE A8.1—The final current polarity *must be cathodic* for rapid removal of the free tin in subsequent steps.

A8.7.2 Two of the hot plates should be located near a sink where distilled water is plentiful. The third hot plate should be next to the AMP analyzer.

A8.7.3 The crystallizing dish, with the 115-mm watch glass placed in it, is filled to a depth of 3.81 cm with stripping solution and placed on one of the two hot plates. The hot plate should be adjusted to maintain the solution at 40°C.

A8.7.4 The two 250-mL beakers and the 400-mL stainless steel beaker are placed on the second hot plate. Fill one of the 250-mL beakers with stripping solution to a depth slightly less than 3.81 cm. Fill the second 250-mL beaker with a 0.5 M citric acid solution to a depth of about 5.08 cm. Fill the 400-mL beaker two thirds full of acetone. Adjust this hot plate so that the acetone almost boils.

A8.7.5 The remaining two 400-mL beakers are placed on the hot plate located adjacent to the analyzer. One should be two thirds full of acetone. The other is two thirds filled with water for rinsing samples following testing. The samples can then be dried and stored for possible retesting.

A8.7.6 Place a sample upright in the crystallizing dish of stripping solution allowing it to lean against the side of the dish. The submerged 115-mm watch glass prevents the sample from falling into the solution. When the last visible trace of free tin dissolves, immediately transfer the sample to the 250-mL beaker containing a second stripping solution. After  $30 \pm 5$  s, remove the sample and rinse in running distilled water.

A8.7.7 Place the sample in the beaker containing citric acid. Swish around 4 to 5 times. Remove the sample and rinse very thoroughly in running distilled water. Dry the sample in the first beaker of hot acetone and transfer it to the second beaker of hot acetone. It is now ready for insertion into the cell.

### A8.8 Aerated Media Polarization Test

A8.8.1 The AMP analyzer settings should be as follows:

Mode Switch:	Position 1 (range card switch in recorder set to Position B)
Zero Adjust Pot:	200 mV (on upper scale)
Current Range:	0.5–5.0 mA
Polarizing Current:	0.800 mA

A8.8.2 Remove the sample from the acetone beaker and allow it to air dry.

A8.8.3 Place the detinned portion of the sample between the O-ring and the follower plate (heavy-coated side to be facing electrode). Tighten the follower just enough to prevent leakage around the O-ring.

NOTE A8.2—Overtightening will drastically reduce the life of the O-ring and may even cause it to be torn loose from the cell.

A8.8.4 Open the stopcock on the levelling funnel and allow the cell to fill with GFJ. (As the cell fills, it is a good technique to tip the cell slightly to preclude trapping air bubbles on the test area.)

A8.8.4.1 Turn voltage switch on.

A8.8.4.2 Turn chart switch on.

A8.8.4.3 As pen point reaches an accented line on the chart paper, turn current switch on.

A8.8.4.4 After 90 s (7.62 cm of chart travel) read the end potential as chart divisions (to nearest tenth).

A8.8.4.5 Repeat A8.8.4.1 through A8.8.4.4, in reverse order, turning switches off to discontinue test.

A8.8.5 Lower the levelling funnel to drain the cell, loosen the follower plate, and remove the sample. Dry the O-ring and follower plate to remove any droplets of GFJ that may have spilled during removal of sample. (It has been found convenient to do this by folding 4 to 5 paper towels together and cutting them into 3.81-cm widths. These can be inserted between the O-ring and the follower plate to effect the removal of any spillage.) The cell and analyzer are now ready for another test.

### A8.9 Interpretation of Results

A8.9.1 In any batch of samples to be run several standards, covering the range of ATC values from about 0.015 to 0.300  $\mu\text{a}/\text{cm}^2$ , are interspersed. The potential values (chart readings at 90 s) for these are plotted versus their known ATC values on 1.2 cycle ( $E_{90}$ ) by 2 cycle (ATC) log-log paper. The best straight line is then drawn through these points to obtain the standard curve (Fig. A8.3).

A8.9.2 The AMP value (equivalent ATC) for the unknown can then be obtained from this standard curve.

A8.9.2.1 *Temperature*—Close temperature control of the GFJ is as critical in this test as it is in the ATC test. Therefore, it is important that the analyzer and cell be installed in a location where temperature can be closely monitored.

(1) It is strongly recommended that the temperature variations of the GFJ be no more than  $\pm 1^\circ\text{F}$  during testing. It is possible to thermostat only the cell, but this would defeat the ease and speed of inserting and removing samples.

A8.9.2.2 *Standard*—Standards for calibration should be developed in the following manner:

(1) Secure 40 to 50 consecutive sheets from a differentially coated coil of tin plate. (This prevents the top and bottom surfaces from getting mixed when the 3.81-cm wide samples are cut.)

(2) Shear the edges from these sheets so that only about 25.4 cm or 27.9 cm of the center of the original sheet width remains.

(3) Select the first, middle, and last sheets of the number taken and cut 3.81-cm wide samples from each across the rolling direction, perpendicular to the (25.4 to 27.94 cm) dimension.

(4) Note, however, that all of the preceding precautions should be observed in obtaining tin plate for this treatment.

A8.9.3 These standards may be obtained by testing 40 to 50 samples of differentially coated tinplate and performing the ATC test in accordance with ASTM.

A8.9.4 Six standards are probably the minimum requirement. The values of these should be well spaced along the standard curve:

- 1—0.015  $\mu\text{a}/\text{cm}^2$  (approximately)
- 2—0.030
- 3—0.060
- 4—0.100
- 5—0.180
- 6—0.300

A8.9.5 If difficulty is experienced in obtaining 1 or 2, it has been found that subjecting the tin plate to a 10-min heating

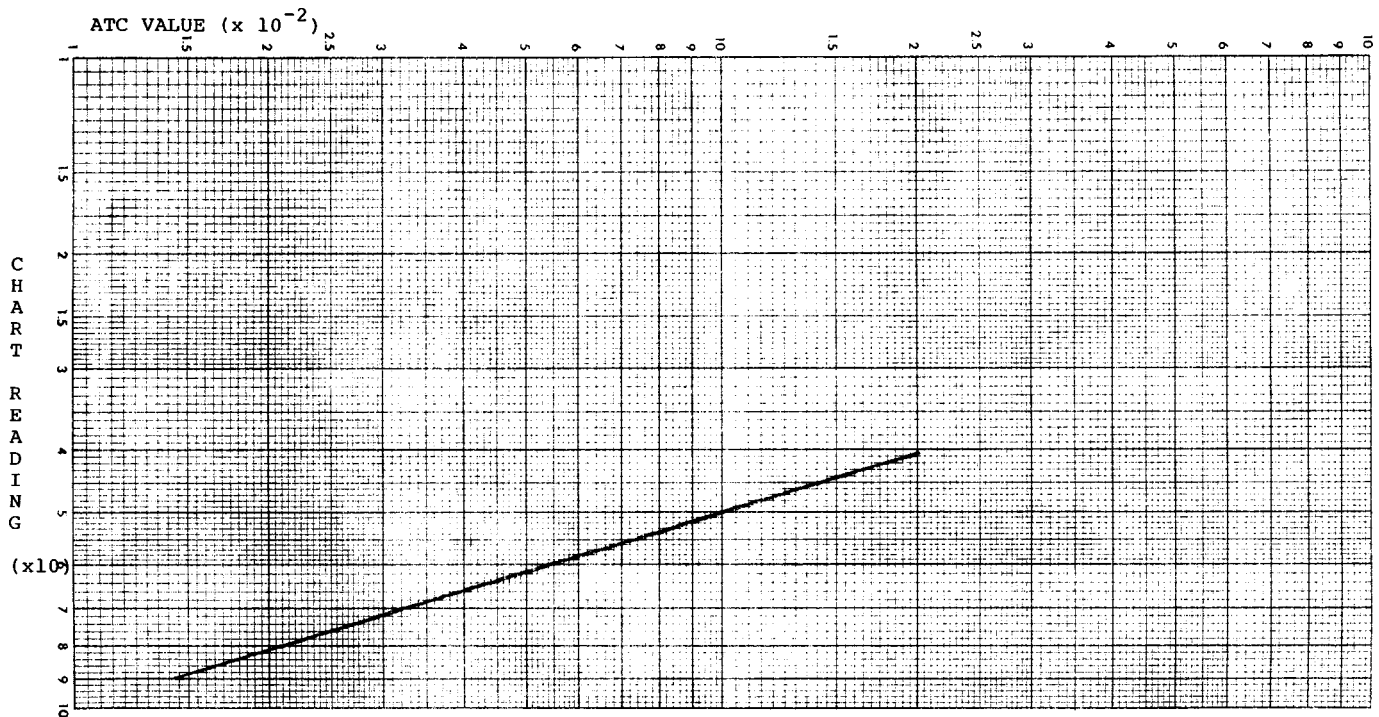


FIG. A8.3 ATC Conversion Chart from Typical Calibration Curve

cycle at 420°F will result in a five- to ten-fold reduction in ATC value.

**A9. METHOD FOR DETERMINING DRAWING TENDENCIES OF TIN MILL PRODUCTS USING A MODUL-R DEVICE**

**A9.1 Scope**

A9.1.1 This method is used to assess drawing tendencies of tin mill products. These tendencies commonly are termed R-bar (normal anisotropy) and  $\Delta r$  (planar anisotropy or earing) and are indicators of a metal's performance during operations, such as can drawing. This procedure provides a method for rapidly approximating the drawing tendencies of tin mill products.

A9.1.2 The drawing tendencies of tin mill products can be rapidly determined using a device called a Modul-R. This device has been used successfully for a material thickness as low as 0.155 mm. The test can be performed on tin plate coatings as heavy as 2.8 g/m<sup>2</sup> without removing the tin coating. If the tin coating weight exceeds 2.8 g/m<sup>2</sup>, the coating should be chemically stripped.

**A9.2 Terminology**

A9.2.1 *Definitions of Terms Specific to This Standard:*

A9.2.1.1 *Modul-R, n*—the device used to measure the resonating frequency of a steel strip sample. The resonating frequency is used to calculate drawing properties, such as R-bar and  $\Delta r$ .

A9.2.1.2 *R-bar, n*—the unitless property of a material used to describe its ability to be drawn. It is a ratio of the average properties in the plane of the sheet to those in the thickness of the sheet. Commonly, it is referred to as “normal anisotropy.”

A9.2.1.3  *$\Delta r, n$* —the unitless property of a material used to describe the variation of properties within the plane of a sheet of material. It also signifies the degree of earing during drawing. Negative values indicate earing will occur in a direction of 45° to the direction of rolling. Positive values indicate earing will occur in a directions along and perpendicular to the direction of rolling. A  $\Delta r$  value of 0 is ideal.  $\Delta r$  commonly is referred to as “planar anisotropy.”

**A9.3 Summary of Method**

A9.3.1 Three rectangular coupons are blanked from a flat sheet of material such that they align with the rolling direction of the material, perpendicular to the rolling direction, and at a 45° angle to the rolling direction. These samples are then placed into a Modul-R testing device where they are vibrated to a resonant frequency. The resultant resonant frequencies then are converted to drawing properties. Minor corrections for surface roughness and thickness effects also are taken into account. The final results are reported as an R-bar value and a  $\Delta r$  value.

**A9.4 Apparatus**

A9.4.1 Modul-R testing device (see Fig. A9.1), surface roughness measurement device, and a micrometer are to be used.



FIG. A9.1 Modul-R Device

### A9.5 Sample Preparation

A9.5.1 Three test samples are blanked from a material to be evaluated. The three samples must be secured such that one is parallel to the rolling direction, one is perpendicular to the rolling direction, and one is at an angle of 45° to the rolling direction. The samples must be sheared to dimensions of 104.63 mm long and 6.35 mm wide. The 104.63-mm dimension allows for easy calculations later in the test method under A9.6.1. Any burrs should be removed with light sanding using a 400-grit paper. TFS coatings or tin plate coatings less than or equal to 2.8 g/m<sup>2</sup> need not be removed.

### A9.6 Procedure

A9.6.1 *Surface Roughness and Thickness Determination*—The surface roughness of the material must be measured to the nearest 0.025 micron using a surface roughness measurement device. Thickness of the material also must be measured to the nearest 0.0025 mm using a micrometer.

A9.6.2 *Frequency Testing of Blanked Samples*—Frequency testing is performed in accordance with the instructions provided by the vendor of the Modul-R device. For convenience they are listed here as follows:

A9.6.2.1 Place the sample in the slot marked *sample* on the right side of the panel. Move the sample into the slot until it has stopped within the holder.

A9.6.2.2 Pull the sample out from the holder just enough to relieve it from the stop. In this position, the sample should have about 6 mm protruding from the surface of the front panel.

A9.6.2.3 Place the bias switch in the positive (+) position.

A9.6.2.4 Place the normal/phase switch in the normal position.

A9.6.2.5 Push the test switch down and note the brightness of the amber indication light marked *oscillator*, and the reading on the counter. Within a few seconds the reading should stabilize between 23.5 and 26.5 kHz with the amber light glowing.

NOTE A9.1—If the amber light does not come on, comes on very dimly, or the reading is either high, low or rapidly fluctuating, remove the sample and reposition it in the sample slot. Turn the sample around end to end or turn it over and again try to obtain a reading. If necessary hold the test button and gently jog the sample in the sample slot. If no reading can be obtained, return the sample to its original position in the sample slot and move the bias switch to the negative (–) position. If the light still fails to come on, reposition the sample as described above. If up to this point normal oscillation will not take place, start again with the sample in the normal position and move the normal/phase switch to the phase position and repeat above steps until a reading is obtained. If no reading can be obtained after all the above steps have been performed, a micrometer should be used to check the parallel sides of the sample. Readings should not vary by more than 0.025 mm. Sample should not be bent, and all rough edges should be sanded smooth. In some instances when readings cannot be obtained from 45° samples, punching an additional sample from the sheeting at approximately 5° from the 45° position will provide a proper reading.

A9.6.2.6 Note the reading on the meter as soon as this occurs. Record it as f0 (frequency reading for sample punched parallel to the rolling direction), f90 (frequency reading for sample punched perpendicular to the rolling direction), and f45 (frequency of reading for sample punched 45° to the rolling direction).

A9.6.3 *Calculation of Drawing Properties*—R-bar values and Δr values can be calculated or obtained from tables. The first step in the process requires converting the frequency values determined above to modulus or E values. The E values

then are adjusted based on surface roughness and thickness effects. The corrected E values then are converted to E-bar and ΔE values. The E-bar and ΔE values finally are converted to R-bar and Δr values.

A9.6.3.1 If the sample length (described in A9.5) is 104.63 mm, then E values are determined from frequency values by using the following equation:

$$E = f^2/20 \quad (A9.1)$$

where:

E = the modulus value, and

f = the frequency obtained from A9.6.2.

NOTE A9.2—The E obtained from the f0 value should be noted as E0, the E from the f45 value should be noted as E45, and the E from the f90 value should be noted as E90.

NOTE A9.3—If the sample length (described in A9.5) is different from 104.63 mm, the E values must be obtained from the following equation:

$$E = 0.0000045671 l^2 f^2 \quad (A9.2)$$

where:

E = the modulus value,

l = the length of the sample in mm (measured to the nearest 0.25 mm), and

f = the frequency obtained from A9.6.2.

A9.6.3.2 The E values are then corrected for the effect of surface roughness and thickness as follows:

$$E_c = E (1 + 2S/T) \quad (A9.3)$$

where:

E<sub>c</sub> = the new corrected modulus value,

E = the original modulus value,

S = the surface roughness in microns (measured to the 0.025 microns), and

T = the thickness in inches (measured to the nearest 0.0025 mm).

NOTE A9.4—The corrected E values should be distinguished by direction as indicated above, that is, E<sub>c0</sub>, E<sub>c45</sub>, and E<sub>c90</sub>.

A9.6.3.3 Calculate E-bar and ΔE values are by the following equations:

$$E\text{-bar} = (E_{c0} + E_{c90} + 2E_{c45}) / 4 \quad (A9.4)$$

$$\Delta E = (E_{c0} + E_{c90} - 2E_{c45}) / 2$$

A9.6.3.4 Determine R-bar by converting from E-bar to R-bar by using the following equation:

$$R\text{-bar} = 101.44 / (E\text{-bar} - 38.83)^2 - 0.564 \quad (A9.5)$$

A9.6.3.5 Determine Δr by converting from ΔE by using the following equation:

$$\Delta r = 0.031 - 0.323 (\Delta E) \quad (A9.6)$$

## A9.7 Precision

A9.7.1 Aside from the normal variation of the product being measured, the precision of the input variables to the above equations can effect the reported final results. The length and width of the blanked samples should not vary by more than ±0.25 mm from the recommended blank dimensions. The thickness of the material should be measured to the nearest 0.0025 mm. The surface roughness should be measured to the nearest 0.025 micron.

## A9.8 Keywords

A9.8.1 Modul-R; R-bar; Δr

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# Standard Specification for Tin Mill Products, Electrolytic Tin Plate, Single Reduced<sup>1</sup>

This standard is issued under the fixed designation A 624/A 624M; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon ( $\epsilon$ ) indicates an editorial change since the last revision or reapproval.

*This standard has been approved for use by agencies of the Department of Defense.*

## 1. Scope\*

1.1 This specification covers single-reduced electrolytic tin plate produced from low-carbon cold-reduced steel furnished in coils and cut sizes for use in the manufacture of cans, closures, crowns, and other products. It is furnished in commercially available tin coating weights [masses], and is normally supplied with a trimmed edge.

1.2 This specification is applicable to orders in either inch-pound units (as A 624) which is supplied in nominal thicknesses from 0.0061 to 0.0149 in. or SI units [as A 624M] which is supplied in nominal thicknesses from 0.155 to 0.378 mm.

1.3 The values stated in either inch-pound or SI units are to be regarded as standard. Within the text, the SI units are shown in brackets. The values stated in each system are not exact equivalents. Therefore, each system must be used independently of the other. Combining values from the two systems may result in nonconformance with this specification.

1.4 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

## 2. Referenced Documents

### 2.1 ASTM Standards:<sup>2</sup>

A 623 Specification for Tin Mill Products, General Requirements

A 623M Specification for Tin Mill Products, General Requirements (Metric)

A 630 Test Methods for Determination of Tin Coating Weights for Hot-Dip and Electrolytic Tin Plate

A 754 Test Method for Coating Thickness by X-Ray Fluorescence

B 339 Specification for Pig Tin

## 3. Ordering Information

3.1 Orders for product under this specification shall include the following information, as required and applicable, to describe adequately the desired product:

3.1.1 Name of product (single-reduced electrolytic tin plate) (Section 1),

3.1.2 Tin coating weight [mass] designation and marking, if any (Section 4, Table 1, and Fig. 1 and Fig. 2),

3.1.3 Surface appearance and finish (Section 5),

3.1.4 Chemical treatment (Section 6),

3.1.5 Oiling (Section 7),

3.1.6 Thickness (Specification A 623 [A 623M]) (this must be consistent with the intended application),

3.1.7 Coil width or cut size in increments of  $\frac{1}{16}$  in. or 1 mm,

3.1.8 Where required, rolling direction will be specified on cut sizes and will be indicated by underlining the slit (rolling width) dimension,

3.1.9 Steel type (Specification A 623 [A 623M]),

3.1.10 Temper designation (Specification A 623 [A 623M]) (this must be consistent with the intended application),

3.1.11 Intended application,

3.1.12 Quantity in base boxes (SITAS) (see Note 4),

3.1.13 On coils, specify minimum or range of acceptable inside diameters. The standard inside diameter is approximately 16 in. if ordered as A 624 [410 mm if ordered as A 624M]. Coils should be specified to a maximum coil weight if ordered as A 624 [mass if ordered as A 624M], or maximum outside diameter or both,

3.1.14 Packaging,

3.1.15 Special requirements where applicable, J = plate or K = plate, and

3.1.16 ASTM specification designation and year of issue.

NOTE 1—A typical ordering description for coils is as follows: 1250 base boxes, single reduced, electrolytic tin plate, No. 20, DOS, L, T-5 CA, 7C, 0.0088 in. thickness  $3\frac{1}{4}$  in. by coil, 16 in. inside diameter, 65 in. maximum outside diameter, 25 000 lbs maximum coil weight, for 300 diameter sanitary open top ends in accordance with Specification A 624/A 624M - XX. [250 SITAS, single reduced electrolytic tin plate, 2.2/2.2,

<sup>1</sup> This specification is under the jurisdiction of ASTM Committee A01 on Steel, Stainless Steel and Related Alloys and is the direct responsibility of Subcommittee A01.20 on Tin Mill Products.

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<sup>2</sup> For referenced ASTM standards, visit the ASTM website, [www.astm.org](http://www.astm.org), or contact ASTM Customer Service at [service@astm.org](mailto:service@astm.org). For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

\*A Summary of Changes section appears at the end of this standard.



**TABLE 1 Electrolytic Tin Plate Coating Weight [Mass]**

NOTE 1—Listed below are commonly produced coating weights [masses]. By agreement between the producer and the purchaser, other combinations of the coatings may be specified and the appropriate minimum average test values will apply.

Designation No.	Nominal Tin Coating Weight [Mass] each Surface, lb/base box [g/m <sup>2</sup> ]	Minimum Average Coating Weight [Mass] each Surface Test Value, lb/base box <sup>A</sup> [g/m <sup>2</sup> ]
5 [0.6/0.6] <sup>B</sup>	0.025/0.025 [0.6/0.6]	0.02/0.02 [0.5/0.5]
10 [1.1/1.1]	0.05/0.05 [1.1/1.1]	0.04/0.04 [0.9/0.9]
15 [1.7/1.7]	0.075/0.075 [1.7/1.7]	0.06/0.06 [1.4/1.4]
20 [2.2/2.2]	0.10/0.10 [2.2/2.2]	0.08/0.08 [1.8/1.8]
25 [2.8/2.8]	0.125/0.125 [2.8/2.8]	0.11/0.11 [2.5/2.5]
35 [3.9/3.9]	0.175/0.175 [3.9/3.9]	0.16/0.16 [3.6/3.6]
50 [5.6/5.6]	0.25/0.25 [5.6/5.6]	0.23/0.23 [5.2/5.2]
75 [8.4/8.4]	0.375/0.375 [8.4/8.4]	0.35/0.35 [7.8/7.8]
100 [11.2/11.2]	0.50/0.50 [11.2/11.2]	0.45/0.45 [10.1/10.1]
D 50/25 [D 5.6/2.8] <sup>C</sup>	0.25/0.125 [5.6/2.8]	0.23/0.11 [5.2/2.5]
D 75/25 [D 8.4/2.8]	0.375/0.125 [8.4/2.8]	0.35/0.11 [7.8/2.5]
D 100/25 [D 11.2/2.8]	0.50/0.125 [11.2/2.8]	0.45/0.11 [10.1/2.5]
D 100/50 [D 11.2/5.6]	0.50/0.25 [11.2/5.6]	0.45/0.23 [10.1/5.2]
D 135/25 [D 15.2/2.8]	0.675/0.125 [15.2/2.8]	0.62/0.11 [14.0/2.5]

<sup>A</sup>The minimum spot value shall be not less than 80 % of the minimum average coating weight [mass] (see 4.3 and 4.4).

<sup>B</sup>Some No. 5 melted applications may require revised minimum and maximum levels for fully alloyed end uses.

<sup>C</sup>The letter D on differentially coated tin plate indicates the coated surface to be marked. For example, the examples indicate that the heavy-coated side is marked (see 4.1.2 and 4.1.3).

DOS, L, T-5, 7C, 0.22 mm thickness, 794 mm by coil, 410 mm inside diameter, 1650 mm maximum outside diameter, 11 500 kg maximum coil mass, for 73-mm diameter sanitary open top ends in accordance with Specification A 624/A 624M - XX.]

NOTE 2—A typical ordering description for cut sizes is as follows: 500 base boxes, single reduced electrolytic tin plate, No. 25, DOS, MR, T-2BA, 7C, 0.0110 in. thickness, 30 ¾ in. by 30 ⅙ in., for 307 diameter general line rings in accordance with Specification A 624/A 624M - XX. [100 SITAS, single reduced electrolytic tin plate, 2.8/2.8, DOS, MR, T-2, 7C, 0.28 mm thickness, 781 by 773 mm, for 83-mm diameter general line rings in accordance with Specification A 624/A 624M - XX.]

NOTE 3—The production of coils does not afford the same opportunity for inspection, grading, and sorting as does the production of cut sizes. Accordingly, appropriate processing and quality-control procedures are required by the purchaser to obtain optimum utilization of the material. Cut sizes are line inspected visually and mechanically during production. Sheets having surface imperfections that will not interfere with their utilization are included.

NOTE 4—In inch-pound units, single reduced electrolytic tin plate is supplied on an area basis expressed in base boxes. In coils the number of base boxes is computed from the measured length and the specified width. In cut sizes the number of base boxes is computed from the specified length and width dimensions and sheet count. [In SI units, single-reduced electrolytic tin plate is supplied on an area basis expressed in SITAS. In coils, the number of SITAS is computed from the measured length and the specified width. In cut sizes, the number of SITAS is computed from the specified length and width dimensions and sheet count]. For calculating mass, the density of steel for tin mill products is 0.2836 lb/in.<sup>3</sup>[7850 kg/m<sup>3</sup>].

## 4. Tin Coating Weight [Mass]

### 4.1 Class Designations and Marking:

4.1.1 Electrolytic tin plate is commonly produced to the class designations shown in Table 1. Other combinations of coatings may be specified by agreement between the producer and the purchaser.

4.1.2 Differentially coated tin plate is a product having one surface more heavily tin coated than the opposite. The class designation is expressed by showing the two tin coating weights [masses] separated by a slash mark, for example, D50/25 [D5.6/2.8]. The first number will represent the coating weight [mass] on the outside of the coil or the top surface of the cut sizes.

4.1.3 In order to distinguish material having differential coatings, the face with the heavier coating is normally marked. By arrangement, a special marking can be supplied on the light-coated face (see Fig. 1 and Fig. 2). The letter *D* is shown along with the coating number to indicate the side of the plate to be marked.

### 4.2 Sampling for Tin Coating Weights [Masses]:

4.2.1 When the purchaser wishes to make tests to ascertain compliance with the requirements of this specification for tin coating weight [mass] on a lot of any specific item of electrolytic tin plate, the following procedure shall be used:

4.2.1.1 *Coils*—One test strip shall be taken at random from a representative section of each coil across its width. A minimum of three test strips, each taken from different coils from any one item of a specific lot shall be selected.

4.2.1.2 From one or two coil lots, each coil shall be sampled. A minimum of three randomly selected test strips shall represent the lot.

4.2.1.3 *Cut Sizes*—One sheet shall be taken at random from each 50 packages, or part thereof, with a minimum of three different sample plates, each taken from different bundles from any one item of a specific shipment.

4.2.2 Each test sheet shall be spot tested at a minimum of three locations across the rolling direction of the sheet. Spot tests are customarily disks or squares 4 in.<sup>2</sup> [26 cm<sup>2</sup>] in area; other sizes may be used. In order to secure representative samples, the following procedure shall be used:

4.2.2.1 All test spots are taken on a center line at right angles to the rolling direction.

4.2.2.2 No test spots shall be closer than 1 in. [25 mm] from the mill-trimmed edge of the test sheets.

4.2.2.3 No test spots shall be closer than 2 in. [50 mm] from one another.

4.2.2.4 If the minimum of three test spots are taken they shall be edge, center, and edge tests.

4.2.2.5 The average of all spot tests on all test strips or sheets represents the average coating weight [mass] test value.

4.3 Coating weight [mass] test values shall conform to the values shown in Table 1.

4.4 *Determination of Tin Coating Weights [Masses]*—Typical methods for determination of tin coating weights [masses] are described in Test Methods A 630. An acceptable method for determining tin coating weight [mass] is the X-ray fluorescence method, performed in accordance with Test Method A 754. In cases of dispute, Method B, Referee Method, shall be used.

4.5 Pig tin used in the production of tin plate shall be Grade A as shown in the latest revision of Specification B 339.

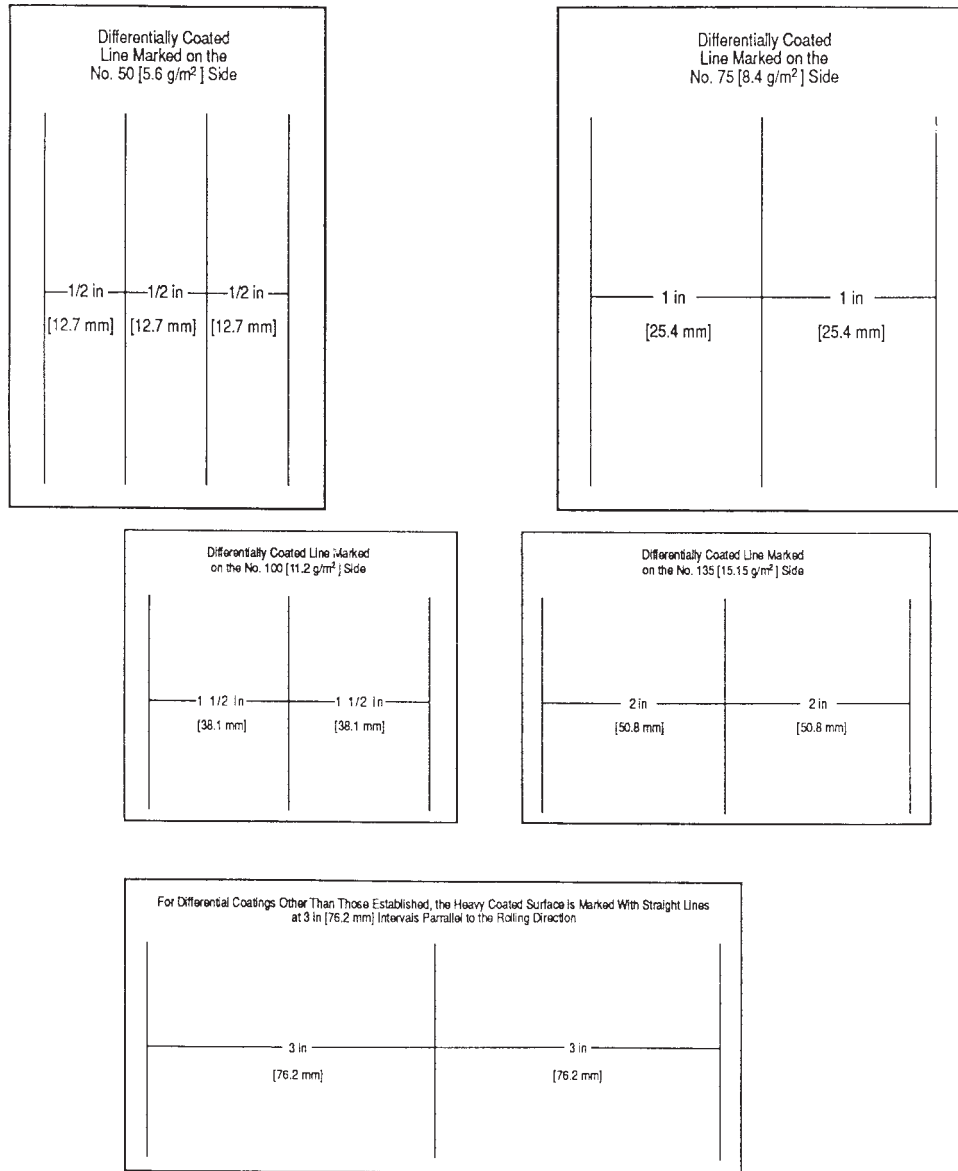


FIG. 1 Standard Heavy Side Marking System for Differential Electrolytic Tin Plate

## 5. Surface Appearance and Finish

5.1 *Surface Appearance*—Single-reduced electrolytic tin plate is customarily produced with a melted coating (bright). Unmelted coating (matte) is also available.

5.2 *Base Metal Finish*—Single-reduced electrolytic tin plate is produced with ground roll finishes and shot-blasted roll finishes as follows:

5.2.1 *Ground Roll Finishes* (produced as either melted or unmelted coatings):

5.2.1.1 *7B*—A smooth finish which may contain fine grit lines. This finish is specified for special applications.

5.2.1.2 *7C*—A smooth finish with grit lines. The surface roughness will range between 10 and 25  $\mu\text{in. Ra}$  [0.254 to 0.635  $\mu\text{m Ra}$ ]. This is the standard finish for tin mill products.

5.2.2 *Blasted and/or Otherwise Textured Roll Finishes* (produced as either melted or unmelted coatings):

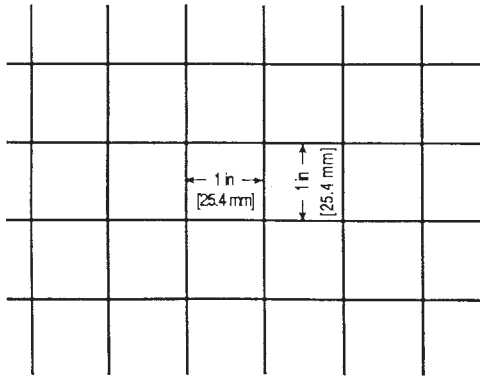
5.2.2.1 *5C*—A shot blasted finish (SBF) for general applications. The surface roughness will range from 30 to 60  $\mu\text{in. Ra}$  [0.760 to 1.52  $\mu\text{m Ra}$ ].

5.2.2.2 *5D*—A shot blasted finish (SBF) for special applications.

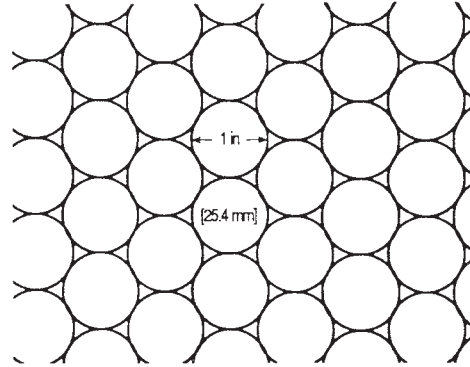
## 6. Chemical Treatment

6.1 Electrolytic tin plate as produced without a surface chemical treatment is subject to tin oxide growth that is manifested by surface discoloration during storage and subsequent baking operations and may adversely affect application and adhesion of organic coatings and lithography, and may cause poor solderability. A chemical treatment is therefore applied in most cases after the tin coating has been deposited and immediately preceding the oiling, to control tin oxide formation and growth. The chemical treatment is applied by passing the strip through a chemical solution with or without

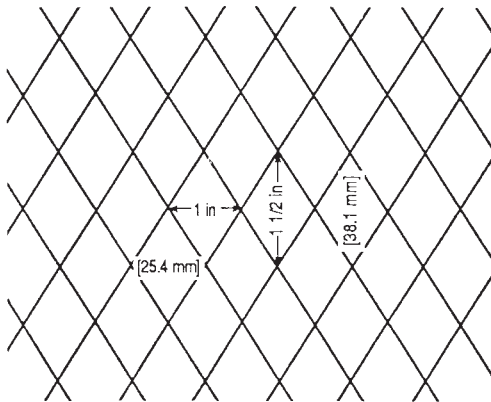
Differentially Coated No. 50 [5.6 g/m<sup>2</sup>],  
Square Marked on the Opposite (Light) Side



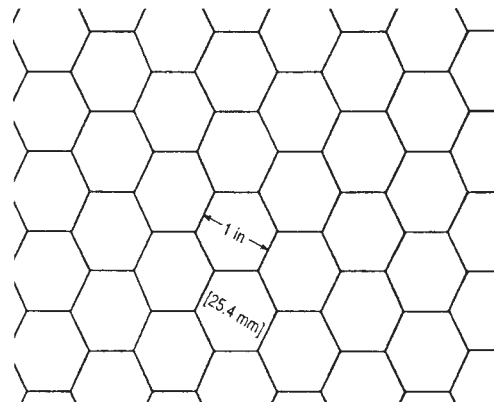
Differentially Coated No. 75 [8.4 g/m<sup>2</sup>],  
Circle Marked on the Opposite (Light) Side



Differentially Coated No. 100 [11.2 g/m<sup>2</sup>], Diamond  
Marked on the Opposite (Light) Side



Differentially Coated No. 135 [15.15 g/m<sup>2</sup>], Hexagon  
Marked on the Opposite (Light) Side



For Differential Coatings Other Than Those Established,  
the Lighter Coated Surface is Marked With Sine Waves

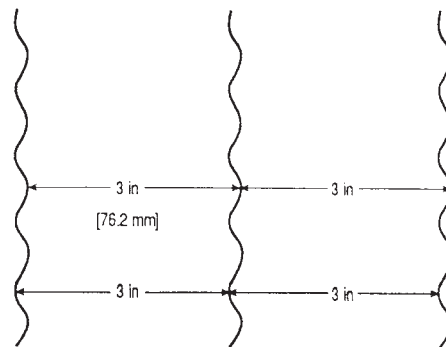


FIG. 2 Standard Light Side Marking System for Differential Electrolytic Tin Plate

current. Chemical treatments on electrolytic tin plate are applied commensurate with each supplier's method and equipment; however, one of the controlling factors is the amount of combined chromium present on the surface. Unless otherwise specified, the surface chemical treatment will be left to the discretion of the tin plate producer.

6.2 In order of decreasing surface passivation, the commonly used chemical treatments for tin plate are as follows:

6.2.1 *Cathodic Sodium Dichromate (CDC) Treatment:*

6.2.1.1 The cathodic sodium dichromate treatment is the most widely used treatment, and provides a highly passivated surface against the formation of tin oxides. It has the following attributes: (1) minimum tin oxide growth after prolonged storage; (2) minimized discoloration during subsequent baking required for organic coatings and lithography; (3) minimized discoloration due to soldering operation; and (4) provides some resistance to tin sulfide discoloration of certain sulfur-bearing food products.

6.2.1.2 Cathodic sodium dichromate-treated tin plate has an aim range of 350 to 650  $\mu\text{g}$  of chromium per square foot of surface. [4000 to 7000  $\mu\text{g}$  of chromium per square metre of surface.]

6.2.2 *Sodium Dichromate Dip (SDCD/SDD) Treatment:*

6.2.2.1 The sodium dichromate dip treatment provides moderate passivation against tin oxide formation.

6.2.2.2 Sodium dichromate dip-treated tin plate has a maximum of 200  $\mu\text{g}$  of chromium per square foot of surface. [2200  $\mu\text{g}$  of chromium per square metre of surface.]

## 7. Oiling

7.1 Electrolytic tin plate is furnished with an oil film applied to both surfaces. The most commonly used oil films are dioctyl sebacate (DOS) and acetyl tributyl citrate (ATBC). Other oil films may be used. Surface active agents such as glycerol monooleate (GMO) may be incorporated into the oil films for application on tin plate.

7.2 Unless indicated by the purchaser the specific oiling treatment will be left to the discretion of the tin plate producer.

7.3 *Weight [Mass] of Oil Films*—The weight [mass] of oil film as applied by the supplier of tin plate normally ranges from approximately 0.10 to 0.40 g/base box [0.50 to 2.00 g/SITA (5 to 20  $\text{mg}/\text{m}^2$ )]. Specific aim ranges required for particular end uses and handling practices may be supplied as agreed upon between the producer and the purchaser.

## 8. General Requirements for Delivery

8.1 Material furnished under this specification shall conform to the applicable requirements of the current edition of Specification A 623 [A 623M], unless otherwise provided herein.

## 9. Keywords

9.1 coated steel sheet; tin mill products; tin plate

## SUMMARY OF CHANGES

Committee A01 has identified the location of selected changes to this standard since the last issue (A 624/A 624M - 98) that may impact the use of this standard.

A 624/A 624M - 03:

(1) Changed metric decimal thickness from two significant figures to three significant figures in paragraph 1.2.

(2) Minor editorial corrections were made throughout the standard.

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## Standard Specification for Tin Mill Products, Black Plate, Single-Reduced<sup>1</sup>

This standard is issued under the fixed designation A 625/A 625M; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reappraisal. A superscript epsilon ( $\epsilon$ ) indicates an editorial change since the last revision or reappraisal.

### 1. Scope

1.1 This specification covers single-reduced black plate produced from low carbon, cold-reduced steel, furnished in coils and cut sizes, for use in the manufacture of containers, closures, signs, toys and other products, as well as for plating applications.

1.2 It may be supplied dry or oiled and with or without surface treatment. This product is normally supplied with a trimmed edge.

1.3 This specification is applicable to orders in either inch-pound units (as A 625), which is supplied in thicknesses from 128-lb base weight (0.0141 in.) and lighter, or SI units (as A 625M), which is supplied in thicknesses from 0.358 mm and lighter.

1.4 The values stated in either inch-pound or SI units are to be regarded as standard. Within the text, the SI units are shown in brackets. The values stated in each system are not exact equivalents; therefore, each system must be used independently of the other. Combining values from the two systems may result in nonconformance with this specification.

### 2. Referenced Documents

#### 2.1 ASTM Standards:

A 623 Specification for Tin Mill Products, General Requirements<sup>2</sup>

A 623M Specification for Tin Mill Products, General Requirements [Metric]<sup>2</sup>

### 3. Ordering Information

3.1 Orders for product under this specification shall include the following information, as required and applicable, to adequately describe the desired materials.

3.1.1 Name of product (single-reduced black plate).

3.1.2 Surface appearance and finish (Section 4).

3.1.2.1 Dry.

3.1.2.2 Oiled (type of oil; mineral or suitable for lithographing) (Section 5).

3.1.2.3 Chemically treated and oiled (see Specification A 623 or Specification A 623M).

3.1.3 Thickness (see Specification A 623 or Specification A 623M).

3.1.4 Width.

3.1.5 Length, for cut sizes only.

3.1.6 Rolling direction must be specified by underlining the steel (rolling width) for cut sizes.

3.1.7 Steel type (see Specification A 623 or Specification A 623M).

3.1.8 Mechanical designation requirements (see Specification A 623 or Specification A 623M).

3.1.9 Intended application.

3.1.10 Quantity, in base boxes [SITAs] (see Note 5).

3.1.11 On coils, specify minimum of range or acceptable inside diameters. The standard inside diameter is approximately 16 in. if ordered to Specification A 625 [410 mm if ordered to Specification A 625M]. Coils should be specified to a maximum coil weight if ordered to Specification A 625 [mass if ordered to Specification A 625M] or maximum outside diameter, or both.

3.1.12 Packaging.

3.1.13 ASTM specification designation and year of issue.

3.1.14 Special requirements, where applicable.

NOTE 1—A typical ordering description is as follows: 1000 Base Boxes, Single-Reduced Black Plate, oiled, 80 lb base weight, 30 in. by coil, MR, T5CA for lithographed can bodies to ASTM A 625/A 625M - XX. [600 SITAs, Single-Reduced Black Plate, oiled, 0.25 mm, 810 mm by coil, MR, T5CA for lithographed can bodies to Specification A 625/A 625M.

NOTE 2—A typical ordering description for cut sizes is as follows: 500 Base Boxes, Single Reduced Black Plate, oiled, 80 lb base weight MR, T-2 BA, 7C, 30<sup>3</sup>/<sub>16</sub> in. by 30<sup>7</sup>/<sub>16</sub> in., for lithographed can bodies in accordance with Specification A 625/A 625M - XX. [100 SITAs, Single Reduced Black Plate, oiled, MR, T-2 BA, 7C, 0.28 mm thickness, 781 by 773 mm, for lithographed can bodies in accordance with Specification A 625M/A 625M - XX.]

NOTE 3—The production of coils does not afford the same opportunity for inspection, grading, and sorting as does the production of cut sizes. Accordingly, appropriate processing and quality control procedures are required by the purchaser to obtain optimum utilization of the material. Cut sizes are line-inspected visually and mechanically during production. Sheets having surface imperfections that will not interfere with their utilizations are included.

NOTE 4—Single-reduced black plate is highly susceptible to rusting and must be properly handled during transit and storage.

<sup>1</sup> This specification is under the jurisdiction of ASTM Committee A01 on Steel, Stainless Steel, and Related Alloys and is the direct responsibility of Subcommittee A01.20 on Tin Mill Products.

Current edition approved September 10, 2003. Published November 2003. Originally approved in 1968. Last previous edition approved in 1998 as A 625/A 625M – 98.

<sup>2</sup> Annual Book of ASTM Standards, Vol 01.06.

NOTE 5—In inch-pound units single-reduced black plate is supplied on an area basis expressed in base boxes. In coils, the number of base boxes is computed from the measured length and the specified width. In cut lengths, the number of base boxes is computed from the specified length and width dimensions and sheet count. For calculating mass, the density of steel for tin mill products is 0.2836 lbf/in.<sup>3</sup>. In SI units single-reduced black plate is supplied on an area basis computed in SITAs. In coils, the number of SITAs is computed from the specified length and the specified width. In cut lengths, the number of SITAs is computed from the specified length and width dimensions and sheet count. For calculating mass, the density of steel for tin mill tests is 7850 kg/m<sup>2</sup>.

#### 4. Surface Appearance and Finish

4.1 *Surface Appearance*—Single-reduced black plate is customarily produced with ground roll and shot-blasted roll finishes as follows:

##### 4.1.1 *Ground-Roll Finishes:*

4.1.1.1 7A—A lustrous smooth finish intended for electroplating by the purchaser.

4.1.1.2 7B—A smooth finish that may contain fine grit lines. This finish is specified for special applications.

4.1.1.3 7C—A smooth finish with grit lines. The surface roughness will range from 10 to 25  $\mu\text{in. Ra}$  [0.254 to 0.635  $\mu\text{m Ra}$ ]. This is the standard finish for tin mill products.

##### 4.1.2 *Blasted and/or Otherwise Textured Roll Finishes:*

4.1.2.1 5A—A shot-blasted finish (SBF) intended for lithographing.

4.1.2.2 5C—A shot-blasted finish (SBF) for general applications. The surface roughness will range from 30 to 60  $\mu\text{in. Ra}$  [0.760 to 1.52  $\mu\text{m Ra}$ ].

#### 5. Oiling

5.1 Black plate is furnished oiled or dry. Unless indicated by the purchaser, single-reduced black plate will be supplied dry. Any required oiling treatment will be negotiated between the purchaser and the supplier.

#### 6. General Requirements for Delivery

6.1 Product furnished under this specification shall conform to the applicable requirements of the current edition of Specification A 623 or Specification A 623M unless otherwise provided herein.

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*This standard is subject to revision at any time by the responsible technical committee and must be reviewed every five years and if not revised, either reapproved or withdrawn. Your comments are invited either for revision of this standard or for additional standards and should be addressed to ASTM International Headquarters. Your comments will receive careful consideration at a meeting of the responsible technical committee, which you may attend. If you feel that your comments have not received a fair hearing you should make your views known to the ASTM Committee on Standards, at the address shown below.*

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## Standard Specification for Tin Mill Products, Electrolytic Tin Plate, Double Reduced<sup>1</sup>

This standard is issued under the fixed designation A 626/A 626M; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reappraisal. A superscript epsilon ( $\epsilon$ ) indicates an editorial change since the last revision or reappraisal.

*This standard has been approved for use by agencies of the Department of Defense.*

### 1. Scope\*

1.1 This specification covers double-reduced electrolytic tin plate produced from low-carbon cold-reduced steel furnished in coils and cut sizes for use predominately in the manufacture of cans. It is furnished in commercially available tin coating weights [masses] and is normally supplied with a trimmed edge.

1.2 This specification is applicable to orders in either inch-pound units (as A 626) which is supplied in thicknesses from 0.0050 to 0.0118 in. or SI units [as A 626M] which is supplied in thicknesses from 0.127 to 0.300 mm.

1.3 The values stated in either inch-pound or SI units are to be regarded as standard. Within the text, the SI units are shown in brackets. The values stated in each system are not exact equivalents. Therefore, each system must be used independently of the other. Combining values from the two systems may result in nonconformance with this specification.

1.4 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

### 2. Referenced Documents

#### 2.1 ASTM Standards:<sup>2</sup>

- A 623 Specification for Tin Mill Products, General Requirements
- A 623M Specification for Tin Mill Products, General Requirements [Metric]
- A 630 Test Methods for Determination of Tin Coating Weights for Hot-Dip and Electrolytic Tin Plate
- A 754 Test Method for Coating Thickness by X-Ray Fluorescence
- B 339 Specification for Pig Tin

<sup>1</sup> This specification is under the jurisdiction of ASTM Committee A01 on Steel, Stainless Steel and Related Alloys and is the direct responsibility of Subcommittee A01.20 on Tin Mill Products.

Current edition approved October 1, 2003. Published December 2003. Originally approved in 1968. Last previous edition approved in 1998 as A 626/A 626M - 98.

<sup>2</sup> For referenced ASTM standards, visit the ASTM website, [www.astm.org](http://www.astm.org), or contact ASTM Customer Service at [service@astm.org](mailto:service@astm.org). For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

### 3. Ordering Information

3.1 Orders for product under this specification shall include the following information, as required and applicable, to describe adequately the desired product:

- 3.1.1 Name of product (double-reduced electrolytic tin plate) (Section 1),
- 3.1.2 Tin coating weight [mass] designation, and marking, if any (Section 5, Table 1, and Fig. 1 and Fig. 2),
- 3.1.3 Surface appearance and finish (Section 6),
- 3.1.4 Chemical treatment (Section 7),
- 3.1.5 Oiling (Section 8),
- 3.1.6 Thickness (Specification A 623 [A 623M]) (consistent with the intended application),
- 3.1.7 Coil width or cut size in increments of  $\frac{1}{16}$  in. or 1 mm,
- 3.1.8 Due to the very distinct directional properties, rolling direction must be specified on cut sizes by underlining the slit (rolling width) dimension (Section 4) (consistent with the intended application),
- 3.1.9 Steel type (Specification A 623 [A 623M]),
- 3.1.10 Mechanical requirement designation (Specification A 623 [A 623M]) (consistent with the intended application),
- 3.1.11 Intended application,
- 3.1.12 Quantity in base boxes SITAS (see Note 4),
- 3.1.13 On coils, specify minimum or range of acceptable inside diameters. The standard inside diameter is approximately 16 in. if ordered to Specification A 626 [410 mm if ordered to Specification A 626M]. Coils should be specified to a maximum coil weight if ordered to Specification A 626 [mass if ordered to Specification A 626M] or maximum outside diameter, or both,
- 3.1.14 Packaging,
- 3.1.15 Special requirements, where applicable (J = plate or K = plate), and
- 3.1.16 ASTM specification number and year of issue.

NOTE 1—A typical ordering description is as follows: 1000 base boxes, double-reduced electrolytic tin plate, D 50/25, melted, CDC, DOS, 0.0066-in. thickness, 30 by coil, MR, DR-8 CA, for 307 by 401 welded can bodies in accordance with Specification A 626/A 626M - XX. [250 SITAS, double-reduced electrolytic tin plate, D 5.6/2.8, melted, CDC, DOS, 0.17-mm thickness, 760 by coil, MR, DR-8, for 99 by 105 mm welded can bodies to Specification A 626/A 626M - XX.]

NOTE 2—A typical ordering description for cut sizes is as follows: 500 base boxes, single reduced electrolytic tin plate, No. 25, DOS, MR, T-2

\*A Summary of Changes section appears at the end of this standard.

**TABLE 1 Electrolytic Tin Plate Coating Weight [Mass]**

NOTE 1—Listed as follows are commonly produced coating weights [masses]. By agreement between the producer and the purchaser, other combinations of the coatings may be specified and the appropriate minimum average test values will apply.

Designation No.	Nominal Tin Coating Weight [Mass] each Surface, lb/base box [g/m <sup>2</sup> ]	Minimum Average Coating Weight [Mass] each Surface Test Value, lb/base box <sup>A</sup> [g/m <sup>2</sup> ]
5 [0.6/0.6] <sup>B</sup>	0.025/0.025 [0.6/0.6]	0.02/0.02 [0.5/0.5]
10 [1.1/1.1]	0.05/0.05 [1.1/1.1]	0.04/0.04 [0.9/0.9]
15 [1.7/1.7]	0.075/0.075 [1.7/1.7]	0.06/0.06 [1.4/1.4]
20 [2.2/2.2]	0.10/0.10 [2.2/2.2]	0.08/0.08 [1.8/1.8]
25 [2.8/2.8]	0.125/0.125 [2.8/2.8]	0.11/0.11 [2.5/2.5]
35 [3.9/3.9]	0.175/0.175 [3.9/3.9]	0.16/0.16 [3.6/3.6]
50 [5.6/5.6]	0.25/0.25 [5.6/5.6]	0.23/0.23 [5.2/5.2]
75 [8.4/8.4]	0.375/0.375 [8.4/8.4]	0.35/0.35 [7.8/7.8]
100 [11.2/11.2]	0.50/0.50 [11.2/11.2]	0.45/0.45 [10.1/10.1]
D 50/25 [D 5.6/2.8] <sup>C</sup>	0.25/0.125 [5.6/2.8]	0.23/0.11 [5.2/2.5]
D 75/25 [D 8.4/2.8]	0.375/0.125 [8.4/2.8]	0.35/0.11 [7.8/2.5]
D 100/25 [D 11.2/2.8]	0.50/0.125 [11.2/2.8]	0.45/0.11 [10.1/2.5]
D 100/50 [D 11.2/5.6]	0.50/0.25 [11.2/5.6]	0.45/0.23 [10.1/5.2]
D 135/25 [D 15.2/2.8]	0.675/0.125 [15.2/2.8]	0.62/0.11 [14.0/2.5]

<sup>A</sup>The minimum spot value shall be not less than 80 % of the minimum average coating weight [mass] (see 5.3 and 5.4).

<sup>B</sup>Some No. 5 melted applications may require revised minimum and maximum levels for fully alloyed end uses.

<sup>C</sup>The letter D on differentially coated tin plate indicates the coated surface to be marked. For example, the examples indicate that the heavy-coated side is marked (see 5.1.2 and 5.1.3).

BA, 7C, 0.0110 in. thickness, 30 <sup>3</sup>/<sub>4</sub> in. by 30 <sup>7</sup>/<sub>16</sub> in., for 307 diameter general line rings in accordance with Specification A 626/A 626M-XX. [100 SITAS, single reduced electrolytic tin plate, 2.8/2.8, DOS, MR, DR-8 CA, 7C, 0.28 mm thickness, 781 by 773 mm, for 99 by 105 mm welded can bodies to Specification A 626/A626M-XX.]

NOTE 3—The production of coils does not afford the same opportunity for inspection, grading, and sorting as does the production of cut sizes. Accordingly, appropriate processing and quality control procedures are required by the purchaser to obtain optimum utilization of the material. Cut sizes are line inspected visually and mechanically during production. Sheets having surface imperfections that will not interfere with their utilization are included.

NOTE 4—In inch-pound units, double-reduced electrolytic tin plate is supplied on an area basis expressed in base boxes. In coils, the number of base boxes is computed from the measured length and the specified width. In cut sizes, the number of base boxes is computed from the specified length and width dimensions and sheet count. [In SI units, double-reduced electrolytic tin plate is supplied on an area basis expressed in SITAS. In coils, the number of SITAS is computed from the measured length and the specified width. In cut sizes, the number of SITAS is computed from the specified length and width dimensions and sheet count.] For calculating mass, the density of steel for tin mill products is 0.2836 lb/in.<sup>3</sup>[7850 kg/m<sup>3</sup>].

#### 4. Rolling Direction

4.1 Double-reduced plate is relatively brittle and has very distinct directional properties. The rolling direction must be specified on cut sizes and will be indicated by underlining the slit (rolling width) dimension. To minimize the flange-cracking hazard when the product is used for can bodies, the rolling direction must be around the circumference of the can.

#### 5. Tin Coating Weight [Mass]

##### 5.1 Class Designation and Marking:

5.1.1 Electrolytic tin plate is commonly produced to the class designations shown in Table 1. Other combinations of coatings may be specified by agreement between the producer and the purchaser.

5.1.2 Differentially coated tin plate is a product having one surface more heavily tin coated than the opposite. The class designation is expressed by showing the two tin coating weights [masses] separated by a slash mark, for example, 50/25 [D 5.6/2.8]. The first number will represent the coating weight [mass] on the outside of the coil or the top surface of the cut sizes.

5.1.3 In order to distinguish material having differential coatings, the face with the heavier coating is normally marked. By arrangement, a special marking can be supplied on the light-coated face (see Fig. 1 and Fig. 2). The letter D is shown along with the coating number to indicate the side of the plate to be marked.

##### 5.2 Sampling for Tin Coating Weights [Masses]:

5.2.1 When the purchaser wishes to make tests to ascertain compliance with the requirements of this specification for tin coating weight [mass] on a lot of any specific item of electrolytic tin plate, the following procedure shall be used:

5.2.1.1 *Coils*—One test strip shall be taken at random from a representative section of each coil across its width. A minimum of three test strips, each taken from different coils from any one item of a specific lot shall be selected.

5.2.1.2 From one or two coil lots, each coil should be sampled. A minimum of three randomly selected test strips shall represent the lot.

5.2.1.3 *Cut Sizes*—One sheet shall be taken at random from each 50 packages or part thereof, with a minimum of three different sample plates, each taken from different bundles from any one item of a specific shipment.

5.2.2 Each test sheet shall be spot tested at a minimum of three locations across the rolling direction of the sheet. Spot tests are customarily disks or squares 4 in.<sup>2</sup> [26 cm<sup>2</sup>] in area; other sizes may be used. In order to secure representative samples, the following procedure shall be used:

5.2.2.1 All test spots are taken on a center line at right angles to the rolling direction.

5.2.2.2 No test spots shall be closer than 1 in. [25 mm] from the mill-trimmed edge of the test sheets.

5.2.2.3 No test spots shall be closer than 2 in. [50 mm] from one another.

5.2.2.4 If the minimum of three test spots are taken, they shall be edge, center, and edge tests.

5.2.2.5 The average of all spot tests on all test strips or sheets represents the average coating weight [mass] test value.

5.3 Coating weight [mass] test values shall conform to the values shown in Table 1.

5.4 *Determination of Tin Coating Weights [Masses]*—Typical methods for determination of tin coating weights [masses] are described in Test Methods A 630. An acceptable method for determining tin coating weight [mass] is the X-ray fluorescence method, performed in accordance with Test Method A 754. In case of dispute, Method B, Referee Method, shall be used.



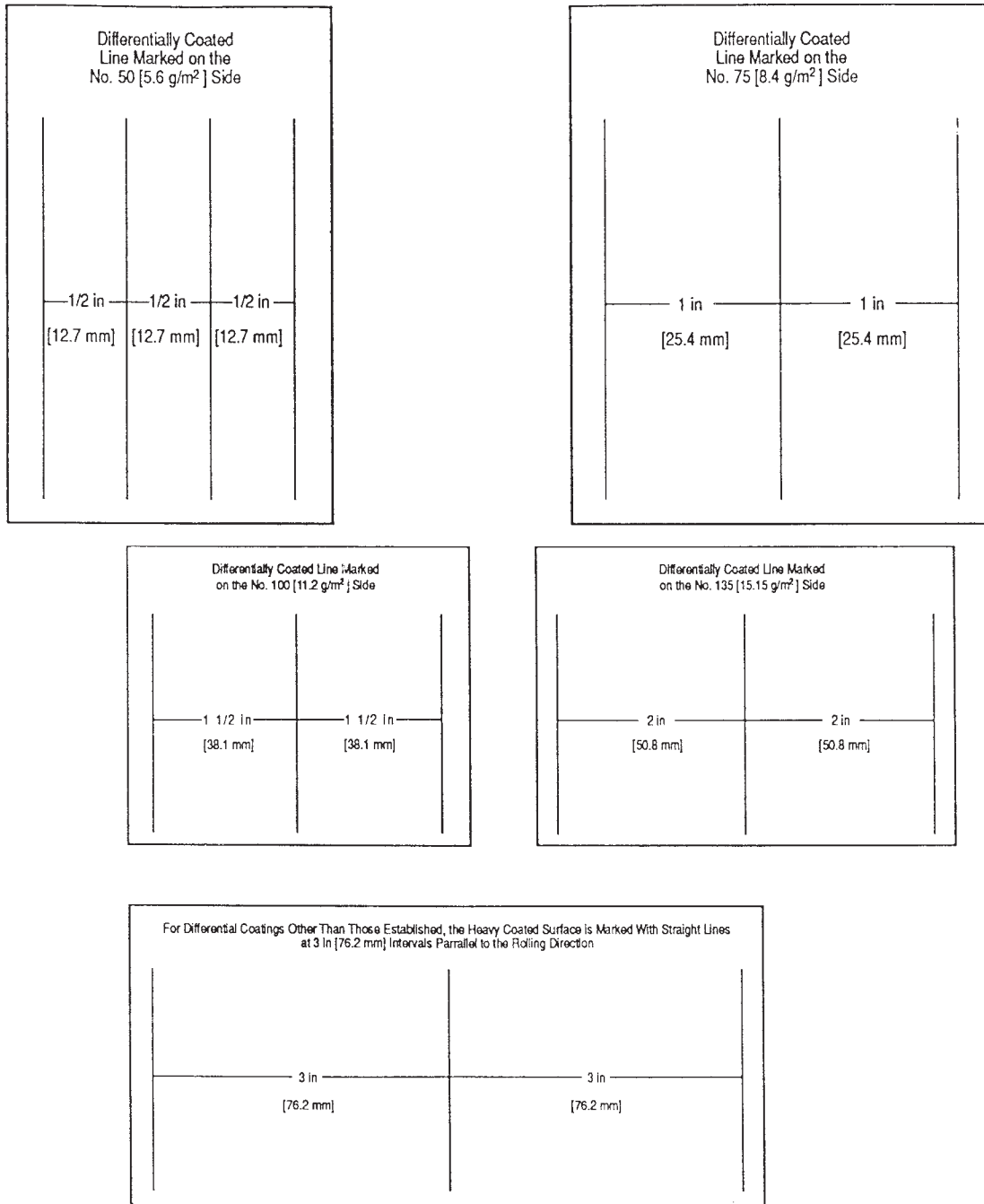


FIG. 1 Standard Heavy-Side Marking System for Differential Electrolytic Tin Plate

5.5 Pig tin used in the production of tin plate shall be Grade A as shown in the latest edition of Specification B 339.

**6. Surface Appearance and Finish**

6.1 *Surface Appearance*—Double-reduced electrolytic tin plate is customarily produced with a melted coating (bright). Unmelted coating (matte) is also available.

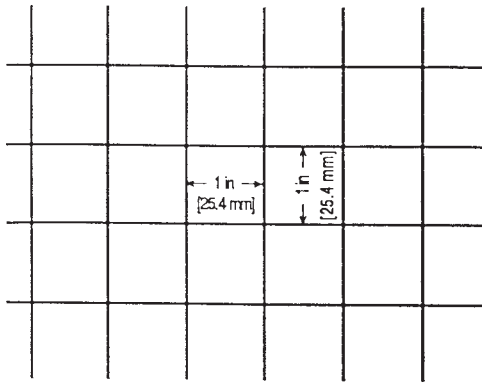
6.2 *Base Metal Finish*—Double-reduced electrolytic tin plate is produced with ground roll finishes.

6.2.1 *7C*—A smooth finish with grit lines. The surface roughness will range between 6 and 25  $\mu\text{in}$ . Ra [0.152 to 0.635  $\mu\text{m}$  Ra].

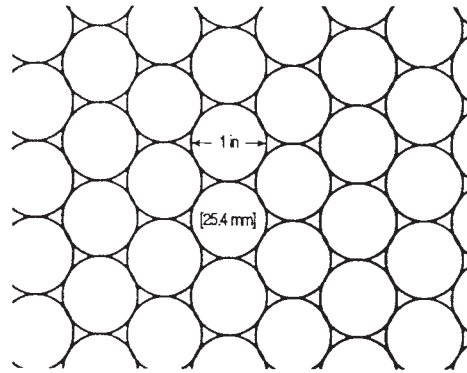
**7. Chemical Treatment**

7.1 Electrolytic tin plate as produced without a surface chemical treatment is subject to tin oxide growth that is manifested by surface discoloration during storage and subsequent baking operations and may adversely affect application and adhesion of organic coatings and lithography, and may cause poor solderability. A chemical treatment is therefore applied in most cases after the tin coating has been deposited and immediately preceding the oiling to control tin oxide formation and growth. The chemical treatment is applied by passing the strip through a chemical solution with or without

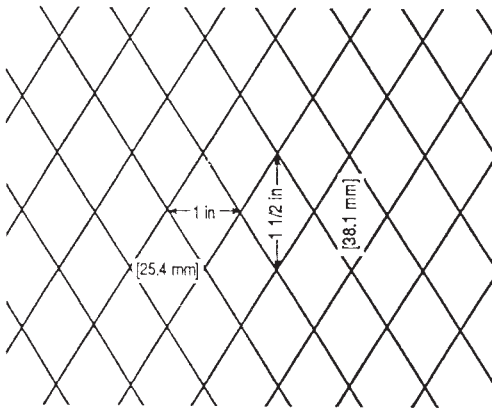
Differentially Coated No. 50 [5.6 g/m<sup>2</sup>],  
Square Marked on the Opposite (Light) Side



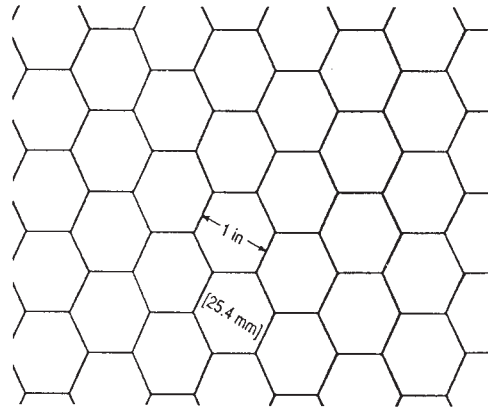
Differentially Coated No. 75 [8.4 g/m<sup>2</sup>],  
Circle Marked on the Opposite (Light) Side



Differentially Coated No. 100 [11.2 g/m<sup>2</sup>], Diamond  
Marked on the Opposite (Light) Side



Differentially Coated No. 135 [15.15 g/m<sup>2</sup>], Hexagon  
Marked on the Opposite (Light) Side



For Differential Coatings Other Than Those Established,  
the Lighter Coated Surface is Marked With Sine Waves

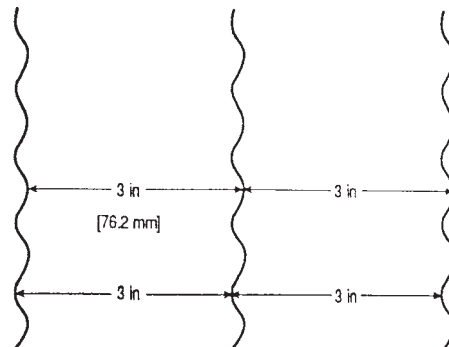


FIG. 2 Standard Light-Side Marking System for Differential Electrolytic Tin Plate

current. Chemical treatments on electrolytic tin plate are applied commensurate with each supplier's method and equipment, however, one of the controlling factors is the amount of combined chromium present on the surface. Unless otherwise specified, the surface chemical treatment will be left to the discretion of the tin plate producer.

7.2 In order of decreasing surface passivation, the commonly used chemical treatments for tin plate are as follows:

7.2.1 *Cathodic Sodium Dichromate (CDC) Treatment:*

7.2.1.1 The cathodic sodium dichromate treatment is the most widely used treatment, and provides a highly passivated surface against the formation of tin oxides. It has the following

attributes: (1) minimum tin oxide growth after prolonged storage; (2) minimized discoloration during subsequent baking required for organic coatings and lithography; (3) minimized discoloration due to soldering operation; and (4) provides some resistance to tin sulfide discoloration of certain sulfur-bearing food products.

7.2.1.2 Cathodic sodium dichromate-treated tin plate has an aim range from 350 to 650  $\mu\text{g}$  of chromium per square foot of surface [4 000 to 7 000  $\mu\text{g}$  of chromium per square metre of surface].

**7.2.2 Sodium Dichromate Dip (SDCD/SDD) Treatment:**

7.2.2.1 The sodium dichromate dip treatment provides moderate passivation against tin oxide formation.

7.2.2.2 Sodium dichromate dip-treated tin plate has a maximum of 200  $\mu\text{g}$  of chromium per square foot of surface [2200  $\mu\text{g}$  of chromium per square metre of surface].

## 8. Oiling

8.1 Electrolytic tin plate is furnished with an oil film applied to both surfaces. The most commonly used oil films are dioctyl

sebacate (DOS) and acetyl tributyl citrate (ATBC). Other oil films may be used. Surface active agents such as glycerol monooleate (GMO) may be incorporated into the oil film for application on tin plate.

8.2 Unless indicated by the purchaser the specific oiling treatment will be left to the discretion of the tin-plate producer.

8.3 *Weight [Mass] of Oil Film*—The weight [mass] of oil film as applied by the supplier of tin plate normally ranges from approximately 0.10 to 0.40 g/base box [0.50 to 2.00 g/SITA (5 to 20  $\text{mg}/\text{m}^2$ )]. Specific aim ranges required for particular end uses and handling practices may be supplied as agreed upon between the producer and the purchaser.

## 9. General Requirements for Delivery

9.1 Material furnished under this specification shall conform to the applicable requirements of the current edition of Specification A 623 [A 623M], unless otherwise provided herein.

## 10. Keywords

10.1 coated steel sheet; tin mill products; tin plate

## SUMMARY OF CHANGES

Committee A01 has identified the location of selected changes to this standard since the last issue (A 626/A 626M - 98) that may impact the use of this standard.

*A 626/A 626M - 03:*

(1) Changed metric decimal thickness from two significant figures to three significant figures in paragraph 1.2.

(2) Changed wording in Chemical Treatment paragraph 7.1 to be consistent with that of A 624/A 624M paragraph 6.1.

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# Standard Test Methods for Determination of Tin Coating Weights for Electrolytic Tin Plate<sup>1</sup>

This standard is issued under the fixed designation A 630; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

*This standard has been approved for use by agencies of the Department of Defense.*

## INTRODUCTION

Four test methods for determination of tin coating weights are described. These are typical methods and represent those most commonly used in the tin plate industry. Publication of these test methods is not intended to preclude the use of any other methods such as X-ray fluorescence measurement systems for control purposes by the consumer or supplier. However, in case of dispute, the referee method is to be used to determine conformance to Specification A 624/A 624M and Specification A 626/A 626M.

Sampling procedures for tin coating-weight testing and applicable standards for the specific class designation are outlined in Specification A 624/A 624M and Specification A 626/A 626M.

### 1. Scope\*

1.1 These test methods include four methods for the determination of tin coating weights for electrolytic tin plate as follows:

Test Method	Sections
A—Bendix Test Method	3 to 9
B—Constant-Current, Electrolytic Test Method (Referee Method)	10 to 18
C—Sellar's Test Method	19 to 28
D—Titration Test Method	29 to 37

1.2 The values stated in inch-pound units are to be regarded as the standard. The values given in parentheses are for information only.

1.3 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

### 2. Referenced Documents

2.1 *ASTM Standards:*<sup>2</sup>

- A 599/A 599M Specification for Tin Mill Products, Electrolytic Tin-Coated, Cold-Rolled Sheet
- A 623 Specification for Tin Mill Products, General Requirements
- A 623M Specification for Tin Mill Products, General Requirements [Metric]
- A 624/A 624M Specification for Tin Mill Products, Electrolytic Tin Plate, Single Reduced
- A 626/A 626M Specification for Tin Mill Products, Electrolytic Tin Plate, Double Reduced
- D 1125 Test Methods for Electrical Conductivity and Resistivity of Water

## METHOD A—DETERMINATION OF THE TIN COATING WEIGHTS BY THE BENDIX TEST METHOD

### 3. Scope

3.1 This test method covers the determination of tin coating weights on steel plate.

### 4. Summary of Test Method

4.1 The procedure involves dissolution of tin from a tin plate anode in a dilute hydrochloric acid solution containing a measured excess of standard potassium iodate-potassium iodide solution. Excess iodine from the iodate-iodide solution is back titrated with standard sodium thiosulfate using a starch indicator.

<sup>1</sup> These test methods are under the jurisdiction of ASTM Committee A01 on Steel, Stainless Steel and Related Alloys and are the direct responsibility of Subcommittee A01.20 on Tin Plate.

Current edition approved November 1, 2003. Published January 2004. Originally approved in 1968. Last previous edition approved in 1998 as A 630 - 98.

<sup>2</sup> For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

\*A Summary of Changes section appears at the end of this standard.

## 5. Apparatus<sup>3</sup>

5.1 The detinning cell consists essentially of two cathodes of carbon rod, the sample that serves as an anode, and a beaker of dilute hydrochloric acid electrolyte. The carbon rods (6 by 0.25 in. or 152 by 6.35 mm, encased in porous porcelain thimbles) are suspended from a suitable frame about 1 in. [25 mm] apart. A small glass-enclosed magnet is attached to the frame in such a manner that it will hold the sample suspended midway between the two cathodes. A movable platform permits the beaker of electrolyte to be brought up around the assembly so that the sample will be completely immersed.

5.2 A source of direct current that can be regulated to supply up to 3 A at 3 to 5 V through the deplater is required.

5.3 Although regular laboratory glassware can be used, it is advisable to use automatic dispensing pipets or burets, a motor-driven stirrer for titrations, and a timing switch when large numbers of determinations are to be made.

5.4 *Precautions*—The apparatus must be kept in continuous operation to prevent iron in the solution adhering to the porous cells from oxidizing and subsequently liberating iodine from the potassium iodate-potassium iodide solution. If the instrument has been idle for some time, it is necessary to remove the ferric iron by running a disk of tinplate through the regular procedure before test samples are run.

## 6. Reagents

6.1 *Purity of Reagents*—Reagent grade chemicals shall be used in all tests. Unless otherwise indicated, it is intended that all reagents shall conform to the specifications of the Committee on Analytical Reagents of the American Chemical Society where such specifications are available.<sup>4</sup> Other grades may be used, provided it is first ascertained that the reagent is of sufficiently high purity to permit its use without lessening the accuracy of the determination.

6.2 *Water*—Deionized or distilled water having a volume resistivity greater than 1 M $\Omega$ -cm at 25°C as determined by Nonreferee Method of Test Methods D 1125.

6.3 *Hydrochloric Acid* (1.7 to 2.0 *N*)—Add 1 part of concentrated hydrochloric acid (HCl, sp gr 1.19, 36.5 to 38.0%) to 5 parts of water and mix well.

6.4 *Potassium Iodate-Potassium Iodide, Standard Solution* (0.0975 *N*)—Dissolve 3.48 g of KIO<sub>3</sub>, 21.74 g of KI, and 1.21 g of NaOH in 1 L of distilled water. Standardize as follows: Transfer 0.2700 g of National Bureau of Standards tin to a 500-mL Erlenmeyer flask. Add 200 mL of HCl (1+1). Connect the flask to a carbon dioxide (CO<sub>2</sub>) system and displace the air in the flask with CO<sub>2</sub>. While continuing the flow of CO<sub>2</sub>, heat the flask but do not boil violently. After the tin has dissolved

add 0.5 g of antimony and 2 g of high-purity aluminum. Heat until the aluminum is completely dissolved and digest for an additional 10 min. Cool the flask to room temperature in running water while maintaining an atmosphere of CO<sub>2</sub>. Disconnect from the CO<sub>2</sub> system and titrate with the KIO<sub>3</sub>-KI solution using starch as an indicator. Calculate the tin titer, *T*, as follows:

$$T = A/B$$

where:

*A* = tin used (0.2700 g),

*B* = KIO<sub>3</sub>-KI solution used for titration, mL, and

*T* = tin titer for above KIO<sub>3</sub>-KI solution, (grams of tin/mL),

*T* = 17.28 = lb/base box (bb)/mL, for a 4-in.<sup>2</sup>[25.81-cm<sup>2</sup>] sample.

6.5 *Sodium Thiosulfate, Standard Solution* (for coatings over 0.50 lb/bb)—Dissolve 15.11 g of Na<sub>2</sub>S<sub>2</sub>O<sub>3</sub>·5 H<sub>2</sub>O and 1.11 g of NaOH in 1 litre of distilled water in a light-proof bottle. Allow this solution to age for 72 h, remix, and standardize as follows: Connect the bottle to the Bendix apparatus and titrate 20 mL of the standardized KIO<sub>3</sub>-KI solution with the thiosulfate solution using the same procedure as is used for making weight of coating determinations, but ignore the stripping unit. The tin equivalent of the Na<sub>2</sub>S<sub>2</sub>O<sub>3</sub> solution in pounds per base box is equal to: 20/*A* × *T* × 17.28, where *A* = millilitres of sodium thiosulfate solution used in titrating 20 mL of standard KIO<sub>3</sub>-KI solution. A chart can be prepared showing lb/bb/mL of thiosulfate.

6.6 *Sodium Thiosulfate, Standard Solution* (for coatings 0.50 lb/bb and under)—Dissolve 6.57 g of Na<sub>2</sub>S<sub>2</sub>O<sub>3</sub>·5 H<sub>2</sub>O and 2.78 g of NaOH in 1 litre of distilled water in a light-proof bottle. Larger quantities in the same proportions may be prepared if desired. Allow that solution to age for 72 h, remix, and standardize by the same procedure used for the stronger Na<sub>2</sub>S<sub>2</sub>O<sub>3</sub> solution but use only 10 mL of potassium iodate-potassium iodide solution.

6.7 *Starch Solution*—Heat 200 mL of distilled water to boiling in a Florence flask and slowly add 2.5 g of soluble starch paste while the solution is agitated. Add the hot starch solution to 500 mL of distilled water containing 2.5 g of NaOH. Dilute to 1 L and thoroughly mix.

## 7. Test Sample

7.1 Tin plate samples for coating weight determinations are obtained by stamping disks 2.257 ± 0.001 in. [57.33 ± 0.02 mm] in diameter which is equivalent to 4 in.<sup>2</sup>[25.81 cm<sup>2</sup>] of area (8 in.<sup>2</sup>[52 cm<sup>2</sup>] of surface area). Recommended methods of obtaining representative samples are described in the Tin Mill Products sections of the American Iron and Steel Institute's Steel Products Manual.<sup>5</sup>

## 8. Procedure

8.1 Make required electrical connections.

8.2 Add HCl (1+1) to the porous tubes containing the carbon cathodes.

<sup>3</sup> Complete details and drawings of the apparatus are contained in U. S. Patent No. 2,455,726 entitled "Method for Electrolytic Stripping and Determination of Plating Metals." A suitable commercial supplier of the apparatus has been found to be the Wilkens-Anderson Company of Chicago.

<sup>4</sup> *Reagent Chemicals, American Chemical Society Specifications*, American Chemical Society, Washington, DC. For suggestions on the testing of reagents not listed by the American Chemical Society, see *Analar Standards for Laboratory Chemicals*, BDH Ltd., Poole, Dorset, U.K., and the *United States Pharmacopeia and National Formulary*, U.S. Pharmacopeial Convention, Inc. (USPC), Rockville, MD.

<sup>5</sup> Available from American Iron and Steel Institute (AISI), 1101 17th St., NW, Suite 1300, Washington, DC 20036.

8.3 Suspend the sample disk of tin plate from the magnetic holder.

NOTE 1—If it is desired to strip on one side only, mask the opposite side and reduce the current to half its normal value. If a heavy oxide film has developed on the tin plate during storage, the plate must be cathodically cleaned prior to testing.

8.4 Place a measured quantity of standardized  $\text{KIO}_3$ -KI solution into a 400-mL beaker (see 8.10). Simultaneously add 250 mL of dilute HCl and mix thoroughly.

8.5 Raise the beaker so that the sample and porous cells are immersed.

8.6 Turn on d-c current and adjust to give 0.5 A/in.<sup>2</sup> of sample.

8.7 Time for complete removal of tin (see 8.10).

8.8 Remove the beaker and add approximately 5 mL of starch indicator solution.

8.9 Titrate with standardized  $\text{Na}_2\text{S}_2\text{O}_3$  solution to the disappearance of the blue color.

8.10 The stripping times and amounts of  $\text{KIO}_3$ -KI solution to use are as follows:

Product	Stripping Time, s	Amount of $\text{KIO}_3$ -KI Solution, mL
Electrolytic 100	90	20
Electrolytic 75	75	20
Electrolytic 50	60	10
Electrolytic 25	60	10
Electrolytic 10	45	10

Stripping time should not be longer than is required to remove all of the tin. Results will be high by approximately 0.01 lb/bb for each minute of over-stripping.

## 9. Reproducibility of Results

9.1 Arbitrary maximum spreads in intermill check tests show the reproducibility of test results by the Bendix Method to be as follows:  $\pm 0.02$  lb/bb for 0.25-lb coatings,  $\pm 0.03$  lb/bb for 0.75-lb coatings, and  $\pm 0.04$  lb/bb for 1.25-lb coatings. Data have not been developed for 0.10-lb coatings.

## METHOD B—DETERMINATION OF THE TIN COATING WEIGHTS BY THE CONSTANT CURRENT, ELECTROLYTIC METHOD (REFEREE METHOD)

### 10. Scope

10.1 This test method<sup>6</sup> may be used to determine not only the total tin coating weight but also to determine that part of the tin coating which is present as free tin and that part which is present in the alloyed form.

### 11. Summary of Test Method

11.1 In this test method, the tin is stripped from a sample of tin-plate anodically at constant current in an electrolyte of the hydrochloric acid. The potential difference developed between

the sample and a reference electrode is plotted against time on a strip chart recorder or an electric digital readout. The time required for stripping the free tin and alloyed tin, respectively, are read from the resulting chart (see Fig. 1) or a digital readout. Since the stripping current has been preset, the free-tin and alloy-tin coating weights are calculated by employing Faraday's law of electrolysis.

### 12. Calibration and Standardization

12.1 Determine the weight loss of pure tin specimens electrolyzed for a given time interval, expressing the results as milligrams or pounds of tin per base box per second.

12.2 The test specimen should be a 4-in.<sup>2</sup> disk of pure tin approximately 0.20 in. [5.1 mm] thick.

12.3 The milliammeter should be frequently checked using a precision milliammeter.

### 13. Available Constant Current Procedures

13.1 There are two commercially available constant current, electrolytic units that are in common use. Either of the following, or equivalent equipment, can be used as an acceptable referee method:

13.1.1 *Wiley & Kunze Coulometric Test Method*—Supplier will provide set up, start up and running procedures.<sup>7</sup>

13.1.2 *The Stannomatic Test Method*—Supplier will provide set up, start up and running procedures.<sup>8</sup>

### 14. Wiley & Kunze Coulometric Test Method

14.1 In this test method, the tin is electrolytically removed from a 4 in.<sup>2</sup>[25.807 cm<sup>2</sup>] circular sample of tinplate anodically at constant current in an electrolyte of 1.0 N hydrochloric acid. The potential difference developed between the sample and a glass calomel reference electrode is plotted against time on a strip chart recorder. The time required for stripping the free tin and alloy tin, respectively are read from the resulting chart (see Fig. 1) or on an electronic digital readout. Since the stripping current is constant and preset, the free tin and alloy tin coating weights are calculated by employing Faraday's law of electrolysis.

14.2 *Significance and Use:*

14.2.1 The amount of tin coating is directly associated with the economics of producing tinplate and the performance of the container or part for which such plate is used. Therefore, the test method was developed for accuracy and as a control. The amount of tin combined in the alloy layer is also essential as the continuity and amount plays an important part in its functional properties. This test method is so designed that the tin coating is determined on only one side of the specimen at a time. This is useful when determining tin coatings on differential tinplate.

14.3 *Apparatus:*

14.3.1 This instrument (Model 8014) consists of an ammeter, volt meter, constant current source and strip recorder. A cell and sample holder are provided.

<sup>6</sup> See Kunze, C. T., and Wiley, A. R., "Electrolytic Determination of Tin and Tin-Iron Alloy Coating Weights on Tin Plate," *Journal, Electrochemical Society*, Vol 99, No. 9, September 1952, pp. 354-359; and "Methods for Determination of Coating Weights of Tin Plate," *American Iron and Steel Institute*, December 1959, pp. 19-26.

<sup>7</sup> Available from Coulometric Systems, Bergholtz, OH.

<sup>8</sup> Available from Products Distribution Service Division, Wilkens Anderson Co., 4525 West Division St., Chicago, IL 60651.

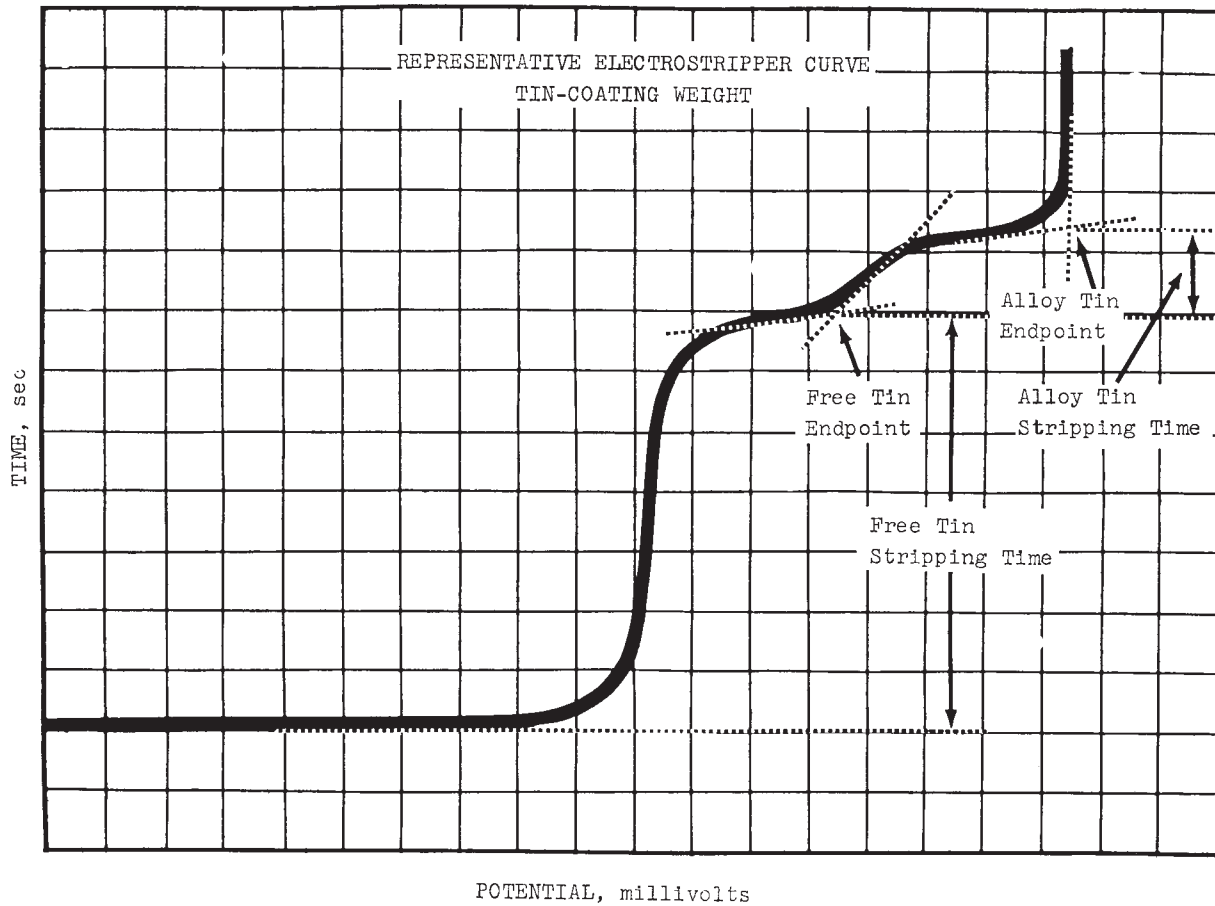


FIG. 1 Representative Electrostripper Curve

14.4 Reagents:

14.4.1 Electrolyte—1.0 N hydrochloric acid (HCl).

14.5 Sample Size:

14.5.1 Tinplate samples for coating weight determinations are obtained by stamping discs  $2.257 \pm 0.001$  in. [ $57.33 \pm 0.02$  mm] in diameter. This is equivalent to  $4$  in.<sup>2</sup> [ $25.81$  cm<sup>2</sup>] of area of one side. Sampling procedures for tin coating weight testing and applicable standards for the specific class designation are outlined in Specifications, A 624, A 624M, A 626, and A 626M.

14.6 Interferences:

14.6.1 The distance of the cathode from the sample is important and should be  $0.75 \pm 0.25$  in. [ $1.90 \pm 0.64$  cm]. Also, it is important that the cathode be approximately the same shape as the sample so that all parts of the anode are equidistant from the cathode.

15. The Stannomatic Test Method

15.1 Principle of Equipment Operation:

15.1.1 The free tin and the alloy tin covering the surface of the tin plate to be examined are dissolved electrolytically. The test size is exactly defined on both sides of the sample by two precision gaskets. The free tin and iron-tin alloy results are a function of the amount of current (Coulombs) used for stripping and are displayed on a numeric readout.

15.2 Apparatus:

15.2.1 This instrument consists of a stripping cell with a standardized sample size control. The stripping controller has a numeric readout which displays separately free tin and alloy tin on both sides of the test sample.

15.3 Reagent:

15.3.1 Electrolyte—As specified by equipment manufacturer.

15.4 Sample Size:

15.4.1 Tinplate samples can be of various dimensions but must be large enough to afford a test area at least  $1\frac{1}{2}$  in. in diameter. The test area must be reasonably flat. Sampling procedures for tin coating weight testing and applicable standards for the specific class designations are outlined in Specifications A 624/A 624M and A 626/A 626M.

15.5 Preparing Sample:

15.5.1 The surface of the tested sample shall be clean. Oil, grease and organic coating such as lacquer shall be removed with suitable solvents. Remove oxides, passivation oxide coatings, and corrosion products, by carefully burnishing the test surface with a clean, soft pencil eraser. Also, cleaning with a tissue impregnated with acetone or solvent is usually sufficient. Electrochemical cleaning may be necessary occasionally.

15.6 Special Precautions:

15.6.1 It should be noted that the reading of the alloy counter represents the actual weight of tin contained in the FeSn<sub>2</sub> alloy. If the tinplate has not undergone heat treatment the

alloy layer does not form. Unless the instrument is adjusted to the proper setting, the alloy counter will become inoperative, and the automatic program will stop after the first layer is completely removed.

15.6.2 Automatic prepolarization and light electro-cleaning of cathodes is performed during the first 3 s after each start of the Stannomatic III or later model.

15.6.2.1 During this initial sequence the auxiliary anodes are activated against the cathodes. This operation may be extended by pressing the start button for several seconds.

15.6.2.2 Failure of this function may cause ghost layers and subsequent premature switch over of the sequence.

15.6.3 One condition for reliable results and a well-defined inflection point displayed on the instrument meters is a uniform stripping of the whole surface.

15.6.3.1 After completion of the measurement the test surface should be examined visually. If the dissolution of the coating is not complete the measurement should be discarded and repeated.

15.6.4 The following factors influence the uniformity of stripping:

15.6.4.1 Contaminated or dirty cathode.

15.6.4.2 Cathode not well fitted and located.

15.6.4.3 Cathode and fixing part substituted with non-original parts.

15.6.4.4 Sample punched too near the edges of the metal strip may have a non-uniform coating.

15.6.4.5 Sample dirty, corroded, partially or totally coated with organic coating.

15.6.4.6 Sample with a thick passivation layer.

## 16. Procedure

16.1 Clean the tinplate sample disk by cathodically treating in 0.5% sodium carbonate solution for 10 s with a current density of 0.5 A/in.<sup>3</sup>

16.2 An alternative procedure is to wipe the surface of the sample with a clean cloth saturated with acetone, this to be followed by immersion of disk in acetone, removing, and air drying. The procedure under 16.1 is preferred as it reduces the tin oxide present on the surface to metallic tin and improves the definition of the end point.

16.3 After following steps under Section 10, the apparatus is ready for determining tin coating weight of the samples. Exactly the same procedure is used for samples with unknown tin coating weights as the “dummy” samples. The recommended recorder has a chart speed of 2 in./min and uses a chart having 10 divisions/in. Therefore, each division is equivalent to 3 s.

## 17. Calculation

17.1 Calculate results as follows:

$$A = ITC \quad (1)$$

$$B = 0.65 IT_1 C \quad (2)$$

$$D = A + B \quad (3)$$

where:

*A* = free tin coating weight, lb/bb

*I* = stripping current, A,

*T* = time required for the removal of free tin, s,

*C* = 0.02126 or the electrochemical equivalent of tin expressed in lb/bb for a 4-in.<sup>2</sup> or 25.81-cm<sup>2</sup> area of tinplate,

*B* = alloy tin coating weight, lb/bb,

0.65 = that portion of the current required for removal of the alloyed tin. Since the tin-iron alloy composition is FeSn<sub>2</sub> and these elements enter the solution stoichiometrically with a two-electron loss for each atom of tin and iron, only two thirds of the current is dissipated for the dissolution of tin. Consequently, the total alloy time must be corrected to compensate for the electrolysis of the iron,

*T<sub>1</sub>* = time required for the removal of the alloy layer, s, and

*D* = total tin coating weight, lb/bb.

## 18. Precision and Bias

18.1 Comparison of data using the Sellar’s method with that obtained using the electrolytic method shows the following expected bias: ±0.01 lb/bb for 0.50-lb coatings and ±0.02 lb/bb for 1.25-lb coatings.

### METHOD C—DETERMINATION OF THE TIN COATING WEIGHTS BY THE SELLAR’S METHOD

## 19. Scope

19.1 This test method covers the determination of the total weight of tin carried by a unit area of tinplate.

## 20. Summary of Test Method

20.1 The tinplate sample is dissolved in hydrochloride acid. The tin goes into the solution as stannous chloride. Accidental air oxidation of the tin from the stannous to the stannic form is prevented by completing the analysis under an atmosphere of carbon dioxide.

20.2 The tin is titrated with a standard iodide-iodate solution, using starch as an indicator.

## 21. Significance and Use

21.1 This test method covers determination of the total tin in the sample tested and does not apportion the tin to one or the other side of the test specimen. The calculations appearing in Section 27 assume uniform distribution of tin over the two surfaces.

21.2 This test method does not differentiate between free tin on the tinplate surface, tin combined with iron in the intermediate alloy layer, or tin alloyed with the steel as a residual trap element.

## 22. Interferences

22.1 This test method relies on a redox reaction. Therefore, any contaminant that may be reduced by the nascent hydrogen liberated as the sample dissolves in hydrochloric acid and may be subsequently oxidized by the KI-KIO<sub>3</sub> titrant, must be avoided. The chromate treatments commonly applied to tinplate have not been found to cause significant errors.



### 23. Apparatus

23.1 *Reaction Vessel*,<sup>9</sup> such as a 500 mL Erlenmeyer flask, closed with a two-hole stopper. One opening in the stopper shall be connected to a source of carbon dioxide (CO<sub>2</sub>) gas, the other, allowing escape of the hydrogen, displaced air, CO<sub>2</sub>, and acid vapors shall be connected to a water trap. This will scrub the hydrochloric acid fumes from the emerging gas and afford a seal against air returning to the flask during cooling. The connections used should be of such length and flexibility as to permit moving the flask from the hot plate to the cooling trough without disconnecting the tubing or removing the stopper.

NOTE 2—The essential feature of the apparatus is the provision of means for passing a stream of CO<sub>2</sub> gas over the acid solution in which the tin is dissolving, during and after the dissolution and during the period of cooling the resultant solution to room temperature.

23.2 Any suitable buret may be used for titration, provided its accuracy is known to be adequate for the purpose. Automatic burets are convenient and those incorporating easy-read features aid in obtaining accurate readings.

### 24. Reagents and Materials

24.1 *Purity of Reagents*—See 6.1.

24.2 *Purity of Water*—See 6.2.

24.3 *Hydrochloric Acid (1+1)*—Add 1 volume of concentrated hydrochloric acid (HCl, sp gr 1.19) to 1 volume of water and mix well.

24.4 *Potassium Iodide-Potassium Iodate Solution (0.0975 N)*—Place 21.8 g of KI, 3.48 g of KIO<sub>3</sub>, and 1.2 g of NaOH in a clean bottle. Add 1 L of water and mix thoroughly.

24.4.1 Standardize the solution as follows: Place 0.2500 g of National Institute of Standards and Technology tin, 0.5 g of antimony, and 1 g of lead in a 500-mL Erlenmeyer flask. Add 200 mL of HCl (1+1). Stopper the flask (reaction vessel) with a two-hole rubber stopper and connect to the apparatus described in Section 24. Purge the air from the flask with CO<sub>2</sub>. Place the flask on the heater and bring the solution to a boil. Boil gently until the tin is completely dissolved as shown by hydrogen no longer being evolved. When cool, titrate with the KI-KIO<sub>3</sub> solution, while maintaining an atmosphere of CO<sub>2</sub> in the flask. Calculate the weight of tin equivalent to 1 mL of iodate solution as follows:

$$\text{Grams of tin/mL solution} = A/B \quad (4)$$

where:

A = tin, g, and

B = KI-KIO<sub>3</sub> solution required for titration of the solution, mL

NOTE 3—The ideal concentration is one that gives a numerical value of 0.005786 g of Sn/mL of solution. Values between 0.00577 and 0.00580 are considered acceptable; otherwise, the concentration should be adjusted. Using a solution of the concentration indicated, 1 mL of solution corresponds to a coating weight of 0.1000 lb Sn/bb [1.121 g Sn/m<sup>2</sup>] of surface when using 4 in.<sup>2</sup>[25.81 cm<sup>2</sup>] of tinplate as the sample.

<sup>9</sup> A diagrammatic sketch of a suitable apparatus can be found in Scott, *Standard Methods of Chemical Analysis*, Fifth Edition, Vol 1, p. 967. Explanatory notes accompany the sketch.

24.5 *Starch Solution*—Dissolve 2.5 g of NaOH in 500 mL of water. Place about 200 mL of water in a Florence flask and bring it to a boil. Add 2.5 g of soluble starch to 10 mL of water and stir to make a smooth paste. Then add this paste cautiously to the boiling water. Remove this solution from the source of heat and shake gently. Pour the starch dispersion into the NaOH solution, dilute to 1 litre, and mix thoroughly.

### 25. Test Specimens or Samples

25.1 Sampling procedures for tin coating weight testing and applicable standards for the specific class designation are outlined in Specification A 624/A 624M and Specification A 626/A 626M.

25.2 The test specimens or areas to be sampled should be free of visible contamination by oil, grease, or other substance that would interfere with the dissolving of the sample. The oil coating normally applied to tinplate is not objectionable and need not be removed.

25.3 The area of the test specimen should be known to the degree of precision required in the result. An area of 4 in.<sup>2</sup> [25.81 cm<sup>2</sup>] of tinplate (8 in.<sup>2</sup>[51.61 cm<sup>2</sup>] total surface) is commonly used, and simplifies the arithmetical calculations.

### 26. Procedure

26.1 The following procedure applies to samples of tinplate approximately 4 in.<sup>2</sup> in area. For substantially larger or smaller areas, the quantities of reagents used should be adjusted appropriately.

26.1.1 Place 200 mL of HCl (1+1) in the test flask.

26.1.2 Insert the test specimen, cutting or bending it as necessary to pass through the neck of the flask.

26.1.3 Immediately replace the two-hole stopper and purge the gas space with CO<sub>2</sub> gas. Permit this gas to flow during the dissolution of the sample and the cooling of the flask.

26.1.4 Place the flask on the heater and boil the solution gently. Continue heating for about 20 min until the sample has completely dissolved. At this point, the small bubbles characterizing the hydrogen evolution will be replaced by the larger steam bubbles.

26.1.5 Immediately transfer the flask from the heater to the cooling tank or trough, without removing the stopper.

26.1.6 When the solution has cooled, remove the two-hole stopper and replace with a solid rubber stopper, unless titration is to begin immediately.

26.1.7 Fill the buret with the KI-KIO<sub>3</sub> solution, run out a few drops to ensure that there are no air bubbles in the buret tip, *except* on automatic burets, which are required to be completely filled. Record the volume (unless 0.00 mL).

26.1.8 To the contents of the flask, add 5 mL of starch solution.

26.1.9 Proceed with the titration, swirling the contents of the flask gently until the end point is nearly reached. When nearing the end point, add the iodate solution dropwise, swirling the contents vigorously.

26.1.10 When a permanent blue color first appears in the solution in the flask, shut off the buret and record the volume used.

## 27. Calculation

27.1 Determine the tin coating weight in pounds of tin per base box as follows:

$$\begin{aligned} \text{Tin coating weight, lb Sn/bb} \\ = [4.00 \times (V_2 - V_1) \times F \times 0.1] / \\ (0.005786 \times A) \end{aligned} \quad (5)$$

where:

$V_2$  = final reading of buret, mL,

$V_1$  = original reading of buret, mL,

$F$  = solution factor, g of Sn/mL of solution (see 24.4.1), and

$A$  = tinplate area, in.<sup>2</sup>

27.2 When the iodate concentration has the value recommended in 36.4, the area of tinplate is the commonly used value of 4.00 in.<sup>2</sup>, and an automatically zeroing buret is used, determine the weight as follows:

$$\text{Tin coating weight, lb Sn/bb} = 0.1 \times V_2.$$

## 28. Precision and Bias

28.1 Since the coating weight of tin on tinplate varies over the surface, it is difficult to provide identical samples for purposes of cross checking. The titration procedures are, however, sufficiently standard that the normal uncertainty of  $\pm 1$  drop of titrant should be attainable, corresponding to  $\pm 0.005$  lb Sn/bb.

## METHOD D—DETERMINATION OF THE TIN COATING WEIGHTS BY THE TITRATION METHOD

### 29. Scope

29.1 This test method is normally applicable to the determination of tin coating weights in the range of 0.50 to 1.50 lb of tin/bb.

NOTE 4—For the determination of the coating weights outside of this range, an iodate solution of appropriate concentration should be prepared so that suitable titrant volumes are obtained. For the determination of low tin coating mass in the range from 0.05–0.49 lb/bb, the number of sample specimens should be adjusted appropriately to maintain a minimum total tin mass equivalent to that present on a 0.50 lb/bb specimen. This test method cannot be used to test single spot tin mass for low tin coating material.

### 30. Summary of Test Method

30.1 The sample is placed in a platinum-wire bracket and the tin coating is dissolved from the steel base with hydrochloric acid. The removal of the tin from the steel base is hastened by development of an electrical potential between the tin and the platinum. This assures complete dissolution of the tin before a substantial amount of iron is dissolved. Any stannic tin that has formed is reduced to the stannous state with the aid of aluminum. The tin is then titrated with a standard iodate-iodide solution.

### 31. Apparatus

31.1 *Platinum Contact Device for Stripping of Sample*—Take a 10-in. [254-mm] piece of platinum wire (0.075 in. [1.90

mm] in diameter), and make a loop at one end approximately 2 in. [51 mm] long and ½ in. [12.7 mm] wide. Make certain that approximately 5 in. [127 mm] of this wire is bent perpendicularly to the loop. Then take approximately 4 in. [102 mm] of fine platinum wire (0.02 in. [0.5 mm] in diameter) and coil it around opposite ends of the loop at various intervals.

31.2 *NBS Certified Buret*, 50 mL.

31.3 *Tin Reduction Apparatus*—Any equipment that will maintain an atmosphere of CO<sub>2</sub> in the reaction flask may be used.

### 32. Reagents

32.1 *Purity of Reagents*—See 6.1.

32.2 *Oxygen-Free Water*—Bubble CO<sub>2</sub> gas through 3 L of water for approximately 15 min.

32.3 *Aluminum Wire*, (A1), tin-free and relatively pure (not less than 99.50% Al). Seven inches [178 mm] of 12-gage [2.05-mm] wire weighs approximately 1 g.

32.4 *Potassium Iodate-Potassium Iodide Solution* (0.05 N) (1 mL = approximately 0.0029 g of tin)—Dissolve 1.7600 g of KIO<sub>3</sub> in 200 mL of water containing 0.5 g of KOH and 15.0 g of KI. When dissolution is complete, transfer to a 1-L volumetric flask, dilute to volume, and mix.

32.5 *Starch Solution* (1 g/100 mL)—Add 1 g of either soluble or arrowroot starch to 5 mL of water and stir to make a paste. Then add the paste to 100 mL of boiling water. Cool the solution before using. This solution must be prepared freshly each day.

32.6 *Standard Tin Solution* (1 mL = approximately 0.0029 g of tin)—Accurately weigh 2.9 g of pure tin in 100 mL of concentrated HCl (sp gr 1.19) at room temperature. When dissolution is complete, transfer to a 1-L volumetric flask, dilute to volume with HCl (1+1), and mix.

NOTE 5—In diluting the standard tin solution to volume, care must be employed in maintaining the temperature at which the volumetric flask was calibrated. This also applies when measuring aliquots for standardization purposes. If a National Institute of Standards and Technology certified volumetric flask is not available, the flask should be standardized with a National Institute of Standards and Technology Certified Buret.

32.7 *Tin Metal*—99.95% tin or better (National Institute of Standards and Technology melting point tin is approximately 99.99% pure).

32.8 *Antimony Metal*—80-mesh, reagent grade.

### 33. Test Specimen or Sample

33.1 Sampling procedures for tin coating weight testing and applicable standards for the specific class designation are outlined in Specification A 624/A 624 and Specification A 626/A 626M.

33.2 Sample specimens of tinplate for coating weight determinations are obtained by stamping disks of  $2.257 \pm 0.001$  in. [ $57.33 \pm 0.02$  mm] in diameter which is equivalent to 4 in.<sup>2</sup> [ $25.81$  cm<sup>2</sup>] of surface area on each face of the disk.

NOTE 6—If it is desirable to strip one side only, mask the opposite side using a suitable material, that is, a cellulose lacquer, wax, or other barrier coating. Appropriate adjustments must be made to the test method to compensate for reducing the test area.

### 34. Calibration and Standardization

34.1 By means of a certified buret add directly to the reaction flask an accurately measured volume of standard tin solution (Note 6). Proceed as directed in Section 28, procedure starting with the connection of the reaction flask to the reduction apparatus. Calculate the tin titer of the iodate solution.

NOTE 7—It is preferable to analyze the unknown samples prior to standardizing the iodate solution so that suitable volumes of standard tin solution can be selected. Such a procedure will not only result in a more accurate standardization of the iodate solution but at the same time eliminate unnecessary and time-consuming standardizations.

### 35. Procedure

35.1 Place a 4-in.<sup>2</sup>[25.81-cm<sup>2</sup>] tinplate specimen on the platinum contact device in such a manner that the specimen rests on the loop and against the perpendicular stem and transfer to a 250-mL beaker. Add 150 mL of HCl (1+1) and strip at room temperature. After the tin coating, including the alloy layer, has been removed withdraw the specimen and rinse well with distilled water, collecting the washings in the original 250-mL beaker. Transfer the stripping solution to a 500-mL Erlenmeyer reaction flask. Add 1 g of aluminum wire and approximately 0.1 g of antimony metal (80 mesh).

NOTE 8—When stripping hot-dipped tinplate, the coating is removed more rapidly by using 100 mL of HCl (9+1) and warming to approximately 70°C.

35.2 Connect the reaction flask to the reduction apparatus. Displace the air in the flask with CO<sub>2</sub> and continue maintaining this flow until the flask is disconnected from the apparatus. After the aluminum wire has dissolved, heat the solution and boil gently for 15 min. Then cool the solution to approximately 20°C. Remove the flask from the reduction apparatus, add 5 mL of starch solution and immediately stopper the reaction

flask with a rubber cap in which a hole has been pierced. By placing the end of the buret through the hole, titrate with standard iodate solution to a blue end point.

### 36. Calculation

36.1 Calculate the weight of tin per base box as follows:

$$lb \text{ of tin/base box} = \frac{A \times B \times C}{D}$$

where:

A = standard iodate solution, mL,

B = tin titer,

C = 17.28 (factor to convert grams of tin on a 4-in.<sup>2</sup> specimen to pounds per base box), and

D = number of 4-in.<sup>2</sup> specimens tested (both sides stripped)

### 37. Precision and Bias

37.1 The following table shows the tin coating weight averages reported by ten participating laboratories. Each tabulated value was the average of 20 determinations except for Laboratory "I" in which case 12 values were reported.

Laboratory	Average lb/bb	Standard Deviation lb/bb
A	0.513	0.0022
B	0.504	0.0027
C	0.512	0.0023
D	0.515	0.0008
E	0.492	0.0033
F	0.509	0.0025
G	0.507	0.0028
H	0.517	0.0032
I	0.532	0.0056
J	0.503	0.0051
Average coating weight	0.510	
Standard deviation of all values reported		0.0013

## SUMMARY OF CHANGES

Committee A01 has identified the location of selected changes to this standard since the last issue (A 630 - 98) that may impact the use of this standard.

A 630 - 03:

(1) Paragraph 15.3.1— Changed electrolyte from 1.N Hydrochloric acid (HCl) to “As specified by equipment manufacturer.”

(2) Paragraph 15.6.2— Changed Stannomatic “IV” to “or later model.”

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## Standard Specification for Zinc-Coated Steel Strand for Messenger Support of Figure 8 Cable<sup>1</sup>

This standard is issued under the fixed designation A 640; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

<sup>ε1</sup> NOTE—Several editorial corrections were made throughout the specification in September 2002.

### 1. Scope

1.1 This specification covers two sizes of extra-high-strength grade of concentric-lay steel wire strand, composed of seven, zinc-coated steel wires, specifically intended for use as the supporting messenger in Figure 8-type communication and electrical cables.

1.2 The values stated in inch-pound units are to be regarded as the standard.

### 2. Referenced Documents

#### 2.1 ASTM Standards:

A 90/A 90M Test Method for Weight of Coating on Zinc-Coated (Galvanized) Iron or Steel Articles<sup>2</sup>

A 902 Terminology Relating to Metallic Coated Steel Products<sup>2</sup>

B 6 Specification for Zinc (Slab Zinc)<sup>3</sup>

### 3. Terminology

3.1 *Definitions*—See Terminology A 902 for definitions of general terminology relating to metallic coated steel products.

### 4. Description

4.1 Figure 8 cable consists of a plastic-sheathed communication or electrical cable made with an integral supporting messenger strand. The supporting messenger strand has a plastic sheath with a narrow, longitudinal web connecting to the plastic sheath of the cable. Generally the plastic sheath over the supporting strand, the connecting web, and the plastic sheath over the cable are all applied by extruding in one operation.

4.2 The galvanized steel strand used for the support messenger of Figure 8-type cable is generally coated by flooding with a sealing compound before the plastic sheath is applied

(Note). It is generally preferred that this sealing compound be applied to the individual wires during the stranding operation just before the wires are laid together. This ensures that all wires are completely covered and the interstices between the wires are sealed with a thermoplastic flooding compound to prevent intrusion of moisture under the plastic sheath. Sometimes the thermoplastic material is only applied to the outside of the finished strand.

NOTE 1—The cable manufacturer should advise the strand manufacturer of the plastic to be used for the sheath so that a sealing compound can be selected to avoid any adverse effects on the sheath.

### 5. Ordering Information

5.1 Orders for material under this specification shall include the following information:

5.1.1 Nominal strand diameter (Table 1),

5.1.2 Quantity of each size of strand, length in feet (metres),

5.1.3 Unit length (see 16.1),

5.1.4 Sealing compound, if required, and the method of application. Special requirements of sealing compound (Note),

5.1.5 Package size if different from standard (Section 16),

5.1.6 Special package marking (see 16.4), and

5.1.7 Inspection (Section 14).

### 6. Materials and Manufacture

6.1 The base metal of the wires shall be steel made by the open-hearth, basic-oxygen, or electric-furnace process and of such quality and purity that, when drawn to the size of wire specified and coated with zinc, the finished strand and the individual wires shall be of uniform quality and have the properties and characteristics as prescribed in this specification.

6.2 The slab zinc, when used for the wire coating, shall be any grade of zinc conforming to Specification B 6.

### 7. Stranding

7.1 Six wires shall be stranded with a uniform left-hand lay about a center wire to form the completed strand. All wires shall be stranded with uniform tension. Stranding shall be

<sup>1</sup> This specification is under the jurisdiction of ASTM Committee A05 on Metallic-Coated Iron and Steel Products and is the direct responsibility of Subcommittee A05.12 on Wire Specifications.

Current edition approved April 10, 1997. Published December 1997. Originally published as A 640 – 71. Last previous edition A 640 – 91.

<sup>2</sup> *Annual Book of ASTM Standards*, Vols 01.06 and 02.03.

<sup>3</sup> *Annual Book of ASTM Standards*, Vols 02.03 and 02.04.



TABLE 1 Mechanical Requirements

	Nominal Diameter of Strand	
	3/16 in. (4.76 mm)	1/4 in. (6.35 mm)
Nominal diameter of coated wires, in. (mm)	0.062 (1.57)	0.080 (2.03)
Minimum breaking strength of the strand, lbf (kN)	3990 (17.748)	6650 (29.581)
Minimum elongation of the strand in 24 in. (610 mm), %	4.0	4.0

sufficiently close to ensure no appreciable reduction in diameter when stressed to 10 % of the specified strength. A left-hand lay is defined as a counter-clockwise twist away from the observer.

7.2 The strand shall have a uniform pitch of not less than 14 times nor more than 22 times the nominal strand diameter.

7.3 All wires in the strand shall lie naturally in their true positions in the completed strand and, when the strand is cut, the ends shall remain in position or be readily replaced by hand and then remain in position. This shall be accomplished by a means or process, such as preforming, post forming, or form setting at the manufacturer's option.

## 8. Joints and Splices

8.1 Electric-welded butt joints made prior to the start of cold drawing of the wire are permitted.

8.2 Joints made in the individual finished wires shall be acceptable, provided there is not more than one joint in any 150-ft (45.7-m) section of the completed strand. Such joints shall either be the brazed-lap type or electric-butt-welded type. When the brazed type of joint is used, the length of the lap shall be not less than three times the diameter of the wire and the overlapping faces shall be smooth, clean, properly fluxed, and completely covered by the brazing metal. When the electric-butt-welded type of joint is used, care shall be taken to prevent injury to the wire during the electric-butt-welding. The wires shall be in alignment and the joints shall be well made and free from sharp burrs and sharp projections. The joints shall be coated with zinc after completion so that the joints shall have protection from corrosion equivalent to that of the zinc-coated wire itself.

8.3 The finished strand shall not be joined or spliced as a unit, unless specifically permitted by the purchaser.

## 9. Physical Requirements

9.1 The minimum breaking strength and minimum elongation in 24 in. (610 mm) of the strand and the nominal diameter of individual wires are given in Table 1. The approximate weights per 1000 ft (305 m) are given in Table 2.

9.2 *Ductility of Steel*—The individual wires of the completed strand shall not fracture when wrapped at a rate of not exceeding 15 turns/min in a close helix of at least two turns around a cylindrical mandrel equal to three times the nominal diameter of the wire under test.

9.3 *Weight of Coating*—The weight of zinc coating shall be not less than 0.65 oz/ft<sup>2</sup> (198 g/m<sup>2</sup>) of uncoated wire surface on the 3/16-in. (4.8-mm) and 1/4-in. (6.4-mm) strand.

9.4 *Adherence of Coating*—When the wire is wrapped on the cylindrical mandrel in accordance with 9.2, the zinc coating

TABLE 2 Approximate Weight of Strand

	Nominal Diameter of Strand	
	3/16 in. (4.76 mm)	1/4 in. (6.35 mm)
Before flooding:		
lb/1000 ft	73	121
kg/km	109	180
With flooding compound:		
lb/1000 ft	75	125
kg/km	112	186

shall not crack or flake to such an extent that any zinc can be removed by rubbing with the bare fingers. Loosening or detachment during the adhesion test of superficial, small particles of zinc formed by mechanical polishing of the surface of the zinc-coated wire shall not be considered cause for rejection.

## 10. Permissible Variations in Diameter

10.1 The diameter of the individual zinc-coated wires shall be the nominal size as given in Table 1 within a tolerance of  $\pm 0.003$  in. (0.08 mm).

## 11. Finish

11.1 The zinc-coated wire shall be free from imperfections not consistent with good commercial practice. The zinc coating shall be continuous and of reasonably uniform thickness.

## 12. Sampling

12.1 Sampling for determination of compliance to this specification shall be performed on each lot of material. A lot shall consist of all strands of one size in each shipment. The number of samples to be taken shall be as follows:

	Number of Samples
One reel	1
Two to four reels	2
Five to ten reels	3
Over ten reels	4

12.2 Each strand sample taken shall be tested for conformance to the requirements of 7.2 and Table 1.

12.3 In addition to the strand testing in 12.2 the individual wires from the strand samples shall be tested. Four wires are to be selected from the seven-wire strand and tested to determine compliance with 9.2, 9.3, 9.4, and Section 10. Individual wire samples selected for compliance to Section 10 shall be discarded if any distortion of the wire occurred during the stranding operation.

12.4 Instead of testing the wires from the completed strand in accordance with 12.3, the purchaser has the option to accept the manufacturer's certification that tests of the wires made prior to stranding meet requirements of 9.2, 9.3, 9.4, and Section 10.

## 13. Test Methods

13.1 The breaking strength shall be determined on the specimen tested for elongation in accordance with 13.2. A test in which the breaking strength is below the minimum specified possibly due to slipping of the specimen in the jaws of the testing machine, by breaking within the jaws or within 1 in.

(25.4 mm) of the jaws, or by the improper socketing of a specimen shall be disregarded and another sample from the same reel shall be tested.

13.2 The elongation shall be determined as the percent increase in separation between the jaws of the testing machine from the position after application of the initial load to the position at the initial failure of the test specimen. The separation of the jaws of the testing machine shall be approximately 2 ft (610 mm) when under an initial load equal to 10 % of the required minimum breaking strength of the strand. The elongation values shall be recorded only for specimens which break over 1 in. from the jaws of the testing machine. Additional samples shall be taken from the same length when previous tests are to be disregarded.

13.3 The weight of the zinc coating shall be determined by a stripping test in accordance with Test Method A 90/A 90M.

#### 14. Inspection

14.1 The manufacturer shall afford the inspector representing the purchaser all reasonable facilities to satisfy him that the material is being furnished in accordance with this specification. All tests and inspection shall be made at the place of manufacture prior to shipment, unless otherwise specified, and shall be so conducted as not to interfere unnecessarily with the operation of the works.

#### 15. Rejection

15.1 If the wire or strand fails in the first test to meet any requirement of this specification, two additional tests shall be made on samples of wire or strand from the same reel. If failure occurs in either of these tests, the lot of strand shall be rejected.

#### 16. Packaging and Marking

16.1 The strand shall be furnished on reels in standard lengths in accordance with Table 3. These standard lengths are multiples of unit lengths of 5000 ft (1500 m) plus 300 ft (91 m) to allow for threading into an extruder. If a length different than these standard lengths or unit lengths of 5000 ft is required, the purchase order shall include this requirement.

16.2 The permissible length of strand is permitted to vary between standard length and 4 % over the standard length.

16.3 Ten percent of any lot of strand is permitted to be supplied in lengths shorter than the standard length, provided the shipped length is one or more of the unit lengths as specified on the purchase order, or if no unit length is specified, a multiple of 5000 ft, plus 300 ft on each piece to allow for threading an extruder.

16.4 Each reel shall have a strong weather-resistant tag securely fastened to it showing the nominal diameter, length, ASTM Specification A 640, and the name and mark of the manufacturer. If additional information is required on the tag, it shall be so specified at the time of purchase.

#### 17. Keywords

17.1 Figure 8 cable support strand; messenger strand; steel wire strand; steel wire-zinc coated

**TABLE 3 Standard Lengths**

Nominal Diameter of Strand, in. (mm)	Standard Length, ft (m)
$\frac{3}{16}$ (4.76)	20 300 (6187)
$\frac{1}{4}$ (6.35)	15 300 (4663)

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# Standard Specification for Zinc-Coated (Galvanized) Carbon Steel Wire<sup>1</sup>

This standard is issued under the fixed designation A 641/A 641M; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reappraisal. A superscript epsilon ( $\epsilon$ ) indicates an editorial change since the last revision or reappraisal.

*This standard has been approved for use by agencies of the Department of Defense.*

## 1. Scope\*

1.1 This specification covers soft, medium, and hard temper zinc-coated (galvanized) carbon steel wire in coils for general use.

1.2 The supplementary requirements of this specification cover zinc-coated weights [masses] for nails, staples, and wire from which nails and staples are cut and formed.

1.3 This specification is applicable to orders in either inch-pound units (as A 641) or SI units (as A 641M). Values stated in either inch-pound units or SI units are to be regarded separately as the standard. Within the text, the SI units are shown in brackets. The values stated in the two systems are not exact equivalents; therefore, each system shall be used independent of the other, without combining values in any way.

1.4 This specification and some referenced specifications are expressed in both inch-pound and SI units. If the order specifies the applicable “M” specification designation, the product shall be furnished to SI units.

1.5 The text of this specification references notes and footnotes which provide explanatory material. These notes and footnotes (excluding those in tables and figures) shall not be considered as requirements of the specification.

## 2. Referenced Documents

### 2.1 ASTM Standards:

A 90/A 90M Test Method for Weight [Mass] of Coating on Iron and Steel Articles with Zinc or Zinc-Alloy Coatings<sup>2</sup>

A 700 Practices for Packaging, Marking, and Loading Methods for Steel Products for Domestic Shipments<sup>3</sup>

A 902 Terminology Relating to Metallic Coated Steel Products<sup>2</sup>

B 6 Specification for Zinc (Slab Zinc)<sup>4</sup>

<sup>1</sup> This specification is under the jurisdiction of ASTM Committee A05 on Metallic-Coated Iron and Steel Products and is the direct responsibility of Subcommittee A05.12 on Wire Specifications.

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<sup>2</sup> Annual Book of ASTM Standards, Vol 01.06.

<sup>3</sup> Annual Book of ASTM Standards, Vol 01.05.

<sup>4</sup> Annual Book of ASTM Standards, Vol 02.04.

E 8 Test Methods of Tension Testing of Metallic Materials<sup>5</sup>  
E 29 Practice for Using Significant Digits in Test Data to Determine Conformance with Specifications<sup>6</sup>

## 3. Terminology

3.1 *Definitions*—For definitions of terms used in this specification, refer to Terminology A 902.

## 4. Classification

4.1 *Temper*—The wire is classified with regard to mechanical properties by temper, which is related to tensile strength and stiffness. The temper designations are soft, medium, and hard.

4.2 *Zinc Coating*—Zinc coating on the wire is classified in a number of classes (Class 1, 2, 3, or A, 4, B, 5, C (see Table 1, Table 2, Table 3, and Table S1.1)) and as “regular coating.”

NOTE 1—Class 2 coating has been eliminated since it is no longer generally specified by users except for nails, staples, and wire from which nails and staples are cut and formed, as presented in the Supplementary Requirements.

## 5. Ordering Information

5.1 Orders for material under this specification shall include the following information:

5.1.1 Quantity (weight [mass]),

5.1.2 Coated wire diameter,

5.1.3 Intended use, when the wire is to be used for nails or staples (see Supplementary Requirement S1),

5.1.4 Class of coating (see Table 1, Table 2, or Table 3 (or Table S1.1 when applicable)),

5.1.5 Temper (soft, medium, or hard) (Table 4 or Table 5),

5.1.6 ASTM designation and year of issue as A 641-\_\_\_\_ for inch-pound units, or A 641M-\_\_\_\_ for SI units.

5.1.7 Supplementary Requirements (if required).

NOTE 2—A typical ordering description (inch-pound units) is as follows: 50 000 lb, 0.120 in., zinc-coated wire, Class 1 coating, soft temper in 1500-lb coils on tubular carriers to ASTM A 641-\_\_\_\_.

<sup>5</sup> Annual Book of ASTM Standards, Vol 03.01.

<sup>6</sup> Annual Book of ASTM Standards, Vol 14.02.

\*A Summary of Changes section appears at the end of this standard.

**TABLE 1 Minimum Weight [Mass] of Zinc per Unit Area of Uncoated Wire Surface (Inch-Pound Units)**

Wire Diameter in. <sup>A</sup>	Class 1	Class 3 or A Coating, oz/ft <sup>2</sup>	Class 4 Coating, oz/ft <sup>2</sup>	Class B Coating, oz/ft <sup>2</sup>	Class 5 Coating, oz/ft <sup>2</sup>	Class C Coating, oz/ft <sup>2</sup>
0.035	0.15	0.45	n/a	0.90	n/a	1.35
0.041	0.15	0.50	n/a	1.00	n/a	1.50
0.048	0.15	0.55	n/a	1.10	n/a	1.65
0.054	0.20	0.60	n/a	1.20	n/a	1.80
0.062	0.20	0.65	n/a	1.20	n/a	1.80
0.072	0.20	0.65	n/a	1.20	n/a	1.80
0.076	0.25	0.70	1.20	1.40	2.00	2.10
0.080	0.25	0.70	1.20	1.40	2.00	2.10
0.092	0.28	0.75	1.20	1.50	2.00	2.25
0.099	0.28	0.80	1.20	1.60	2.00	2.40
0.106	0.30	0.80	1.20	1.60	2.00	2.40
0.120	0.30	0.85	1.20	1.70	2.00	2.55
0.135	0.30	0.85	1.20	1.70	2.00	2.55
0.148	0.35	0.90	1.20	1.80	2.00	2.70
0.162	0.35	0.90	1.20	1.80	2.00	2.70
0.177	0.44	0.90	1.20	1.80	2.00	2.70
0.192	0.50	1.00	1.20	2.00	2.00	3.00
0.207	0.53	1.00	1.20	2.00	2.00	3.00
and larger						

<sup>A</sup>Coating weights [mass] for diameters other than those shown in Table 1 are the coating weights [mass] for the next smaller diameter.

**TABLE 2 Minimum Weight [Mass] of Zinc per Unit Area of Uncoated Wire Surface (SI Units)**

Wire Diameter, mm	Class 1 Coating, g/m <sup>2</sup>
0.20 to under 0.25	20
0.25 to under 0.40	25
0.40 to under 0.50	30
0.50 to under 0.60	35
0.60 to under 0.80	40
0.80 to under 1.10	45
1.10 to under 1.50	55
1.50 to under 1.90	65
1.90 to under 2.30	75
2.30 to under 3.20	85
3.20 to under 4.00	100
4.00 to under 4.90	115
4.90 to under 5.90	150
5.90 and over	190

NOTE 3—A typical ordering description (SI units) is as follows: 50 000 kg, 3.00 mm., zinc-coated wire, Class 1 coating, soft temper in 1000-kg coils on tubular carriers to ASTM A 641M—\_\_\_\_\_.

## 6. Materials and Manufacture

6.1 The steel from which the wire is produced shall be made by any commercially accepted steel making process.

6.2 The slab zinc when used shall be any grade of zinc conforming to Specification B 6.

## 7. Mechanical Properties

7.1 The zinc-coated wire, as represented by the test specimens tested in accordance with Test Methods E 8, shall conform to the tensile strength requirements prescribed in Table 4 or Table 5

7.2 Test specimens found to contain a weld or obvious imperfections shall be discarded and another test specimen obtained to verify conformance to the tensile strength requirements.

## 8. Permissible Variations

8.1 The permissible variation in diameter of the zinc-coated wire as represented by the test specimens shall meet the requirements shown in Table 6 or Table 7.

## 9. Weight [Mass] of Coating

9.1 The zinc-coated wire, as represented by the test specimens tested in accordance with Section 12 and Test Method A 90/A 90M, shall conform to the requirements of Table 1, Table 2, or Table 3 for minimum weight [mass] of zinc coating of the class specified.

9.2 Zinc-coated wire produced as “regular coating” shall have the full surface covered with zinc, but there is no specified minimum weight of coating.

## 10. Adherence of Coating

10.1 The zinc-coated wire as represented by the test specimens shall be capable of being wrapped in a close helix at a rate not exceeding 15 turns/min around a cylindrical steel mandrel having a diameter as prescribed in Table 8 or Table 9 without cracking or flaking the zinc coating to such an extent that any zinc can be removed by rubbing with the bare fingers. Loosening or detachment during the adhesion test of superficial, small particles of zinc formed by mechanical polishing of the surface of the zinc-coated wire shall not be considered cause for rejection.

## 11. Workmanship, Finish, and Appearance

11.1 The zinc-coated wire shall be free of slivers, scale, and other imperfections not consistent with good commercial practice. The coating shall be continuous and reasonably uniform. To ensure large continuous length coils, welds are permitted in the finished wire.

## 12. Number of Tests and Retests

12.1 The number of test specimens taken from the ends of coils during production to ensure compliance with Sections 7, 8, 9, and 10 vary with the quality control procedures and the manufacturing facilities of each manufacturer but is generally not less than 10 % of the coils produced. For the purpose of final product testing, one specimen from every ten coils or fraction thereof in a lot shall be selected at random or a total of seven specimens, whichever is less.



**TABLE 3 Minimum Weight [Mass] of Zinc per Unit Area of Uncoated Wire Surface (SI Units)**

Diameter, mm <sup>A</sup>	Class 3 or A Coating, g/m <sup>2</sup>	Class 4 Coating, g/m <sup>2</sup>	Class B Coating g/m <sup>2</sup>	Class 5 Coating, g/m <sup>2</sup>	Class C Coating g/m <sup>2</sup>
0.90	137	n/a	275	n/a	412
1.00	153	n/a	305	n/a	458
1.20	168	n/a	336	n/a	504
1.40	183	n/a	366	n/a	549
1.60	198	n/a	366	n/a	549
1.80	198	n/a	366	n/a	549
1.90	214	366	427	610	641
2.00	214	366	427	610	641
2.30	229	366	458	610	687
2.50	244	366	488	610	732
2.70	244	366	488	610	732
3.00	259	366	519	610	778
3.40	259	366	519	610	778
3.80	275	366	549	610	824
4.10	275	366	549	610	824
4.50	275	366	549	610	824
4.90	305	366	610	610	915
5.30	305	366	610	610	915
and larger					

<sup>A</sup>Coating weights [mass] for diameters other than those shown in this table are the coating weights [mass] for the next smaller diameter.

**TABLE 4 Tensile Strength for Temper Designation (Inch-Pound Units)**

Wire Diameter, in.	Soft, Ksi <sup>A</sup>	Medium, Ksi <sup>A</sup>	Hard, Ksi <sup>A</sup>
0.035 to under 0.080	75 max	70 to 100	90 to 120
0.080 to under 0.106	75 max	70 to 95	85 to 115
0.106 to 0.176 <sup>A</sup> , incl	70 max	65 to 90	80 to 110
Over 0.176	70 max	60 to 85	75 to 105

<sup>A</sup>For the purpose of determining conformance with this specification, and observed value shall be rounded to the nearest 1 Ksi in accordance with the rounding method of Practice E 29.

**TABLE 5 Tensile Strength for Temper Designation (SI Units)**

Wire Diameter, mm	MPa		
	Soft <sup>A</sup>	Medium <sup>A</sup>	Hard <sup>A</sup>
0.20 to under 2.00	515 max	485 to 690	620 to 825
2.00 to under 2.50	515 max	485 to 655	585 to 795
2.50 to under 4.70	485 max	450 to 620	550 to 760
4.70 and over	485 max	415 to 585	515 to 715

<sup>A</sup>For the purpose of determining conformance with this specification, an observed value shall be rounded to the nearest 1 MPa in accordance with the rounding method of Practice E 29.

12.2 A wire sample of sufficient length, approximately 4 ft [1.2 m], shall be cut from either end of each coil selected for tests described in Sections 7, 8, 9, and 10.

12.3 If one or more of the wire specimens fail any requirement, the lot shall be subjected to retest. For retest purposes, the original lot shall be regrouped into 50 coil lots or fractions thereof. Each lot shall be 10 % tested for the property in which the original sample failed to comply. The number of samples thus selected shall be at least twice the number of the original sampling. Any lot that exhibits a failure shall be rejected.

12.3.1 The manufacturer has the option of testing each coil in the failed lot for the property in which the failure occurred, rejecting the nonconforming coils. The coils which conform for the property tested shall be deemed to conform to the specification requirements.

### 13. Inspection

13.1 Unless otherwise specified in the purchase order or contract, the manufacturer is responsible for the performance

**TABLE 6 Diameter Tolerance for Zinc-Coated Wire in Coils (Inch-Pound Units)<sup>A</sup>**

Wire Diameter, in.	Tolerance <sup>B</sup> Plus and Minus, in.	
	Regular and Class 1 Coating	Class 3, 4, 5 or B and C Coating
0.035 to under 0.076	0.002	0.002
0.076 to under 0.148	0.003	0.004
0.148 to 0.250, incl.	0.003	0.004
Over 0.250 to 0.500, incl.	0.003	0.005

<sup>A</sup>For the purpose of determining conformance with this specification, an observed value shall be rounded to the nearest 0.001 in. in accordance with the rounding method of Practice E 29.

<sup>B</sup>It is recognized that the surfaces of heavy zinc coating, particularly those produced by hot galvanizing, are not perfectly smooth and devoid of irregularities. The tolerances shown in Table 6 shall not be rigidly applied to such irregularities that are inherent to the product, so that unjustified rejections of wire that are actually satisfactory for use do not occur. Therefore, it is intended that these tolerances be used in gaging the uniform areas of the zinc-coated wire.

**TABLE 7 Diameter Tolerance for Zinc-Coated Wire in Coils (SI Units)<sup>A</sup>**

Wire Diameter, mm	Tolerance <sup>B</sup> , Plus and Minus, mm	
	Regular and Class 1 Coating	Class 3, 4, 5 or A, B, and C Coating
0.20 to under 1.90	0.05	0.05
1.90 to under 3.70	0.08	0.10
3.70 to under 5.90	0.08	0.10
5.90 and over	0.08	0.13

<sup>A</sup>For the purpose of determining conformance with this specification, an observed value shall be rounded to the nearest 0.01 mm in accordance with the rounding method of Practice E 29.

<sup>B</sup>It is recognized that the surfaces of heavy zinc coating, particularly those produced by hot galvanizing, are not perfectly smooth and devoid of irregularities. The tolerances shown in Table 7 shall not be rigidly applied to such irregularities that are inherent to the product, so that unjustified rejections of wire that is actually satisfactory for use do not occur. Therefore, it is intended that these tolerances be used in gaging the uniform areas of the zinc-coated wire.

of all inspection and test requirements specified in this specification. Except as otherwise specified in the purchase order or contract, the manufacturer shall use his own or other suitable facilities for the performance of the inspection and test requirements, at his option, unless disapproved by the purchaser at the time the order is placed. The purchaser shall have the right to perform any of the inspection and tests prescribed

**TABLE 8 Mandrel Diameters for Test for Adherence of Zinc Coating (Inch-Pound Units)**

Wire Diameter, in.	Mandrel Diameters for Coating Classes	
	Regular and 1	Class 3, 4, 5 or A, B, and C
0.035 to under 0.076	1D <sup>A</sup>	2D <sup>A</sup>
0.076 to under 0.148	1D	3D
0.148 to 0.500, incl	2D	4D

<sup>A</sup>D = nominal wire diameter being tested.

**TABLE 9 Mandrel Diameters for Test for Adherence of Zinc Coating (SI Units)**

Wire Diameter, mm	Mandrel Diameters for Coating Classes	
	Regular and 1	Class 3, 4, 5 or A, B, and C
0.20 to under 1.90	1D <sup>A</sup>	2D <sup>A</sup>
1.90 to under 3.70	1D	3D
3.70 and over	2D	4D

<sup>A</sup>D = nominal wire diameter being tested.

in this specification when such inspections and tests are deemed necessary to ensure that the material conforms to prescribed requirements.

#### 14. Rejection and Rehearing

14.1 Material that fails to conform to the requirements of this specification is subject to rejection. Rejection shall be

reported to the producer or supplier promptly and in writing. In case of dissatisfaction with the results of the test, the producer or supplier shall make claim for a rehearing.

#### 15. Certification

15.1 When specified in the purchase order or contract, a producer’s or supplier’s certification shall be furnished to the purchaser that the material was manufactured, sampled, tested, and inspected in accordance with this specification and has been found to meet the requirements. When specified in the purchase order or contract, a report of the test results shall be furnished.

#### 16. Package and Package Marking

16.1 Unless otherwise specified, packaging, marking, and loading for shipment shall be in accordance with Practices A 700.

#### 17. Keywords

17.1 galvanized wire; steel wire; wire; zinc-coated carbon steel wire

### SUPPLEMENTARY REQUIREMENTS

**TABLE S1.1 Minimum Weight [Mass] of Zinc per Unit Area of Uncoated Nail, Staple, or Wire Surface**

Diameter of Staple Leg, Nail Shank, or Wire, in. [mm] <sup>A</sup>	Class 1	Class 2
	Coating, oz/ft <sup>2</sup> [g/m <sup>2</sup> ]	Coating, oz/ft <sup>2</sup> [g/m <sup>2</sup> ]
0.035 [0.89]	0.10 [30]	0.30 [90]
0.048 [1.22]	0.15 [45]	0.30 [90]
0.062 [1.57]	0.15 [45]	0.35 [105]
0.076 [1.93]	0.20 [60]	0.40 [120]
0.080 [2.03]	0.25 [75]	0.45 [135]
0.092 [2.34]	0.28 [85]	0.50 [150]
0.148 [3.76]	0.35 [105]	0.60 [180]
0.192 [4.88]	0.50 [150]	0.70 [215]
0.207 [5.26] and larger	0.53 [160]	0.75 [230]

<sup>A</sup>Coating weights [mass] for diameters other than those shown in Table S1.1 are the coating weights [mass] for the next smaller diameter.

The following supplementary requirements shall apply only when specified by the purchaser in the contract or order.

#### S1. Zinc Coating on Wire for Nails and Staples

S1.1 These requirements apply only to nails and staples, and coated wire from which nails and staples are cut and formed, which are specified to have a Class 1 or Class 2 zinc coating.

S1.2 *Coating Weight [Mass]*—The zinc coating weight [mass] on the nails or staples, or on the wire to be used in the manufacture of nails and staples, as represented by test specimens tested in accordance with Section 12 of this specification and Test Method A 90/A 90M, shall conform to the requirements of Table S1.1 for the class specified.

S1.3 *Class 2 Coating Requirements*—The permissible variation in diameter of nails, staples, or wire specified to have Class 2 coating shall be the same as shown for Class 1 coating in Table 6 or Table 7. The test for coating adherence on nails, staples, or wire specified to have Class 2 coating shall be conducted using the mandrel diameter as shown for Class 1 coating in Table 8 or Table 9.

**SUMMARY OF CHANGES**

Committee A05 has identified the location of selected changes to this standard since the last issue (A 641/A 641M - 98) that may impact the use of this standard.

*A 641/A 641M - 03:*

in the Referenced Documents section.

(1) Corrected the spelling of weight in the title of A 90/A 90M

(2) Modified Table 3.

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## Standard Specification for Tin Mill Products, Black Plate, Double Reduced<sup>1</sup>

This standard is issued under the fixed designation A 650/A 650M; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reappraisal. A superscript epsilon ( $\epsilon$ ) indicates an editorial change since the last revision or reappraisal.

### 1. Scope\*

1.1 This specification covers double-reduced black plate, produced from low-carbon cold-reduced steel, furnished in coils and cut sizes, for use predominantly in the manufacture of containers. The product may be specified “as rolled,” without the removal of the rolling solution, and with no additional surface or oiling treatment. It may also be specified “cleaned” with the rolling solution removed, with or without surface treatment and oiling. This product is normally supplied with trimmed edges.

1.2 This specification is applicable to orders in either inch-pound units (as A 650) which is supplied in thicknesses 0.0050 in. to 0.0113 in. or SI units [as A 650M] which is supplied in thicknesses from 0.127 to 0.287 mm.

1.3 The values stated in either inch-pound or SI units are to be regarded as standard. Within the text, the SI units are shown in brackets. The values stated in each system are not exact equivalents; therefore, each system must be used independently of the other. Combining values from the two systems may result in nonconformance with this specification.

### 2. Referenced Documents

#### 2.1 *ASTM Standards*:<sup>2</sup>

A 623 Specification for Tin Mill Products, General Requirements

A 623M Specification for Tin Mill Products, General Requirements [Metric]

### 3. Ordering Information

3.1 Orders for material under this specification shall include the following information, as required and applicable, to adequately describe the desired materials.

3.1.1 Name of material (double-reduced black plate),

3.1.1.1 As rolled, with the rolling solution not removed,

3.1.1.2 Cleaned, with the rolling solution removed, not reoiled,

3.1.1.3 Cleaned and oiled, with the rolling solution removed and reoiled,

3.1.1.4 Cleaned, chemically treated and oiled, with the rolling solution removed, chemically treated and reoiled.

3.1.2 Thickness (see Specification A 623 [Specification A 623M]),

3.1.3 Width,

3.1.4 Length, for cut sizes only,

3.1.5 Rolling direction must be specified by underlining the slit (rolling width) for cut sizes (see 4.1),

3.1.6 Steel type (see Specification A 623 [Specification A 623M]),

3.1.7 Mechanical designation requirements (see Specification A 623 [Specification A 623M]),

3.1.8 Intended application,

3.1.9 Quantity, in base boxes [SITAS] (see Note 5),

3.1.10 On coils, specify minimum or range of acceptable inside diameters. The standard inside diameter is approximately 16 in. if ordered to Specification A 650 [410 mm if ordered to Specification A 650M]. Coils should be specified to a maximum coil weight if ordered to Specification A 650 [mass if ordered to Specification A 650M] or maximum outside diameter,

3.1.11 Packaging,

3.1.12 Special requirements where applicable, and

3.1.13 ASTM specification number and year of issue (A 650/A 650M – 88).

NOTE 1—A typical ordering description is as follows: 1200 base boxes double-reduced black plate, cleaned and oiled, 60-lb base weight, 33 1/16 in. by coil, MR, DR8 CA, for 401 by 411 can bodies to ASTM Specification A 650/A 650M - XX. [250 SITAS, double-reduced black plate, cleaned and oiled, 0.17 mm thickness, 840 mm by coil, MR, DR8 CA, for 99 mm can bodies to ASTM Specification A 650/A 650M.]

NOTE 2—A typical ordering description for cut sizes is as follows: 500 base boxes, double-reduced black plate, cleaned and oiled, 60-lb base weight MR, DR8 CA, 7C, 28 by 33 1/16 in., for 401 by 411 can bodies in accordance with Specification A 650/A 650M - XX. [100 SITAS, double-reduced black plate, cleaned and oiled, MR, DR8 CA, 7C, 0.28 mm thickness, 781 by 773 mm, for 401 by 411 can bodies in accordance with Specification A 650M/A 650M - XX.]

NOTE 3—The production of coils does not afford the same opportunity for inspection, grading, and sorting as does the production of cut sizes. Accordingly, appropriate processing and quality control procedures are

<sup>1</sup> This specification is under the jurisdiction of ASTM Committee A01 on Steel, Stainless Steel, and Related Alloys and is the direct responsibility of Subcommittee A01.20 on Tin Mill Products.

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<sup>2</sup> For referenced ASTM standards, visit the ASTM website, [www.astm.org](http://www.astm.org), or contact ASTM Customer Service at [service@astm.org](mailto:service@astm.org). For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

\*A Summary of Changes section appears at the end of this standard.

required by the purchaser to obtain optimum utilization of the material. Cut sizes are line-inspected visually and mechanically during production. Sheets having surface imperfections that will not interfere with their utilization are included.

NOTE 4—Double-reduced black plate is highly susceptible to rusting and must be properly handled during transit and storage.

NOTE 5—In inch-pound units, double-reduced black plate is supplied on an area basis expressed in base boxes. In coils, the number of base boxes is computed from the measured length and the specified width. The theoretical weight of a coil is computed by multiplying the number of base boxes in a coil by the specified base weight. In cut lengths, the number of base boxes is computed from the specified length and width dimensions and sheet count. The theoretical weight of a bundle is computed by multiplying the number of base boxes in the bundle by the specified base weight.

[In SI units, double-reduced black plate is supplied on an area basis expressed in SITAS. In coils, the number of SITAS is computed from the measured length and the specified width. In cut sizes, the number of SITAS is computed from the specified length and width dimensions and sheet count. For calculating mass, the density of steel for tin mill products is 7850 kg/m<sup>3</sup> (see Specification A 623M).]

#### 4. Rolling Direction

4.1 Double-reduced black plate is relatively brittle and has very distinct directional properties. The rolling direction must

be specified on cut lengths and will be indicated by underlining the slit (rolling width) dimension. To minimize the flange-cracking hazard when the product is used for can bodies, the rolling direction must be around the circumference of the can.

#### 5. Surface Finish

5.1 *Base Metal Finish*—Double-reduced black plate is produced with a ground roll finish.

5.1.1 7C—A smooth finish with grit lines. The surface roughness will range from 6 to 25  $\mu\text{in}$ . Ra [0.152 to 0.635  $\mu\text{m}$  Ra]. This is the standard finish for tin mill products.

#### 6. General Requirements for Delivery

6.1 Material furnished under this specification shall conform to the applicable requirements of the current edition of Specification A 623 [Specification A 623M] unless otherwise provided herein.

### SUMMARY OF CHANGES

Committee A01 has identified the location of selected changes to this standard since the last issue (A 650/A 650M - 98) that may impact the use of this standard.

A 650/A 650M - 03:

(1) Decrease minimum ordered thickness from 0.0055 in. to 0.0050 in. [0.140 mm to 0.127 mm] in paragraph 1.2 to be consistent with the minimum thickness of like products for

A 626/A 626M and A 657/A 657M.

(2) Change metric decimal thickness from two significant figures to three significant figures in paragraph 1.2.

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Designation: A 653/A 653M – 04a

## Standard Specification for Steel Sheet, Zinc-Coated (Galvanized) or Zinc-Iron Alloy- Coated (Galvannealed) by the Hot-Dip Process<sup>1</sup>

This standard is issued under the fixed designation A 653/A 653M; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon ( $\epsilon$ ) indicates an editorial change since the last revision or reapproval.

### 1. Scope\*

1.1 This specification covers steel sheet, zinc-coated (galvanized) or zinc-iron alloy-coated (galvannealed) by the hot-dip process in coils and cut lengths.

1.2 The product is produced in various zinc or zinc-iron alloy-coating weights [masses] or coating designations as shown in Table 1.

1.3 Product furnished under this specification shall conform to the applicable requirements of the latest issue of Specification A 924/A 924M, unless otherwise provided herein.

1.4 The product is available in a number of designations, types, grades and classes in three general categories that are designed to be compatible with different application requirements.

1.4.1 Steels with mandatory chemical requirements and typical mechanical properties.

1.4.2 Steels with mandatory chemical requirements and mandatory mechanical properties.

1.4.3 Steels with mandatory chemical requirements and mandatory mechanical properties that are achieved through solid-solution or bake hardening.

1.5 This specification is applicable to orders in either inch-pound units (as A 653) or SI units (as A 653M). Values in inch-pound and SI units are not necessarily equivalent. Within the text, SI units are shown in brackets. Each system shall be used independently of the other.

1.6 Unless the order specifies the “M” designation (SI units), the product shall be furnished to inch-pound units.

1.7 The text of this specification references notes and footnotes that provide explanatory material. These notes and footnotes, excluding those in tables and figures, shall not be considered as requirements of this specification.

1.8 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

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<sup>1</sup> This specification is under the jurisdiction of ASTM Committee A05 on Metallic-Coated Iron and Steel Products and is the direct responsibility of Subcommittee A05.11 on Sheet Specifications.

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\*A Summary of Changes section appears at the end of this standard.

## 2. Referenced Documents

### 2.1 ASTM Standards:<sup>2</sup>

A 90/A 90M Test Method for Weight [Mass] of Coating on Iron and Steel Articles with Zinc or Zinc-Alloy Coatings

A 370 Test Methods and Definitions for Mechanical Testing of Steel Products

A 568/A 568M Specification for Steel, Sheet, Carbon, and High-Strength, Low-Alloy, Hot-Rolled and Cold-Rolled, General Requirements for

A 902 Terminology Relating to Metallic Coated Steel Products

A 924/A 924M Specification for General Requirements for Steel Sheet, Metallic-Coated by the Hot-Dip Process

D 2092 Guide for Treatment of Zinc-Coated (Galvanized) Steel Surfaces for Painting

E 517 Test Method for Plastic Strain Ratio *r* for Sheet Metal

<sup>2</sup> For referenced ASTM standards, visit the ASTM website, [www.astm.org](http://www.astm.org), or contact ASTM Customer Service at [service@astm.org](mailto:service@astm.org). For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

**TABLE 1 Weight [Mass] of Coating Requirements<sup>A,B,C</sup>**

NOTE 1— Use the information provided in 8.1.2 to obtain the approximate coating thickness from the coating weight [mass].

		Minimum Requirement <sup>D</sup>			
		Triple-Spot Test	Single-Spot Test		
Inch-Pound Units					
Type	Coating Designation	Total Both Sides, oz/ft <sup>2</sup>	One Side	Total Both Sides, oz/ft <sup>2</sup>	
Zinc	G360	3.60	1.28	3.20	
	G300	3.00	1.04	2.60	
	G235	2.35	0.80	2.00	
	G210	2.10	0.72	1.80	
	G185	1.85	0.64	1.60	
	G165	1.65	0.56	1.40	
	G140	1.40	0.48	1.20	
	G115	1.15	0.40	1.00	
	G90	0.90	0.32	0.80	
	G60	0.60	0.20	0.50	
	G40	0.40	0.12	0.30	
	G30	0.30	0.10	0.25	
	G01	no minimum	no minimum	no minimum	
	Zinc-iron alloy	A60	0.60	0.20	0.50
A40		0.40	0.12	0.30	
A25		0.25	0.08	0.20	
A01		no minimum	no minimum	no minimum	
SI Units					
Type	Coating Designation	Total Both Sides, g/m <sup>2</sup>	One Side	Total Both Sides, g/m <sup>2</sup>	
Zinc	Z1100	1100	390	975	
	Z900	900	316	790	
	Z700	700	238	595	
	Z600	600	204	510	
	Z550	550	190	475	
	Z500	500	170	425	
	Z450	450	154	385	
	Z350	350	120	300	
	Z275	275	94	235	
	Z180	180	60	150	
	Z120	120	36	90	
	Z90	90	30	75	
	Z001	no minimum	no minimum	no minimum	
	Zinc-iron alloy	ZF180	180	60	150
		ZF120	120	36	90
		ZF75	75	24	60
ZF001		no minimum	no minimum	no minimum	

<sup>A</sup>The coating designation number is the term by which this product is specified. Because of the many variables and changing conditions that are characteristic of continuous hot-dip coating lines, the zinc or zinc-iron alloy coating is not always evenly divided between the two surfaces of a coated sheet; nor is it always evenly distributed from edge to edge. However, the minimum triple-spot average coating weight (mass) on any one side shall not be less than 40 % of the single-spot requirement.

<sup>B</sup>As it is an established fact that the atmospheric corrosion resistance of zinc or zinc-iron alloy-coated sheet products is a direct function of coating thickness (weight (mass)), the selection of thinner (lighter) coating designations will result in almost linearly reduced corrosion performance of the coating. For example, heavier galvanized coatings perform adequately in bold atmospheric exposure whereas the lighter coatings are often further coated with paint or a similar barrier coating for increased corrosion resistance. Because of this relationship, products carrying the statement "meets ASTM A 653/A 653M requirements" should also specify the particular coating designation.

<sup>C</sup>International Standard, ISO 3575, continuous hot-dip zinc-coated carbon steel sheet contains Z100 and Z200 designations and does not specify a ZF75 coating.

<sup>D</sup>No minimum means that there are no established minimum requirements for triple- and single-spot tests.

E 646 Test Method for Tensile Strain-Hardening Exponents ( $n$  values) of Metallic Sheet Materials

2.2 *ISO Standard:*

ISO 3575 Continuous Hot-Dip Zinc-Coated Carbon Steel of Commercial and Drawing Qualities<sup>3</sup>

ISO 4998 Continuous Hot-Dip Zinc-Coated Carbon Steel of Structural Quality<sup>3</sup>

### 3. Terminology

3.1 *Definitions*— See Terminology A 902 for definitions of general terminology relating to metallic-coated hot-dip products.

3.2 *Definitions of Terms Specific to This Standard:*

3.2.1 *bake hardenable steel, n*—steel sheet in which a significant increase in yield strength is realized when moderate heat treatment, such as that used for paint baking, follows straining or cold working.

3.2.2 *differentially coated, n*—galvanized steel sheet having a specified “coating designation” on one surface and a significantly lighter specified “coating designation” on the other surface.

3.2.2.1 *Discussion*—The single side relationship of either specified “coating designation” is the same as shown in the note of Table 1 regarding uniformity of coating.

3.2.3 *high strength low alloy steel, Type A sheet, n*—steel sheet intended for applications where mechanical properties are specified and where improved formability is required compared to structural steel.

3.2.3.1 *Discussion*—Suppliers use one or a combination of microalloying elements as strengthening agents.

3.2.4 *high strength low alloy steel, Type B sheet, n*—steel sheet intended for applications where mechanical properties are specified and where improved formability is required compared to high strength low alloy steel, Type A.

3.2.4.1 *Discussion*—Suppliers use one or a combination of microalloying elements as strengthening agents and also treat the steel with additional small alloy additions to effect sulfide inclusion control.

3.2.5 *minimized spangle, n*—the finish produced on hot-dip zinc-coated steel sheet in which the grain pattern is visible to the unaided eye, and is typically smaller and less distinct than the pattern visible on regular spangle.

3.2.5.1 *Discussion*—This finish is produced by one of two methods: either (1) the zinc crystal growth has been started but arrested by special production practices during solidification of the zinc, or (2) the zinc crystal growth is inhibited by a combination of coating-bath chemistry plus cooling during solidification of the zinc. Minimized spangle is normally produced in coating designations G90 [Z275] and lighter.

3.2.6 *regular spangle, n*—the finish produced on hot-dip zinc-coated steel sheet in which there is a visible multifaceted zinc crystal structure.

3.2.6.1 *Discussion*—Solidification of the zinc coating is typically uncontrolled, which produces the variable grain size associated with this finish.

3.2.7 *spangle-free, n*—the uniform finish produced on hot-dip zinc-coated steel sheet in which the visual spangle pattern, especially the surface irregularities created by spangle formation, is not visible to the unaided eye.

3.2.7.1 *Discussion*—This finish is produced when the zinc crystal growth is inhibited by a combination of coating-bath chemistry, or cooling, or both during solidification of the zinc.

3.2.8 *solid-solution hardened steel or solution hardened steel, n*—steel sheet strengthened through additions of substitutional alloying elements such as Mn, P, or Si.

3.2.8.1 *Discussion*—Substitutional alloying elements such as Mn, P, and Si can occupy the same sites as iron atoms within the crystalline structure of steels. Strengthening arises as a result of the mismatch between the atomic sizes of these elements and that of iron.

3.2.9 *zinc-iron alloy, n*—a dull grey coating with no spangle pattern that is produced on hot-dip zinc-coated steel sheet.

3.2.9.1 *Discussion*—Zinc-iron alloy coating is composed entirely of inter-metallic alloys. It is typically produced by subjecting the hot-dip zinc-coated steel sheet to a thermal treatment after it emerges from the molten zinc bath. This type of coating is suitable for immediate painting without further treatment except normal cleaning (refer to Guide D 2092). The lack of ductility of the alloy coating presents a potential for powdering, etc.

### 4. Classification

4.1 The material is available in several designations as follows:

4.1.1 Commercial steel (CS Types A, B, and C),

4.1.2 Forming steel (FS Types A and B),

4.1.3 Deep drawing steel (DDS),

4.1.4 Extra deep drawing steel (EDDS),

4.1.5 Structural steel (SS),

4.1.6 High strength low alloy steel (HSLAS Type A),

4.1.7 High strength low alloy steel (HSLAS Type B),

4.1.8 Solution hardened steel (SHS), and

<sup>3</sup> Available from American National Standards Institute (ANSI), 25 W. 43rd St., 4th Floor, New York, NY 10036.



4.1.9 Bake hardenable steel (BHS)

4.2 Structural steel, high strength low alloy steel, solution hardened steel, and bake hardenable steel are available in several grades based on mechanical properties. Structural Steel Grade 50 [340] is available in four classes based on tensile strength.

4.3 The material is available as either zinc-coated or zinc-iron alloy-coated in several coating weights [masses] or coating designations as shown in Table 1, and

4.3.1 The material is available with the same or different coating designations on each surface.

## 5. Ordering Information

5.1 Zinc-coated or zinc-iron alloy-coated sheet in coils and cut lengths is produced to thickness requirements expressed to 0.001 in. [0.01 mm]. The thickness of the sheet includes both the base metal and the coating.

5.2 Orders for product to this specification shall include the following information, as necessary, to adequately describe the desired product:

5.2.1 Name of product (steel sheet, zinc-coated (galvanized) or zinc-iron alloy-coated (galvannealed)),

5.2.2 Designation of sheet [CS (Types A, B, and C), FS (Types A and B), DDS, EDDS, SS, or HSLAS (Types A and B), SHS, or BHS].

5.2.2.1 When a CS type is not specified, CS Type B will be furnished. When an FS type is not specified, FS Type B will be furnished.

5.2.3 When an SS, HSLAS, SHS, or BHS designation is specified, state the type, grade, or class, or combination thereof.

5.2.4 ASTM designation number and year of issue, as A 653 for inch-pound units or A 653M for SI units.

5.2.5 Coating designation,

5.2.6 Chemically treated or not chemically treated,

5.2.7 Oiled or not oiled,

5.2.8 Minimized spangle (if required),

5.2.9 Extra smooth (if required),

5.2.10 Phosphatized (if required),

5.2.11 Dimensions (show thickness, minimum or nominal, width, flatness requirements, and length, if cut lengths). The purchaser shall specify the appropriate table of thickness tolerances in Specification A 924/A 924M that applies to the order, that is, the table of thickness tolerances for  $\frac{3}{8}$ -in. [10-mm] edge distance, or the table of thickness tolerances for 1-in. [25-mm] edge distance.

5.2.12 Coil size requirements (specify maximum outside diameter (OD), acceptable inside diameter (ID), and maximum weight [mass]),

5.2.13 Packaging,

5.2.14 Certification, if required, heat analysis and mechanical property report,

5.2.15 Application (part identification and description), and

5.2.16 Special requirements (if any).

5.2.16.1 If required, the product may be ordered to a specified base metal thickness (see Supplementary Requirement S1.)

NOTE 1—Typical ordering descriptions are as follows: steel sheet, zinc-coated, commercial steel Type A, ASTM A 653, Coating Designation G 115, chemically treated, oiled, minimum 0.040 by 34 by 117 in., for stock tanks, or steel sheet, zinc-coated, high strength low alloy steel Type A Grade 340, ASTM A 653M, Coating Designation Z275, minimized spangle, not chemically treated, oiled, minimum 1.00 by 920 mm by coil, 1520-mm maximum OD, 600-mm ID, 10 000-kg maximum, for tractor inner fender.

NOTE 2—The purchaser should be aware that there are variations in manufacturing practices among the producers and therefore is advised to establish the producer's standard (or default) procedures for thickness tolerances.

## 6. Chemical Composition

6.1 *Base Metal:*

6.1.1 The heat analysis of the base metal shall conform to the requirements shown in Table 2 for CS (Types A, B, and C), FS (Types A and B), DDS, and EDDS, and Table 3 for SS, HSLAS (Types A and B), SHS, and BHS.

6.1.2 Each of the elements listed in Tables 2 and 3 shall be included in the report of heat analysis. When the amount of copper, nickel, chromium, or molybdenum is less than 0.02 %, report the analysis as either <0.02 % or the actual determined value. When the amount of vanadium, titanium, or columbium is less than 0.008 %, report the analysis as either <0.008 % or the actual determined value.

6.1.3 See Specification A 924/A 924M for chemical analysis procedures and product analysis tolerances.

6.2 *Zinc Bath Analysis*—The bath metal used in continuous hot-dip galvanizing shall contain not less than 99 % zinc.

NOTE 3—To control alloy formation and promote adhesion of the zinc coating with the steel base metal, the molten coating metal composition normally contains a percentage of aluminum usually in the range from 0.05 to 0.25. This aluminum is purposely supplied to the molten coating bath, either as a specified ingredient in the zinc spelter or by the addition of a master alloy containing aluminum.

## 7. Mechanical Properties

7.1 Structural steel, high-strength, and low-alloy steel, solution hardened steel, and bake hardenable steel shall conform to the mechanical property requirements in Table 4 for the type, grade, or class, or all, specified.

**TABLE 2 Chemical Requirements<sup>A</sup>**

Designation	Composition, %—Heat Analysis Element, max (unless otherwise shown)												
	Carbon	Manganese	Phosphorus	Sulfur	Aluminum, min	Cu	Ni	Cr	Mo	V	Cb	Ti <sup>B</sup>	N
CS Type A <sup>C,D,E</sup>	0.10	0.60	0.030	0.035	...	0.20	0.20	0.15	0.06	0.008	0.008	0.025	...
CS Type B <sup>F,C</sup>	0.02 to 0.15	0.60	0.030	0.035	...	0.20	0.20	0.15	0.06	0.008	0.008	0.025	...
CS Type C <sup>C,D,E</sup>	0.08	0.60	0.100	0.035	...	0.20	0.20	0.15	0.06	0.008	0.008	0.025	...
FS Type A <sup>C,G</sup>	0.10	0.50	0.020	0.035	...	0.20	0.20	0.15	0.06	0.008	0.008	0.025	...
FS Type B <sup>F,C</sup>	0.02 to 0.10	0.50	0.020	0.030	...	0.20	0.20	0.15	0.06	0.008	0.008	0.025	...
DDS <sup>D,E</sup>	0.06	0.50	0.020	0.025	0.01	0.20	0.20	0.15	0.06	0.008	0.008	0.025	...
EDDS <sup>H</sup>	0.02	0.40	0.020	0.020	0.01	0.20	0.20	0.15	0.06	0.10	0.10	0.15	...

<sup>A</sup> Where an ellipsis ( . . . ) appears in this table, there is no requirement, but the analysis shall be reported.

<sup>B</sup>For steels containing more than 0.02% carbon, titanium is permitted to 0.025% provided the ratio of % titanium to % nitrogen does not exceed 3.4.

<sup>C</sup>When a deoxidized steel is required for the application, the purchaser has the option to order CS and FS to a minimum of 0.01 % total aluminum.

<sup>D</sup>Steel is permitted to be furnished as a vacuum degassed or chemically stabilized steel, or both, at the producer's option.

<sup>E</sup>For carbon levels less than or equal to 0.02%, vanadium, columbium, or titanium, or combinations thereof are permitted to be used as stabilizing elements at the producer's option. In such cases, the applicable limit for vanadium and columbium shall be 0.10 % max. and the limit for titanium shall be 0.15% max.

<sup>F</sup>For CS and FS, specify Type B to avoid carbon levels below 0.02 %.

<sup>G</sup>Shall not be furnished as a stabilized steel.

<sup>H</sup>Shall be furnished as a stabilized steel.

**TABLE 3 Chemical Requirements<sup>A</sup>**

Designation	Composition, %—Heat Analysis Element, max (unless otherwise shown)													
	Carbon	Manganese	Phosphorus	Sulfur	Si	Al, min.	Cu	Ni	Cr	Mo	V <sup>B</sup>	Cb <sup>B</sup>	Ti <sup>C,B,D</sup>	N
SS Grade														
33 [230]	0.20	...	0.04	0.04			0.20	0.20	0.15	0.06	0.008	0.008	0.025	...
37 [255]	0.20	...	0.10	0.04			0.20	0.20	0.15	0.06	0.008	0.008	0.025	...
40 [275]	0.25	...	0.10	0.04			0.20	0.20	0.15	0.06	0.008	0.008	0.025	...
50 [340] Class 1, 2, and 4	0.25	...	0.20	0.04			0.20	0.20	0.15	0.06	0.008	0.008	0.025	...
50 [340] Class 3	0.25	...	0.04	0.04			0.20	0.20	0.15	0.06	0.008	0.008	0.025	...
80 [550]	0.20	...	0.04	0.04			0.20	0.20	0.15	0.06	0.008	0.015	0.025	...
HSLAS Type A <sup>E</sup>														
40 [275]	0.20	1.20	...	0.035			...	0.20	0.15	0.16	0.01 min	0.005 min	0.01 min	...
50 [340]	0.20	1.20	...	0.035			0.20	0.20	0.15	0.16	0.01 min	0.005 min	0.01 min	...
60 [410]	0.20	1.35	...	0.035			0.20	0.20	0.15	0.16	0.01 min	0.005 min	0.01 min	...
70 [480]	0.20	1.65	...	0.035			0.20	0.20	0.15	0.16	0.01 min	0.005 min	0.01 min	...
80 [550]	0.20	1.65	...	0.035			0.20	0.20	0.15	0.16	0.01 min	0.005 min	0.01 min	...
HSLAS Type B <sup>E,F</sup>														
40 [275]	0.15	1.20	...	0.035			...	0.20	0.15	0.16	0.01 min	0.005 min	0.01 min	...
50 [340]	0.15	1.20	...	0.035			0.20	0.20	0.15	0.16	0.01 min	0.005 min	0.01 min	...
60 [410]	0.15	1.20	...	0.035			0.20	0.20	0.15	0.16	0.01 min	0.005 min	0.01 min	...
70 [480]	0.15	1.65	...	0.035			0.20	0.20	0.15	0.16	0.01 min	0.005 min	0.01 min	...
80 [550]	0.15	1.65	...	0.035			0.20	0.20	0.15	0.16	0.01 min	0.005 min	0.01 min	...
SHS	0.12	1.50	0.12	0.030	...	...	0.20	0.20	0.15	0.06	0.008	0.008	0.025	...
BHS	0.12	1.50	0.12	0.030	...	...	0.20	0.20	0.15	0.06	0.008	0.008	0.025	...

<sup>A</sup>Where an ellipsis ( . . . ) appears in this table there is no requirement, but the analysis shall be reported.

<sup>B</sup>For carbon levels less than or equal to 0.02%, vanadium, columbium, or titanium, or combinations thereof, are permitted to be used as stabilizing elements at the producer's option. In such cases, the applicable limit for vanadium and columbium shall be 0.10% max., and the limit for titanium shall be 0.15% max.

<sup>C</sup>Titanium is permitted for SS steels to 0.025% provided the ratio of % titanium to % nitrogen does not exceed 3.4.

<sup>D</sup>For steels containing more than 0.02% carbon, titanium is permitted to 0.025%, provided the ratio of % titanium to % nitrogen does not exceed 3.4.

<sup>E</sup>HSLAS and HSLAS-F steels commonly contain the strengthening elements columbium, vanadium, and titanium added singly or in combination. The minimum requirements only apply to the microalloy elements selected for strengthening of the steel.

<sup>F</sup>The producer has the option to treat HSLAS Type B steels by means of small alloy additions to effect sulfide inclusion control.

7.1.1 Bake hardenable steel shall conform to bake hardening index requirements included in Table 4 for the grade specified. The method for measuring the bake hardening index is described in the Annex. Bake hardenable steel shall exhibit a minimum increase in yield strength of 4 ksi [25 MPa] as based on the upper yield point or of 3 ksi [20 MPa] as based on the lower yield stress, after a prestrained specimen has been exposed to a standard bake cycle (340°F [170°C] for 20 minutes).

7.2 The typical mechanical properties for CS (Types A, B, and C), FS (Types A and B), DDS, and EDDS sheet designations



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## TABLE 4 Mechanical Requirements, Base Metal (Longitudinal)

Inch-Pound Units

Designation	Type	Grade	Yield Strength, min, ksi	Tensile Strength, min, ksi <sup>A</sup>	Elongation in 2 in., min, % <sup>A</sup>	Bake Hardening Index, min, ksi Upper Yield / Lower Yield <sup>A</sup>
<del>SS<sup>B</sup></del>	...	33	33	45	20	...
<u>SS<sup>B</sup></u>	...	33	33	45	20	...
		37	37	52	18	...
		40	40	55	16	...
		40	40	55	16	...
		50 Class 1	50	65	12	...
		50 Class 2	50	65	12	...
		50 Class 3	50	70	12	...
		50 Class 4	50	60	12	...
		80 <sup>C</sup>	80 <sup>D</sup>	82	...	...
<del>HSLAS</del>	Type A	40	40	50 <sup>E</sup>	22	...
<u>HSLAS</u>	Type A	40	40	50 <sup>E</sup>	22	...
		50	50	60 <sup>E</sup>	20	...
		60	60	70 <sup>E</sup>	16	...
		70	70	80 <sup>E</sup>	12	...
		80	80	90 <sup>E</sup>	10	...
<del>HSLAS</del>	Type B	40	40	50 <sup>E</sup>	24	...
<u>HSLAS</u>	Type B	40	40	50 <sup>E</sup>	24	...
		50	50	60 <sup>E</sup>	22	...
		60	60	70 <sup>E</sup>	18	...
		70	70	80 <sup>E</sup>	14	...
		80	80	90 <sup>E</sup>	12	...
		80	80	90 <sup>E</sup>	12	...
<del>SHS<sup>B</sup></del>	...	26	26	43	32	...
<u>SHS<sup>B</sup></u>	...	26	26	43	32	...
		34	34	46	30	...
		31	31	46	30	...
		35	35	50	26	...
		35	35	50	26	...
		44	44	53	24	...
		44	44	53	22	...
		44	44	57	22	...
<del>BHS<sup>B</sup></del>	...	26	26	43	30	4 / 3
<u>BHS<sup>B</sup></u>	...	26	26	43	30	4 / 3
		34	34	46	28	4 / 3
		31	31	46	28	4 / 3
		35	35	50	24	4 / 3
		35	35	50	24	4 / 3
		44	44	53	22	4 / 3
		44	44	53	20	4 / 3
		44	44	57	20	4 / 3

SI Units

Designation	Type	Grade	Yield Strength, min, MPa	Tensile Strength, min, MPa <sup>A</sup>	Elongation in 50 mm, min, % <sup>A</sup>	Bake Hardening Index, min, MPa Upper Yield / Lower Yield
<del>SS<sup>B</sup></del>	...	230	230	310	20	...
<u>SS<sup>B</sup></u>	...	230	230	310	20	...
		255	255	360	18	...
		26	26	43	32	...
		34	34	46	30	...
		31	31	46	30	...
		35	35	50	26	...
		35	35	50	26	...
		44	44	53	24	...
		44	44	53	22	...
		44	44	57	22	...
<del>BHS<sup>B</sup></del>	...	26	26	43	30	4 / 3
<u>BHS<sup>B</sup></u>	...	26	26	43	30	4 / 3
		34	34	46	28	4 / 3
		31	31	46	28	4 / 3
		35	35	50	24	4 / 3
		35	35	50	24	4 / 3
		44	44	53	22	4 / 3
		44	44	53	20	4 / 3
		44	44	57	20	4 / 3

are listed in Table 5. These mechanical property values are nonmandatory. They are intended solely to provide the purchaser with as much information as possible to make an informed decision on the steel to be specified. Values outside of these ranges are to be expected.

7.3 When base metal mechanical properties are required, all tests shall be conducted in accordance with the methods specified in Specification A 924/A 924M.

7.4 *Bending Properties Minimum Cold Bending Radii*—Structural steel and high-strength low-alloy steel are commonly fabricated by cold bending. There are many interrelated factors that affect the ability of a steel to cold form over a given radius under shop conditions. These factors include thickness, strength level, degree of restraint, relationship to rolling direction, chemistry, and base metal microstructure. The table in Appendix X1 lists the suggested minimum inside radius for 90° cold bending for structural steel and high-strength low-alloy steel. They presuppose “hard way” bending (bend axis parallel to rolling direction) and reasonably good shop forming practices. Where possible, the use of larger radii or “easy way” bends are recommended for improved performance.

## 8. Coating Properties

### 8.1 Coating Weight [Mass]:

8.1.1 Coating weight [mass] shall conform to the requirements as shown in Table 1 for the specific coating designation.

8.1.2 Use the following relationships to estimate the coating thickness from the coating weight [mass]:

8.1.2.1 1 oz/ft<sup>2</sup> coating weight = 1.7 mils coating thickness, and

8.1.2.2 7.14 g/m<sup>2</sup> coating mass = 1 μm coating thickness.

### 8.2 Coating Weight [Mass] Tests :

8.2.1 Coating weight [mass] tests shall be performed in accordance with the requirements of Specification A 924/A 924M.

8.2.2 The referee method to be used shall be Test Method A 90/A 90M.

### 8.3 Coating Bend Test:

8.3.1 The bend test specimens of coated sheet designated by prefix “G” [“Z”] shall be capable of being bent through 180° in any direction without flaking of the coating on the outside of the bend only. The coating bend test inside diameter shall have a relation to the thickness of the specimen as shown in Table 6. Flaking of the coating within 0.25 in. [6 mm] of the edge of the bend specimen shall not be cause for rejection.

8.3.2 Because of the characteristics of zinc-iron alloy coatings designated by prefix “A” [“ZF”] as explained in 3.2.3, coating bend tests are not applicable.

## 9. Dimensions and Permissible Variations

9.1 All dimensions and permissible variations shall comply with the requirements of Specification A 924/A 924M, except for flatness of SS and HSLAS, which is specified in Table 7 and Table 8, respectively.

## 10. Keywords

10.1 alloyed coating; bake hardenable steel; high strength low alloy; minimized spangle coating; sheet steel; solution hardened steel; spangle; steel; steel sheet; structural steel; zinc; zinc coated (galvanized); zinc iron-alloy; zinc iron-alloy coated

**TABLE 5 Typical Ranges of Mechanical Properties<sup>A,B</sup> (Nonmandatory)**

Designation	(Longitudinal Direction)				
	Yield Strength		Elongation in 2 in. [50 mm], %	$r_m$ Value <sup>C</sup>	$n$ Value <sup>D</sup>
	ksi	[MPa]			
CS Type A	25/55	[170/380]	≥20	<i>E</i>	<i>E</i>
CS Type B	30/55	[205/380]	≥20	<i>E</i>	<i>E</i>
CS Type C	25/60	[170/410]	≥15	<i>E</i>	<i>E</i>
FS Types A and B	25/45	[170/310]	≥26	1.0/1.4	0.17/0.21
DDS	20/35	[140/240]	≥32	1.4/1.8	0.19/0.24
EDDS <sup>F</sup>	15/25	[105/170]	≥40	1.6/2.1	0.22/0.27

<sup>A</sup>The typical mechanical property values presented here are nonmandatory. They are intended solely to provide the purchaser with as much information as possible to make an informed decision on the steel to be specified. Values outside of these ranges are to be expected. The purchaser may negotiate with the supplier if a specific range or a more restrictive range is required for the application.

<sup>B</sup>These typical mechanical properties apply to the full range of steel sheet thicknesses. The yield strength tends to increase and some of the formability values tend to decrease as the sheet thickness decreases.

<sup>C</sup> $r_m$  Value—Average plastic strain ratio as determined by Test Method E 517.

<sup>D</sup> $n$  Value—Strain-hardening exponent as determined by Test Method E 646.

<sup>E</sup>No typical mechanical properties have been established.

<sup>F</sup>EDDS Sheet will be free from changes in mechanical properties over time, that is, nonaging.



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**TABLE 6 Coating Bend Test Requirements**

Inch-Pound Units									
Ratio of the Inside Bend Diameter to Thickness of the Specimen (Any Direction) CS, FS, DDS, EDDS, SHS, BHS									
Sheet Thickness									
Coating Designation <sup>B</sup>	Sheet Thickness			33	37	40	SS, Grade <sup>A</sup>		
	Through 0.039 in.	Over 0.039 through 0.079 in.	Over 0.079 in.						
G235	2	3	3	3	3	3			
G210	2	2	2	2	2	2			2½
G185	2	2	2	2	2	2			2½
G165	2	2	2	2	2	2			2½
G140	1	1	2	2	2	2			2½
G115	0	0	1	1½	2	2			2½
G90	0	0	1	1½	2	2			2½
G60	0	0	0	1½	2	2			2½
G40	0	0	0	1½	2	2			2½
G30	0	0	0	1½	2	2			2½
G01	0	0	0	1½	2	2			2½
HSLAS Type A <sup>A</sup>									
HSLAS Type B									
	40	50	60	40	50	60	70	80	
G115	1½	1½	3	1	1	1	1½	1½	1½
G90	1½	1½	3	1	1	1	1½	1½	1½
G60	1½	1½	3	1	1	1	1½	1½	1½
G40	1½	1½	3	1	1	1	1½	1½	1½
G30	1½	1½	3	1	1	1	1½	1½	1½
G01	1½	1½	3	1	1	1	1½	1½	1½

SI Units									
Ratio of the Inside Bend Diameter to Thickness of the Specimen (Any Direction) CS, FS, DDS, EDDS, SHS, BHS									
Sheet Thickness									
Coating Designation <sup>B</sup>	Sheet Thickness			230	255	275	SS, Grade <sup>C</sup>		
	Through 1.0 mm	Over 1.0 mm through 2.0 m	Over 2.0 mm						
Z700	2	3	3	3	3	3			
Z600	2	2	2	2	2	2			2½
Z550	2	2	2	2	2	2			2½
Z500	2	2	2	2	2	2			2½
Z450	1	1	2	2	2	2			2½
Z350	0	0	1	1½	2	2			2½
Z275	0	0	1	1½	2	2			2½
Z180	0	0	0	1½	2	2			2½
Z120	0	0	0	1½	2	2			2½
Z90	0	0	0	1½	2	2			2½
Z001	0	0	0	1½	2	2			2½
HSLAS Type A <sup>C</sup>									
HSLAS Type B									
	275	340	410	275	340	410	480	550	
Z350	1½	1½	3	1	1	1	1½	1½	1½
Z275	1½	1½	3	1	1	1	1½	1½	1½
Z180	1½	1½	3	1	1	1	1½	1½	1½
Z120	1½	1½	3	1	1	1	1½	1½	1½
Z90	1½	1½	3	1	1	1	1½	1½	1½
Z001	1½	1½	3	1	1	1	1½	1½	1½

<sup>A</sup>SS Grades 50 and 80 and HSLAS Type A Grades 70 and 80 are not subject to bend test requirements.

<sup>B</sup>If other coatings are required, the user should consult the producer for availability and suitable bend test requirements.

<sup>C</sup>SS Grades 340 and 550 and HSLAS Type A Grades 480 and 550 are not subject to bend test requirements.

**TABLE 7 Structural Steel—Flatness Tolerances  
(Cut Lengths Only)**

NOTE 1—This table also applies to sheets cut to length from coils by the consumer when adequate flattening measures are performed.

NOTE 2— For Grade 50 [340] (Classes 1, 2, 3, and 4) use 1½ times the values given in this table.

NOTE 3—For Grade 80 [550], there are no defined flatness standards.

Specified Thickness, in. [mm]	Specified Width, in. [mm]	Flatness Tolerance (Maximum Deviation from a Horizontal Flat Surface), in. [mm]
Over 0.060 [1.5]	to 60 [1500], inclusive	½ [12]
	over 60 [1500] to 72 [1800], inclusive	¾ [20]
0.060 [1.5] and thinner	to 36 [900], inclusive	½ [12]
	over 36 [900] to 60 [1500], inclusive over 60 [1500] to 72 [1800], inclusive	¾ [20] 1 [25]

**TABLE 8 High-Strength Low-Alloy Steel—Flatness Tolerances  
(Cut Lengths Only)**

NOTE 1—This table also applies to sheets cut to length from coils by the consumer when adequate flattening measures are performed.

		Inch-Pound Units				
Specified Thickness, in.	Specified Width, in.	Flatness Tolerances (Maximum Deviation from a Horizontal Flat Surface), in.				
		Grade				
		40	50	60	70	80
Over 0.060	to 60, inclusive	5/8	¾	7/8	1	1 1/8
	over 60	1	1 1/8	1 1/4	1 3/8	1 1/2
0.060 and thinner	to 36, inclusive	5/8	¾	7/8	1	1 1/8
	over 36 to 60, inclusive	1	1 1/8	1 1/4	1 3/8	1 1/2
	over 60	1 3/8	1 1/2	1 5/8	1 3/4	1 7/8
		SI Units				
Specified Thickness, mm	Specified Width, mm	Flatness Tolerances (Maximum Deviation from a Horizontal Flat Surface), mm				
		Grade				
		275	340	410	480	550
Over 1.5	to 1500, inclusive	15	20	22	25	30
	over 1500	25	30	32	35	38
1.5 and thinner	to 900, inclusive	15	20	22	25	30
	over 900 to 1500, inclusive	25	30	32	35	38
	over 1500	35	38	40	45	48

## SUPPLEMENTARY REQUIREMENTS

The following standardized supplementary requirements are for use when desired by the purchaser. These additional requirements shall apply only when specified on the order.

### S1. Base Metal Thickness

S1.1 The specified minimum thickness shall apply to the base metal only.

S1.2 The coating designation shown on the order indicates the coating to be applied to the specified minimum base metal thickness.

S1.3 The applicable tolerances for base metal thickness are shown in Tables 16 and Tables 17, Thickness Tolerance of Cold-Rolled Sheet (Carbon and High-Strength, Low-Alloy Steel), of Specification A 568/A 568M.

ANNEX

A1. BAKE HARDENABLE STEELS

A1.1 Determination of Bake Hardening Index

A1.1.1 The bake hardening index (BHI) is determined by a two-step procedure using a standard longitudinal (rolling direction) tensile-test specimen, prepared in accordance with Test Methods A 370. The test specimen is first strained in tension. The magnitude of this tensile “pre-strain” shall be 2 % (extension under load). The test specimen is then removed from the test machine and baked at a temperature of 340°F [170°C] for a period of 20 minutes. Referring to Fig. A1.1, the bake hardening index (BHI) of the material is calculated as follows:

$$BHI = B - A \tag{A1.1}$$

where:

A = flow stress at 2 % extension under load

B = yield strength [upper yield strength ( $B_U$ ) or lower yield stress ( $B_L$ )] after baking at 340°F [170°C] for 20 minutes.

A1.1.2 The original test specimen cross section (width and thickness) is used in the calculation of all engineering strengths in this test.

A1.1.3 The pre-straining of 2 % in tension is intended to simulate a modest degree of forming strain, while the subsequent baking is intended to simulate a paint-curing or similar treatment. In the production of actual parts, forming strains and baking treatments can differ from those employed here and, as a result, final properties can differ from the values obtained under these controlled conditions.

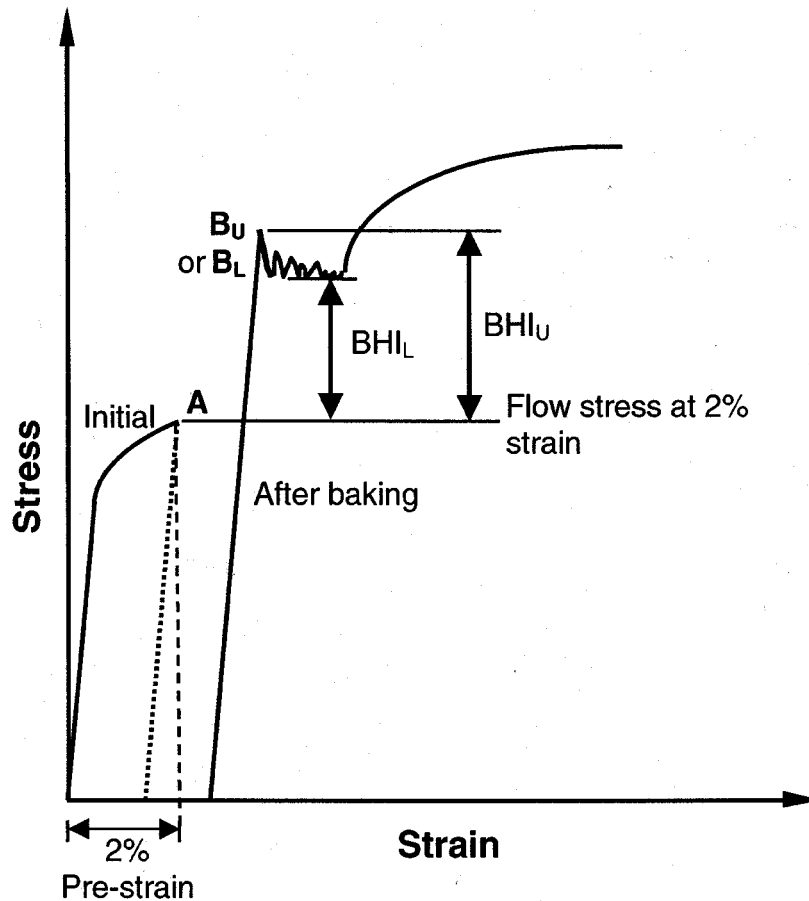


FIG. A1.1 Representation of Bake Hardening Index

**APPENDIXES**
**(Nonmandatory Information)**
**X1. BENDING PROPERTIES**

X1.1 Table X1.1 lists suggested minimum inside radii for cold bending.

**TABLE X1.1 Suggested Minimum Inside Radii for Cold Bending<sup>A</sup>**

NOTE 1— (*t*) equals a radius equivalent to the steel thickness.

NOTE 2—The suggested radii should be used as minimums for 90° bends in actual shop practice.

Designation	Type	Grade	Minimum Inside Radius for Cold Bending <sup>B</sup>
SS		33 [230]	1½ <i>t</i>
		37 [255]	2 <i>t</i>
		40 [275]	2 <i>t</i>
		50 [340] Class 1	not applicable
		50 [340] Class 2	not applicable
		50 [340] Class 3	not applicable
		50 [340] Class 4	not applicable
HSLAS	Type A	80 [550]	not applicable
		40 [275]	2 <i>t</i>
		50 [340]	2½ <i>t</i>
		60 [410]	3 <i>t</i>
		70 [480]	4 <i>t</i>
HSLAS	Type B	80 [550]	4½ <i>t</i>
		40 [275]	1½ <i>t</i>
		50 [340]	2 <i>t</i>
		60 [410]	2 <i>t</i>
		70 [480]	3 <i>t</i>
SHS		80 [550]	3 <i>t</i>
		26 [180]	½ <i>t</i>
		31 [210]	1 <i>t</i>
		35 [240]	1½ <i>t</i>
		41 [280]	2 <i>t</i>
BHS		44 [300]	2 <i>t</i>
		26 [180]	½ <i>t</i>
		31 [210]	1 <i>t</i>
		35 [240]	1½ <i>t</i>
		41 [280]	2 <i>t</i>
		44 [300]	2 <i>t</i>

<sup>A</sup>Material that does not perform satisfactorily, when fabricated in accordance with the requirements in Table X1.1, may be subject to rejection pending negotiation with the steel supplier.

<sup>B</sup>Bending capability may be limited by coating designation.

**X2. RATIONALE FOR CHANGES IN PRODUCT DESIGNATIONS**

X2.1 Subcommittee A05.11 has revised the designations used to classify the various products available in each hot-dip coated specification. The previous “quality” designations have been replaced with designations and descriptions more closely related with product characteristics. Many of the former “quality” specifications described the steel only in terms of limited chemical composition, which in some cases was identical for two or more qualities. The former designations also did not reflect the availability of new steels which are the result of the use of new technologies such as vacuum degassing and steel ladle treatments.

X2.2 The former “quality” designators, defined in very broad qualitative terms, did not provide the user with all the information needed to select the appropriate steel for an application. The new designations are defined with technical information such as specific chemical composition limits and typical nonmandatory mechanical properties. These steel characteristics are important to users concerned with the weldability and formability of the coated steel products. The typical mechanical properties included in the new designation system are those indicated by the tension test. These properties are more predictive of steel formability than other tests such as the hardness test which may not compensate adequately for product variables such as substrate thickness and coating weight.

X2.3 The new designations also provide the user with the flexibility to restrict the steels applied on any order. For example, a user can restrict the application of ultra low carbon steels on an application through the selection of an appropriate “type” designator.



X2.4 There is a limited relationship between the former and current systems of designation. Some of the reasons for this limited relationship are: addition of steels not previously described in ASTM specifications, restrictions placed on ranges of chemical composition, the addition of typical mechanical properties, and the enhanced capability of steel producers to combine chemical composition and processing methods to achieve properties tailored to specific applications.

X2.5 The changes in designation are significant which may create transition issues that will have to be resolved. Continued dialogue between users and producers will have to be maintained to assist with the transition to the new system of designations. A user with concerns about the appropriate coated steel to order for a specific application should consult with a steel supplier or producer.

### **X3. RELATIONSHIP BETWEEN SPECIFICATIONS THAT DESCRIBE REQUIREMENTS FOR A COMMON PRODUCT**

X3.1 ISO 3575 and ISO 4998 may be reviewed for comparison with this standard. The relationship between the standards may only be approximate; therefore, the respective documents should be consulted for actual requirements. Those who use these documents must determine which specifications address their needs.

### **X4. COATING MASS SELECTION BASED ON ATMOSPHERIC CORROSION RATES<sup>4</sup> FOR ZINC-COATED STEEL SHEET**

X4.1 The proper selection of coating mass to meet a user's needs for zinc-coated steel sheet requires some knowledge about the relative corrosiveness of the environment in which the product will be used. The corrosion rate of the zinc coating varies widely depending upon many factors of the environment. For example, the time of wetness is an important issue that affects the corrosion rate. The presence of impurities such as chlorides, nitrates, and sulfates can also dramatically affect the rate of corrosion. Other issues such as the presence or absence of oxygen and the temperature of the environment are important determinants for predicting the "life of the product."

X4.2 The final performance requirements can also impact the minimum coating mass needed for a given application. For example, is the application an aesthetic one that requires no red rust. In this case, the time to failure is thus defined as the time for the onset of red rust (the time for the zinc coating to be consumed in a large enough area for rusting of the steel to be observed). Or, is the application one in which the time to failure is defined as the time when perforation of the steel sheet is observed? In this case, the thickness of the steel sheet as well as the thickness of the zinc coating impact the time to failure.

X4.3 No matter how one defines the "product life," there are data in the published literature to assist users once the environment and desired product life are determined.

X4.4 Although the corrosion rate can vary considerably depending on the environmental factors, it is well known that, in most instances, the life of the zinc coating is a linear function of coating mass for any specific environment. That means, to achieve twice the life for any specific application, the user should order twice the coating mass.

#### *X4.4.1 Examples:*

X4.4.1.1 A G60 coating mass will exhibit approximately twice the life of a G30 coating mass.

X4.4.1.2 A G90 coating mass will exhibit about 50 % longer life than a G60 coating mass.

X4.5 The following two reference books are excellent sources for additional and more detailed information on the corrosion behavior of zinc-coated steel sheet products:

X4.5.1 *Corrosion and Electrochemistry of Zinc*, X. Gregory Zhang, published by Plenum Press, 1996.

X4.5.2 *Corrosion Resistance of Zinc and Zinc Alloys*, Frank C. Porter, Published by Marcel Dekker, Inc., 1994

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<sup>4</sup> Atmospheric corrosion rates do not apply to zinc-iron alloy coatings.

**SUMMARY OF CHANGES**

This section identifies the location of selected changes to this specification. For the convenience of the user, Committee A05 has highlighted those changes that may impact the use of this specification. This section may also include descriptions of the changes or reasons for the changes, or both.

A 653/A 653M - 04a:

(1) Table 4 was revised to include tensile strength requirements for SHS and BHS designations.

A 653/A 653M - 04:

(1) Added new Class of Structural Steel, SS Grade 50 Class 4.

A 653/A 653M - 03:

(1) Added Appendix X4.

(2) Addition of the requirements for two types of Dent Resistant Steels (Type A SHS and Type B) BHS designations.

(3) Added Summary of Changes section.

(4) Changes to: Sections 1, 2, 3, 4, 5, 6, 7, 8 and 10 revised Table 3, Table 4, Appendix X1.1 and new Annex A.1

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# Standard Specification for Tin Mill Products, Black Plate Electrolytic Chromium- Coated, Single and Double Reduced<sup>1</sup>

This standard is issued under the fixed designation A 657/A 657M; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

## 1. Scope

1.1 This specification covers single- and double-reduced tin mill black plate electrolytically coated with chromium and chromium oxide. The steel is furnished in coils and cut lengths for use in the manufacture of cans, closures, crowns, and other products.

1.2 This specification is applicable to orders in either inch-pound units (as A 657) which is supplied in thicknesses from 0.0050 to 0.0149 in. or in SI units [as A 657M] which is supplied in thicknesses from 0.127 to 0.378 mm.

1.3 The values stated in either inch-pound or SI units are to be regarded as standard. Within the text, the SI units are shown in brackets. The values stated in each system are not exact equivalents. Therefore, each system must be used independently of the other. Combining values from the two systems may result in nonconformance with this specification.

1.4 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

## 2. Referenced Documents

### 2.1 ASTM Standards:

A 623 Specification for Tin Mill Products, General Requirements<sup>2</sup>

A 623M Specification for Tin Mill Products General Requirements [Metric]<sup>2</sup>

A 700 Practices for Packaging, Marking, and Loading Methods for Steel Products for Domestic Shipment<sup>3</sup>

D 1125 Test Methods for Electrical Conductivity and Resistivity of Water<sup>4</sup>

<sup>1</sup> This specification is under the jurisdiction of ASTM Committee A01 on Steel, Stainless Steel, and Related Alloys and is the direct responsibility of Subcommittee A01.20 on Tin Mill Products.

Current edition approved September 10, 2003. Published November 2003. Originally approved in 1972. Last previous edition approved in 1998 as A 657/A 657M – 98a.

<sup>2</sup> *Annual Book of ASTM Standards*, Vol 01.06.

<sup>3</sup> *Annual Book of ASTM Standards*, Vol 01.05.

<sup>4</sup> *Annual Book of ASTM Standards*, Vol 11.01.

## 3. Ordering Information

3.1 Orders for product under this specification shall include the following information, as required and applicable, to adequately describe the desired product:

3.1.1 Name of product (include whether single- or double-reduced),

3.1.2 Thickness (must be consistent with intended application),

3.1.3 Oiling (Section 6),

3.1.4 Steel type (MR, L, etc.),

3.1.5 Temper designation (T-3, T-4, etc. for single-reduced) or mechanical designation (DR-8, DR-9, etc., double-reduced),

3.1.6 Surface finish (7B, 7C, etc.).

3.1.7 Coil width or cut size,

3.1.8 Rolling direction must be specified on cut sizes and should be indicated by underlining the slit (rolling width) dimension,

3.1.9 On coils, specify minimum or range of acceptable inside diameters. The standard inside diameter is approximately 16 in. if ordered as Specification A 657 [410 mm if ordered as Specification A 657M]. Coils should be specified to a maximum coil weight if ordered as Specification A 657 [mass if ordered as Specification A 657M], or maximum outside diameter, or both.

3.1.10 Packaging,

3.1.11 Special requirements where applicable, and,

3.1.12 ASTM specification designation and year of issue.

NOTE 1—A typical ordering description for coils is as follows: 1250 base boxes, single reduced, black plate electrolytic chromium coated, DOS, (0.0093 in.) MR, T-3 BA, 35<sup>3</sup>/<sub>8</sub> in. by coil, 16 in. inside diameter, 59 in. maximum outside diameter, 25 000 lb maximum coil weight, for regular crowns in accordance with Specification A 657/A 657M - XX. [250 Sitas, single reduced, black plate electrolytic chromium coated, DOS, 0.235 mm thickness, MR, T-3 BA, 513, 900 mm by coil, 410 mm inside diameter, 1500 mm maximum outside diameter, 11 500 kg maximum coil mass for regular crowns in accordance with Specification A 657/A 657M - XX].

NOTE 2—A typical ordering description of cut sizes is as follows: 1000 base boxes, double reduced black plated electrolytic chromium coated, BSC, 0.0061 in., MR, DR CA 8, 31 by 32 in., for cap closures in accordance with Specification A 657/A 657M - XX. [200 SITAS, double

reduced, black plate electrolytic chromium coated, DOS, 0.155 mm thickness, MR, DR8 CA, 788 by 813 mm, cap closures in accordance with Specification A 657/A 657M - XX].

NOTE 3—The production of coils does not afford the same opportunity for inspection, grading, and sorting as does the production of cut sizes. Accordingly, appropriate processing and quality-control procedures are required by the purchaser to obtain optimum utilization of the material. Cut sizes are line inspected visually and mechanically during production. Sheets having surface imperfections that will not interfere with their utilization are included.

NOTE 4—Tin mill products are supplied on an area basis expressed in base boxes. In coils, the number of base boxes is computed from the measured length and the specified width. In cut sizes, the number of base boxes is computed from the specified length and width dimensions and sheet count. For calculating weight, the density of steel for tin mill products is 0.2836 lb/in.<sup>3</sup> [Tin mill products are supplied on an area basis expressed in SITAS. In coils, the number of SITAS is computed from the measured length and the specified width. In cut sizes, the number of SITAS is computed from the specified length and width dimensions and sheet count. For calculating mass, the density of steel for tin mill products is 7850 kg/m<sup>3</sup>].

#### 4. Chromium Coating Weights [Masses]

4.1 *Total Coating* is made up of chromium metal and chromium oxides. These are determined separately.

4.1.1 *Metallic Chromium* is expressed as milligrams of chromium metal per square foot [milligrams of chromium per square metre] on each side of the sheet or strip.

Nominal	Average	Max
mg/ft <sup>2</sup> [mg/m <sup>2</sup> ]	mg/ft <sup>2</sup> [mg/m <sup>2</sup> ]	mg/ft <sup>2</sup> [mg/m <sup>2</sup> ]
5 [54]	3 [32]	13 [140]

4.1.2 *Chromium Oxide* is expressed as milligrams of chromium in the oxide per square foot [milligrams of chromium per square metre] as shipped on each side of the sheet or strip.

Min,	Average	Max,
mg/ft <sup>2</sup> [mg/m <sup>2</sup> ]		mg/ft <sup>2</sup> [mg/m <sup>2</sup> ]
0.7 [8]		2.5 [27]

#### 4.2 Sampling for Chromium Coating Weights [Masses]:

4.2.1 *Coils*—When the purchaser wishes to make tests to ascertain compliance with the requirements of this specification for metallic chromium and chromium oxide weights [masses] on a lot of any specific item of electrolytic chromium-coated steel in coils, use the following procedure:

4.2.1.1 Take one test strip at random from a representative section of each coil across its width. Select a minimum of three test strips, each taken from different coils from any one item of a specific lot. Spot test each test strip at three positions (edge, center, edge) across the rolling direction of the strip. Spot samples are customarily disks or squares, each of 4 in.<sup>2</sup> [25.8 cm<sup>2</sup>] in area. In order to secure representative samples, take samples so that the outer edge of the sample is at least 1 in. [25 mm] from either edge of the test strip. The average value of all spot tests on all test strips represents the average coating-weight [mass] test value.

4.2.1.2 From one- or two-coil lots, sample each coil. A minimum of three randomly selected test strips shall represent the lot.

4.2.2 *Cut Lengths*—When the purchaser wishes to make tests to ascertain compliance with the requirements of this specification for metallic chromium and chromium oxide weights [mass] on a specification of electrolytic chromium-coated steel in cut sizes, use the following procedure:

4.2.2.1 Take one sheet at random from each 50 packages, or part thereof, with a minimum of three different sample sheets, each taken from different bundles from any one item of a specific shipment. Spot test each sample at three positions across the rolling direction of the sheet (edge, center, edge). Spot samples are customarily disks or squares, each of 4 in.<sup>2</sup> [25.8 cm<sup>2</sup>] in area. In order to secure representative samples, take edge specimens so that the outer edge of the sample is at least 1 in. [25 mm] from either edge of the sheet. The average value of all spot tests on all sheets tested represents the average coating-weight (mass) test value.

4.3 *Determination of Chromium Coating Weights [Masses]*—Typical method for determining metallic chromium and chromium oxide weights [masses] for electrolytic chromium-coated steel is described in Annex A1, Annex A2, Annex A3, and Fig. A1.1 and Fig. A3.1.

#### 5. Surface Appearance and Finish

5.1 *Single-Reduced Base Metal Finish*—Single-reduced electrolytic chromium coated steel is produced with ground roll finishes and shot-blasted roll finishes as follows:

##### 5.1.1 *Ground Roll Finishes:*

5.1.1.1 *7B*—A smooth finish that may contain fine grit lines. This finish is specified for special applications.

5.1.1.2 *7C*—A smooth finish with grit lines. The surface roughness will range from 10 to 25  $\mu\text{in. Ra}$  [0.254 to 0.635  $\mu\text{m Ra}$ ]. This is the standard finish for tin mill products.

##### 5.1.2 *Blasted and/or Otherwise Textured Roll Finishes:*

5.1.2.1 *5C*—A shot-blasted finish (SBF) for general applications. The surface roughness will range from 30 to 60  $\mu\text{in. Ra}$  [0.760 to 1.52  $\mu\text{m Ra}$ ].

##### 5.1.2.2 *5D*—A shot-blasted finish for special applications.

5.2 *Double-Reduced Base Metal Finish*—Double-reduced electrolytic chromium-coated steel is produced only with ground-roll finishes.

##### 5.2.1 *Ground Roll Finishes:*

5.2.1.1 *7C*—A smooth finish with grit lines. The surface roughness will range from 6 to 25  $\mu\text{in. Ra}$  [0.152 to 0.635  $\mu\text{m Ra}$ ]. This is the standard finish for tin mill products.

#### 6. Oiling

6.1 *Electrolytic Chromium-Coated Steel* is furnished with an extremely thin oil film on both surfaces to minimize abrasion in shearing, coiling or uncoiling, shipping, and handling. Acetyl tributylcitrate, butyl stearate or dioctyl (di(2-ethylhexyl) sebacate) is used. Surface active agents such as glycerol monooleate may be incorporated into the oil film. Oil film other than normal should be negotiated with the producer. The oil film is not a drawing lubricant.

6.1.1 Unless indicated by the purchaser, the special oiling treatment will be left to the discretion of the plate supplier.

6.1.2 Weight [mass] of oil film as applied by the plate supplier normally ranges from approximately 0.10 g/base box to 0.40 g/base box [0.50 to 200 g/SITA (5 to 20 mg/m<sup>2</sup>)].

Specific aim ranges required for particular end uses and handling practices may be furnished as agreed upon by the purchaser and supplier.

## 7. Workmanship and Quality Level Requirements

7.1 The production of coils does not afford the same opportunity for inspection, grading, and sorting as does the production of cut lengths. Accordingly, appropriate processing and quality-control procedures are required by the purchaser to obtain optimum utilization of the material. Cut lengths are line

inspected visually and mechanically during production. Sheets having surface imperfections that will not interfere with their utilization are included.

## 8. General Requirements for Delivery

8.1 Product furnished under this specification shall conform to the applicable requirements of the latest edition of Specification A 623 [A 623M], unless otherwise provided herein.

## 9. Keywords

9.1 chromium coated; coated steel sheet; tin mill products

# ANNEXES

## (Mandatory Information)

### A1. METHOD FOR DETERMINATION OF METALLIC-CHROMIUM COATING WEIGHT (MASS) ON CHROMIUM-PLATED TIN-FREE STEEL

#### A1.1 Scope

A1.1.1 This method is applicable to the determination of from 1 to 15 mg Cr/ft<sup>2</sup> [10.8 to 161 mg Cr/m<sup>2</sup>] of surface in chromium-plated tinfree steel (TFS).

#### A1.2 Principle

A1.2.1 The oxide layer is removed chemically with a hot sodium hydroxide (NaOH) solution. The metallic chromium is then electrostripped at a current of from 10 to 20 mA with 1 N NaOH solution as the electrolyte. The stripping solution after acidification is then analyzed for chromium by oxidation with ammonium persulfate (NH<sub>4</sub>)<sub>2</sub>S<sub>2</sub>O<sub>8</sub> followed by photometric determination with diphenylcarbazide.

#### A1.3 Reagents

A1.3.1 *Purity of Reagents*—Reagent grade chemicals shall be used in all tests. Unless otherwise indicated, it is intended that all reagents shall conform to the specifications of the Committee on Analytical Reagents of the American Chemical Society, where such specifications are available.<sup>5</sup> Other grades may be used, provided it is first ascertained that the reagent is of sufficiently high purity to permit its use without lessening the accuracy of the determination.

A1.3.2 *Purity of Water*—Unless otherwise indicated, references to water shall be understood to mean distilled water or water of equal purity.

A1.3.3 *Ammonium Persulfate Solution (30 %)*—Dissolve 30 g of ammonium persulfate (NH<sub>4</sub>)<sub>2</sub>S<sub>2</sub>O<sub>8</sub> in 100 mL of water. This solution should be prepared fresh each day.

A1.3.4 *Chromium, Standard Solution (1 mL = 0.02 mg Cr)*—Dissolve 0.2828 g of dry, primary standard grade potassium dichromate (K<sub>2</sub>Cr<sub>2</sub>O<sub>7</sub>) in distilled water and dilute to 500

mL in a volumetric flask. This solution contains 0.2 mg Cr/mL. Pipet a 100-mL aliquot of this stock solution to a 1-L volumetric flask and dilute to volume with distilled water. This dilute standard contains 0.02 mg Cr/mL.

A1.3.5 *Diphenylcarbazide Solution (0.24 %)*—Dissolve 0.25 g of diphenylcarbazide in 95 mL of acetone. Add 5 mL of glacial acetic acid, mix well, and store in a refrigerator until used.

A1.3.6 *Oxide Stripping Solution (Hot (90°C) 10 N NaOH Solution)*—Dissolve 200 g of NaOH pellets in 400 mL of water and dilute to 500 mL. Prepare as needed.

A1.3.7 *Silver Nitrate Solution (2 %)*—Dissolve 2 g of silver nitrate (AgNO<sub>3</sub>) in 100 mL of water. Keep protected from light.

A1.3.8 *Sodium Hydroxide (Electrolyte) Solution (1 N)*—Dissolve 40 g of NaOH pellets in 1000 mL of distilled water.

A1.3.9 *Sulfuric-Phosphoric Acid Mixture*—Cautiously add 200 mL of sulfuric acid (H<sub>2</sub>SO<sub>4</sub>) to 500 mL of distilled water. Mix well and cool. Slowly add 300 mL of 85 % phosphoric acid (H<sub>3</sub>PO<sub>4</sub>), mix well, and store in a borosilicate bottle.

#### A1.4 Apparatus

A1.4.1 *Cell and Electrodes*—The cell is constructed of TFE-fluorocarbon with a TFE-fluorocarbon gasket to define the area to be stripped. A platinum rod is used as the cathode. This is the same cell as used for oxide determinations as shown in determination of chromium in the oxide.

A1.4.2 *Power Supply*—Philbrick Researches PR-30, 15-V regulated constant-current power supply or equivalent.

A1.4.3 *Milliammeter*, 0–50 mA full scale.

A1.4.4 *Voltmeter*, 0–2 V full scale.

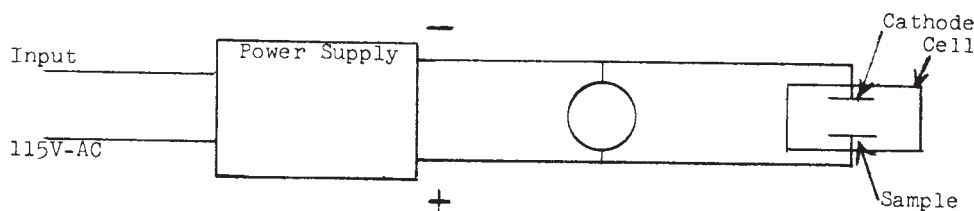
A1.4.5 *Spectrophotometer*—Beckman Model B or equivalent.

A1.4.6 *Vacuum Pump* for specimen hold down.

#### A1.5 Preparation of Chromium Calibration Curve

A1.5.1 Pipet 0 (blank), 5, 10, 15, and 20-mL aliquots of standard chromium solution (1 mL = 0.02 mg Cr) to 400-mL beakers. Add the same volume of electrolyte as is used in the stripping cell, and neutralize with H<sub>2</sub>SO<sub>4</sub>(1+3).

<sup>5</sup> *Reagent Chemicals, American Chemical Society Specifications*, American Chemical Society, Washington, DC. For suggestions on the testing of reagents not listed by the American Chemical Society, see *Analar Standards for Laboratory Chemicals*, BDH Ltd., Poole, Dorset, U.K., and the *United States Pharmacopeia and National Formulary*, U.S. Pharmacopeial Convention, Inc. (USPC), Rockville, MD.



V = Voltmeter (0-2 V F.S.)  
 Cell = as described in method for chromium oxide determination

FIG. A1.1 Circuit Diagram for Stripping

A1.5.2 Add 25 mL of  $H_2SO_4-H_3PO_4$  solution, 2 mL of  $AgNO_3$  solution, and 5 mL of  $(NH_4)_2S_2O_8$  solution. Heat the solutions to boiling and continue the boiling for about 10 min after the persulfate has been decomposed. Cool, and then transfer the solutions to 500-mL volumetric flasks. Add 5 mL of diphenylcarbazide solution and dilute to volume. Measure the absorbance after 2 min at 560 nm in a 1-cm cell using water as a reference. Correct for the absorbance of the reagent blank, and plot absorbance versus milligrams of chromium per 500 mL.

**A1.6 Procedure**

A1.6.1 Remove the surface oxides from the sample with 90°C 10 N NaOH solution for 10 min. Clamp the sample into the cell and introduce enough 1 N NaOH solution electrolyte to cover the sample completely. Connect the positive lead of the power supply to sample and the negative lead to the platinum cathode. Strip the metallic chromium coating with a current of 10 to 20 mA. The completion of the stripping is indicated by a pronounced sharp rise in cell voltage (=0.5 V). During the stripping operation the voltmeter will read several tenths of a volt. At the completion of stripping the voltage will rise rapidly from this value to a value approximately 0.5 V higher, a noticeable change in the 0 to 2-V instrument.

A1.6.2 After stripping, transfer the electrolyte solution to a 400-mL beaker, and with  $H_2SO_4(1+3)$  neutralize to pH 7 using

a pH meter or pH paper to determine neutrality. Then add 25 mL of  $H_2SO_4-H_3PO_4$  acid solution. Then add 2 mL of  $AgNO_3$  solution, 5 mL of  $(NH_4)_2S_2O_8$  solution, and heat to boiling. Continue boiling for about 10 min after the excess persulfate is decomposed as evidenced by lack of formation of small bubbles. Cool the solution to room temperature and transfer to a 500-mL volumetric flask. Add 5 mL of diphenylcarbazide solution, and dilute to volume. Measure the absorbance after 2 min in a spectrophotometer at 560 nm in a 1-cm cell using water as the reference. After correcting for the reagent blank, determine the milligrams of chromium from a calibration curve previously prepared with solutions containing known amounts of chromium. Calculate the coating weight [mass] in milligrams per square foot [per square metre].

**A1.7 Calculations**

A1.7.1 Calculate the coating weight [mass] in milligrams per square foot [per square metre] as follows:

$$Cr, \text{ mg/ft}^2 \text{ of surface} = W \times 144/A$$

$$\left[ Cr, \text{ mg/m}^2 \text{ of surface} = W \times \frac{1}{A} \right]$$

where:

W = chromium obtained from calibration curve, milligrams, and

A = area stripped, in.<sup>2</sup> [m<sup>2</sup>].

**A2. PREFERRED TEST METHOD FOR DETERMINATION OF CHROMIUM IN THE OXIDE ON THE SURFACE OF ELECTROLYTIC CHROMIUM COATED STEEL**

**A2.1 Scope**

A2.1.1 This test method covers the determination of chromium present as oxide on the surface of electrolytic chromium coated steel.

**A2.2 Summary Of Test Method**

A2.2.1 The chromium oxide layer on the surface of the chromium coated steel is dissolved with 7.5 N sodium hydroxide (NaOH) solution, diluted to specific volume and aspirated into an air-acetylene flame (yellow-reducing). The absorbance at 357.9 nm is compared to the absorbances obtained from a series of standard chromium solutions and the chromium present as oxide is calculated in milligrams per square foot [per square metre].

**A2.3 Reagents**

A2.3.1 *Purity of Reagents*—Reagent grade chemicals shall be used in all tests. Unless otherwise indicated, it is intended that all reagents shall conform to the specifications of the Committee on Analytical Reagents of the American Chemical Society, where such specifications are available. Other grades may be used, provided it is first ascertained that the reagent is of sufficiently high purity to permit its use without lessening the accuracy of the determination.

A2.3.2 *Purity of Water*—Deionized or distilled water having a volume resistivity greater than 1 MΩcm at 25°C as determined by Method B of Test Methods D 1125.

A2.3.3 *Sodium Hydroxide Solution (7.5N)*—Dissolve 300 g of NaOH pellets in distilled water, cool, and then dilute to 1 L.

A2.3.4 *Standard Solution, Chromium*—Dissolve 0.2828 µg of dry, primary standard grade potassium dichromate ( $K_2Cr_2O_7$ ) in distilled water and dilute to 1000 mL in a volumetric flask. This solution contains 0.1 mg Cr/mL.

A2.3.5 *Standard Solution* (blank, 1.0, 2.0, and 5.0 µg Cr/mL levels)—Pipet into four 100 mL volumetric flasks, the following amounts of the chromium standard solution (A2.3.4). First flask, no solution. Second flask, 1.0 mL. Third flask, 2.0 mL. Fourth flask, 5.0 mL. Add 50 mL of 7.5 *N* NaOH solution to each flask. Dilute each flask to 100 mL with distilled water.

#### A2.4 Apparatus

A2.4.1 *Atomic Absorption Spectrometer*—Perkin Elmer 403 equipped with a standard Perkin-Elmer nebulizer-burner assembly with a 4-in. [10.2 cm] single slot head (or equivalent instrumentation).

A2.4.2 *Hollow Cathode Discharge Source*—Westinghouse, chromium, WL-2293A (or equivalent).

A2.4.3 *Cutter*, to blank 2.257 in. [5.73 cm] diameter discs or a size of known area greater than 4 in.<sup>2</sup> [10.2 cm<sup>2</sup>].

#### A2.5 Preparation of Chromium Calibration Curve

A2.5.1 Set the following settings on the atomic absorption spectrometer: lamp current, 15.0 mA; wave length, 357.9 nm; spectral slit, 0.7 nm; flame, air/acetylene.

A2.5.2 Ignite the air-acetylene flame (yellow-reducing) and allow the instrument to warm up for five minutes. While aspirating the 5.0 µg/mL standard solution (A2.3.5), optimize the flame composition and burner position for maximum absorbance (approximately 0.200 absorbance unit). Aspirate the other standard solutions (blank, 1.0, 2.0, and 5.0) and chart the four standard solution values. Plot absorbance versus µg/mL of chromium in solution.

#### A2.6 Use of Blank Disc or Sample Size

A2.6.1 Blank disc or sample size to be used. (If one side test is desired, spray one side with high-temperature clear Krylon lacquer and let dry. This prevents the sprayed side from being dissolved).

A2.6.2 Clean disc with chloroform or acetone.

A2.6.3 The uncoated side(s) are analyzed for chromium present as chromium oxide as follows. Place 50 mL of 7.5 *N* NaOH in a 600-mL beaker and heat to boiling. Remove from hot plate and allow to stand until boiling ceases. Add the sample disc to the beaker and strip for 5 min while swirling to maintain contact of solution over the sample. Prevent sample from lying flat on the bottom of the beaker by bending the disc slightly through the center. Remove sample after 5 min with a stirring bar retriever, rinse with distilled water, and allow the solution to cool to room temperature. Transfer the NaOH solution into a 100-mL volumetric flask, dilute to volume and mix thoroughly.

#### A2.7 Calculation

A2.7.1 Calculate the amount of chromium present in the oxide as follows:

$$C = A \times B \times \frac{144 \text{ in.}^2/\text{ft}^2}{D} \times \frac{1}{1000}$$

where:

*A* = concentration of Cr in µg/mL from chromium calibration curve,

*B* = dilution factor, millilitres (100),

*C* = chromium in the oxide per square foot, milligrams, and

*D* = area in in.<sup>2</sup> of surface dissolved.

### A3. METHOD FOR DETERMINATION OF CHROMIUM IN THE OXIDE ON THE SURFACE OF ELECTROLYTIC CHROMIUM-COATED STEEL

#### A3.1 Scope

A3.1.1 This method covers the determination of chromium present as oxide on the surface of electrolytic chromium coated steel.

#### A3.2 Summary of Method

A3.2.1 The oxide layer on the surface of the sheet is dissolved with a hot 10 *N* sodium hydroxide (NaOH) solution. After acidifying the solution, the chromium is oxidized with ammonium persulfate ( $(NH_4)_2S_2O_8$ ) and then determined photometrically with diphenylcarbazide.

#### A3.3 Reagents

A3.3.1 *Purity of Reagents*—Reagent grade chemicals shall be used in all tests. Unless otherwise indicated, it is intended that all reagents shall conform to the specifications of the Committee on Analytical Reagents of the American Chemical Society, where such specifications are available.<sup>5</sup> Other grades may be used, provided it is first ascertained that the reagent is

of sufficiently high purity to permit its use without lessening the accuracy of the determination.

A3.3.2 *Purity of Water*—Deionized or distilled water having a volume resistivity greater than 1 MΩ cm at 25°C as determined by Method B of Test Methods D 1125.

A3.3.3 *Ammonium Persulfate Solution (30 %)*—Dissolve 30 g of ammonium persulfate ( $(NH_4)_2S_2O_8$ ) in 100 mL of distilled water. This solution should be prepared freshly each day.

A3.3.4 *Chromium Standard Solution (1 mL = 0.01 mg Cr)*—Dissolve 0.2828 g of dry, primary standard grade potassium dichromate ( $K_2Cr_2O_7$ ) in distilled water and dilute to 1000 mL in a volumetric flask. This solution contains 0.1 mg Cr/mL. Pipet a 100-mL aliquot of this stock solution to a 1-L volumetric flask, and dilute to volume with distilled water. This dilute standard solution contains 0.01 mg Cr/mL.

A3.3.5 *Diphenylcarbazide Solution (0.25 %)*—Dissolve 0.25 g of diphenylcarbazide in 95 mL of acetone. Add 5 mL of glacial acetic acid, mix well, and store in a refrigerator until used.

A3.3.6 *Silver Nitrate Solution (2 %)*—Dissolve 2 g of silver nitrate ( $\text{AgNO}_3$ ) in 100 mL of distilled water. Keep protected from light.

A3.3.7 *Sodium Hydroxide Solution (10 N)*—Dissolve 400 g of NaOH pellets in distilled water, cool, and then dilute to 1 L.

A3.3.8 *Sulfuric-Phosphoric Acid Mixture*—Cautiously add 200 mL of sulfuric acid ( $\text{H}_2\text{SO}_4$ ) to 500 mL of distilled water. Mix well and cool. Slowly add 300 mL of 85 % phosphoric acid ( $\text{H}_3\text{PO}_4$ ), mix well, and store in a borosilicate bottle.

**A3.4 Apparatus**

A3.4.1 *Spectrophotometer*—Bausch and Lomb Spectronic 20 or equivalent.

A3.4.2 *Sample Holder*, for holding sample while stripping oxide surface film from only one surface of the sample.

A3.4.3 *Vacuum Pump*, for attachment of sample holder to test surface.

**A3.5 Preparation of Chromium Calibration Curve**

A3.5.1 Pipet 0 (blank), 1.0, 2.0, 5.0, 8.0, and 10.0-mL aliquots of standard chromium solution (1 mL = 0.01 mg Cr) to 250-mL beakers and dilute to approximately 100 mL with distilled water. Add 5 mL of  $\text{H}_2\text{SO}_4$ - $\text{H}_3\text{PO}_4$  solution 2 mL of  $\text{AgNO}_3$  solution, and 5 mL of  $(\text{NH}_4)_2\text{S}_2\text{O}_8$  solution. Heat the solutions to boiling and continue the boiling for about 10 min to decompose the excess persulfate. Cool, and then transfer the solutions to 100-mL volumetric flasks. Add 3 mL of diphenylcarbazide solution and dilute to volume. Measure the absorbance after 2 min at 560 nm in a 1-cm cell using water as a

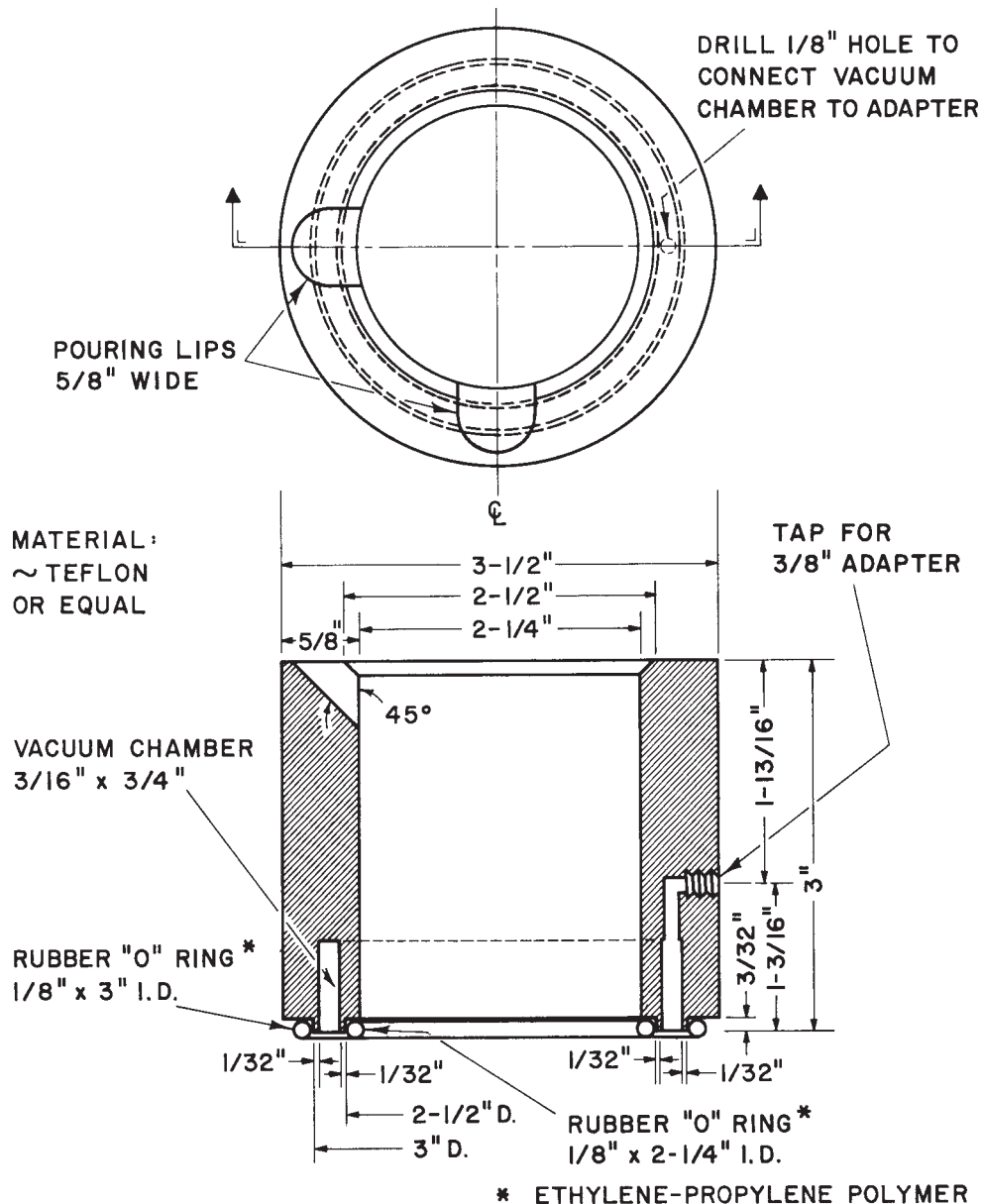


FIG. A3.1 Sample Holder



reference. Correct for the absorbance of the blank, and plot absorbance versus milligrams of chromium per 100 mL.

### A3.6 Procedure

A3.6.1 To remove the oxide surface film on each side of the sample separately, attach an appropriate size sample to the sample holder. The inner O-ring of the sample holder will define an area of 4.18-in<sup>2</sup> [10.6 cm<sup>2</sup>] when the sample holder is attached to a vacuum pump. Place the sample, with cell attached, on a hot plate that is regulated to maintain the temperature of the stripping solution at 90°C. Add 15 mL of hot 10 N NaOH solution to the cell. After 10-min, transfer the stripping solution to a 250-mL beaker, rinsing the cell thoroughly. Cool, neutralize to litmus with (1+1) H<sub>2</sub>SO<sub>4</sub>, and add 5 mL of H<sub>2</sub>SO<sub>4</sub>-H<sub>3</sub>PO<sub>4</sub> solution. Add 2 mL of AgNO<sub>3</sub> solution, and 5 mL of (NH<sub>4</sub>)<sub>2</sub>S<sub>2</sub>O<sub>8</sub> solution. Heat the solution to boiling and continue boiling for about 10 min to decompose the excess persulfate. Cool the solution to room temperature and transfer to a 100-mL volumetric flask. Add 3 mL of diphenylcarbazide

solution and dilute to volume. Measure the absorbance after 2 min at 560 nm in a 1-cm cell using distilled water as a reference. Correct for the absorbance of the reagent blank that is carried through the procedure and obtain the milligrams of chromium from the calibration curve.

### A3.7 Calculation

A3.7.1 Calculate the coating weight in milligrams per square foot [square metre] as follows:

$$\begin{aligned} \text{Cr, mg/ft}^2 \text{ of surface} &= W \times 144 / A \\ \left[ \text{Cr, mg/m}^2 \text{ of surface} &= W \times \frac{1}{A} \right] \end{aligned}$$

where:

$W$  = chromium from the calibration curve, milligrams, and  
 $A$  = area stripped, in.<sup>2</sup> [m<sup>2</sup>].

NOTE A3.1—A 4-in.<sup>2</sup> [25.8 cm<sup>2</sup>] disk may be stripped in a 250-mL beaker when the analysis of each separate side is not required.

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# Standard Specification for Hardware Cloth (Woven or Welded Galvanized Steel Wire Fabric)<sup>1</sup>

This standard is issued under the fixed designation A 740; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon ( $\epsilon$ ) indicates an editorial change since the last revision or reapproval.

*This standard has been approved for use by agencies of the Department of Defense.*

## 1. Scope

1.1 This specification covers woven or welded galvanized steel wire fabric commercially known as hardware cloth. It is customarily used for window and screen door guards, tree guards, industrial machine guards, sand screens, and grain bins. It serves as a protective screen against rodents and is used for many other home, farm, and industrial purposes.

1.2 The values stated in inch-pound units are to be regarded as the standard.

## 2. Referenced Documents

### 2.1 ASTM Standards:

A 90/A 90M Test Method for Weight (Mass) of Coating on

Iron and Steel Articles with Zinc or Zinc-Alloy Coatings<sup>2</sup>

B 6 Specification for Zinc (Slab Zinc)<sup>3</sup>

E 29 Practice for Using Significant Digits in Test Data to Determine Conformance with Specifications<sup>4</sup>

### 2.2 Military Standards:

MIL-STD-129 Marking for Shipment and Storage<sup>5</sup>

MIL-STD-147 Palletized and Containerized Unit Loads 40 Inch  $\times$  48 Inch Pallets, Skids, Runners, or Pallet Type Base<sup>5</sup>

MIL-STD-1188 Commercial Packaging of Supplies and Equipment<sup>5</sup>

## 3. Terminology

### 3.1 Definitions of Terms Specific to This Standard:

3.1.1 *hardware cloth*—as used in this specification, designates a material composed of cold-drawn steel wires which have been fabricated into fabric (or so-called “mesh”), formed by the process of weaving or electrical welding, and subsequently galvanized (zinc coated) by the hot-dip process. The

finished material consists essentially of a series of longitudinal (warp) and transverse (filler) wires arranged substantially at right angles to each other.

3.1.2 *mesh size*—as it pertains to cloth, is the dimensional center-to-center distance between warp wires and filler wires in that order. Measurements include the width of one opening plus the thickness of one parallel zinc-coated wire. Examples are 1 by 2 in., ½ by 1 in., etc. Thus, a 1 by 2-in. mesh denotes that the warp and filler wires are spaced on 1-in. [25.4-mm] and 2-in. [50.8-mm] centers respectively. For fabric with a square mesh the mesh size is indicated by a single value.

## 4. Ordering Information

4.1 Orders for material under this specification shall include the following information:

4.1.1 Quantity (number of rolls),

4.1.2 Name of material (1.1),

4.1.3 Mesh size (Table 1),

4.1.4 Wire size (Table 1),

4.1.5 Width (5.7.1),

4.1.6 Roll length (5.7.2),

4.1.7 Woven or welded, if necessary (Table 1), and

4.1.8 ASTM designation and year of issue.

NOTE 1—A typical ordering description is as follows: “ten 100-ft Rolls of ¼ -in. Hardware Cloth, Wire Size 0.0258 in., 24 in. wide, to ASTM A 740 – \_\_\_\_.”

## 5. Manufacture

5.1 *Base Metal*—The base metal of hardware cloth shall be of good commercial quality carbon steel wire.

5.2 *Zinc for Coating*—The zinc used in the galvanizing process shall be any grade of zinc conforming to Specification B 6.

5.3 *Fabrication*—Hardware cloth shall be of wire woven or welded into squares or rectangles and then galvanized by the hot-dip process. The mesh size and wire size after galvanizing shall conform to Table 1. Approximate weights for the product are also shown in Table 1.

<sup>1</sup> This specification is under the jurisdiction of ASTM Committee A05 on Metallic Coated Iron and Steel Products and is the direct responsibility of Subcommittee A05.12 on Wire Specifications.

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<sup>2</sup> Annual Book of ASTM Standards, Vol 01.06.

<sup>3</sup> Annual Book of ASTM Standards, Vol 02.04.

<sup>4</sup> Annual Book of ASTM Standards, Vol 14.02.

<sup>5</sup> Available from Standardization Documents Order Desk, Bldg. 4 Section D, 700 Robbins Ave., Philadelphia, PA 19111-5094, Attn: NPODS.

**TABLE 1 Mesh Size, Wire Size, and Weight<sup>A</sup>**

Mesh Size, in. [mm]	Construction	Diameter of Wire After Galvanizing, in. [mm]	Approximate Weight, lb/100 ft <sup>2</sup> [kg/m <sup>2</sup> ]
1 by ½ [25.4 by 12.7]	Welded	0.062 [1.57]	38 [1.86]
1 by ½ [25.4 by 12.7]	Welded	0.057 [1.45]	34 [1.66]
¾ [19.0]	Welded	0.062 [1.57]	38 [1.86]
¾ [19.0]	welded	0.057 [1.45]	36 [1.77]
¾ [19.0]	Welded	0.041 [1.04]	13 [0.65]
⅝ [15.9]	Welded	0.047 [1.20]	25 [1.21]
½ by 1 [12.7 by 25.4]	Welded	0.062 [1.57]	38 [1.86]
½ by 1 [12.7 by 25.4]	Welded	0.057 [1.45]	34 [1.66]
½ by 1 [12.7 by 25.4]	Welded	0.041 [1.04]	16 [0.78]
½ [12.7]	Welded	0.062 [1.57]	52 [2.54]
½ [12.7]	Welded	0.041 [1.04]	25 [1.22]
½ [12.7]	Woven	0.041 [1.04]	27 [1.32]
½ [12.7]	Welded	0.0317 [0.805]	14 [0.70]
½ [12.7]	Welded	0.0258 [0.655]	10 [0.47]
⅝ <sub>12</sub> [10.6]	Welded	0.0354 [0.899]	23 [1.11]
⅓ [8.5]	Welded	0.0317 [0.805]	23 [1.11]
⅓ [8.5]	Woven	0.0317 [0.805]	26 [1.27]
¼ [6.4]	Woven	0.0258 [0.655]	25 [1.22]
¼ [6.4]	Welded	0.0217 [0.551]	14 [0.69]
⅛ [3.2]	Woven	0.0173 [0.439]	22 [1.07]

<sup>A</sup>First dimension of rectangular meshes is spacing of warp wires (see 3.2).

5.4 *Mesh Count*—The mesh size in inches shall be determined by counting the meshes for any interval of one continuous linear foot, in the direction of either the warp or filler wires and finding the mesh size in Table 2.

5.5 *Wire Diameter*—All wire diameter designations in this specification for hardware cloth are finished sizes after galvanizing. Wire diameter for the warp and filler wires shall be determined separately by checking the average measured diameters of not less than ten warp wires and the same number of filler wires, taken at random from a single roll of finished hardware cloth.

#### 5.6 *Weight of Coating:*

5.6.1 The weight of zinc coating shall be determined on a sample of cloth approximately 25 in.<sup>2</sup> [161 cm<sup>2</sup>] in area. The coating shall be tested for weight by a stripping test in accordance with Test Method A 90/A 90M. Wire diameter for calculating purposes shall be the average measured diameters, after stripping, of at least five warp wires and an equal number of filler wires.

5.6.2 As the fabric is galvanized after welding/weaving the coating weight will be much higher than the present specification and we suggest the following with the addition of Table 3.

5.6.3 Coating weight thus determined shall be to the minimums shown in Table 3. The values are a minimum as determined by the rounding method in Practice E 29.

**TABLE 2 Mesh Count Versus Mesh Size**

Mesh Count in 1 ft [305 mm]	Mesh Size, in. [mm]
96	⅛ [3.2]
48	¼ [6.4]
36	⅓ [8.5]
29	⅝ <sub>12</sub> [10.6]
24	½ [12.7]
19	⅝ [15.9]
16	¾ [19.0]
12	1 [25.4]

**TABLE 3 Mesh Size and Minimum Coating Weight—Surface Area**

Mesh Size, in. [mm] <sup>A</sup>	Coating Weight, min, oz/ft <sup>2</sup> [g/m <sup>2</sup> ]
mesh size ≤ ½ [12.7]	1.3 [400]
½ [12.7] < mesh size ≤ ¾ [19]	1.2 [375]
¾ [19] < mesh size ≤ 1 [25.4]	1.1 [335]

<sup>A</sup>When the distance between warp and filler wires is different, the minimum distance is taken.

#### 5.7 *Width and Length:*

5.7.1 Stock widths of all standard sizes of hardware cloth are 24, 30, 36, and 48 in. [610, 762, 914, and 1219 mm].

5.7.2 Unless otherwise specified, hardware cloth shall be furnished in standard stock rolls of 50 linear ft [15.2 m] or 100 linear ft [30.5 m] in length. No standard stock roll shall contain more than two pieces, and no single piece shall be less than 10 linear ft [3.0 m] in length.

5.8 *Splices*—Splices not more than 1½ in. [38 mm] long, and with no projecting ends (tails), shall be permitted at any point of any individual wire if the number of splices does not exceed 30 in any roll, or two in any square foot [0.093 m<sup>2</sup>].

5.9 *Edges*—Both edges of woven cloth shall be selvaged. Edges, either woven or welded, shall be so formed as to prevent raveling.

### 6. Permissible Variations

6.1 For specified wire diameters 0.0317 in. [0.805 mm] or larger, the average diameter as determined in 5.5 for either the warp or filler wires shall not be more than 0.0015 in. [0.038 mm] below the diameter specified. For specified diameters smaller than 0.0317 in., the average value as determined in 5.5 shall not be more than 0.001 in. [0.025 mm] below the specified diameter.

6.2 The average diameter of the stripped wire as determined in 5.6.1 shall not be below the specified diameter more than 0.0025 in. [0.064 mm] for sizes 0.0317 in. [0.805 mm] or larger, or more than 0.002 in. [0.051 mm] for sizes smaller than 0.0317 in.

NOTE 2—For purposes of determining conformance with this specification, the specified tolerance limits are absolute limits as defined in Practice E 29.

6.3 *Tolerance on Mesh*—The tolerance on the mesh sizes shall comply with Table 4.

6.4 *Tolerance on Fabric Width*—The tolerance on the fabric width shall comply with Table 5.

6.5 The measured length of the roll shall not be more than 4 in. [102 mm] under the specified length.

### 7. Workmanship

7.1 Hardware cloth shall have smooth edges and shall be free of tears and projecting tails. The coating shall be continuous and reasonably uniform.

**TABLE 4 Tolerance on Mesh**

Mesh Size, in. [mm]	Tolerance, in. [mm]
mesh size ≤ ½ [12.7]	±0.031 [±0.79]
½ [12.7] < mesh size ≤ ¾ [19.0]	±0.042 [±1.07]
¾ [19.0] < mesh size ≤ 1 [25.4]	±0.063 [±1.60]

**TABLE 5 Tolerance on Fabric Width**

Fabric Width, in. [mm]	Tolerance, in. [mm]
width $\leq$ 24 [610]	$\pm 0.125$ [ $\pm 3.17$ ]
24 [610] < width $\leq$ 36 [914]	$\pm 0.187$ [ $\pm 4.75$ ]
36 [914] < width $\leq$ 48 [1219]	$\pm 0.250$ [ $\pm 6.35$ ]

## 8. Sampling

8.1 For purposes of tests, one roll from each of 50 rolls of hardware cloth or fraction thereof in a shipment shall be selected as a sample. When the rolls are palletized for shipment, the pallet containing the selected sample roll shall first be inspected for conformance to 10.2 and 10.3.

8.2 The roll shall be inspected for length (5.7.2), the number and condition of splices (5.8), the condition of the edges (5.9), general workmanship (7.1), and conformance to prescribed packaging, marking, and loading requirements (Section 10).

8.3 The sample shall be subjected to tests for width, wire diameter, and mesh count in accordance with 5.4, 5.5, and 5.7.1.

8.4 A sample shall be cut from near the end of the roll and tested for weight of zinc coating in accordance with 5.6.

## 9. Retests and Rejection

9.1 Should the hardware cloth in the sample roll fail to pass inspection or fail on one or more of the tests (8.2, 8.3, and 8.4) the roll shall be rejected. Four additional rolls in the lot shall be similarly checked. If any of these four fail, the lot shall be rejected.

9.2 Rejected lots may be screened and subsequently resubmitted for inspection.

## 10. Packaging, Marking, and Loading

10.1 Each roll of hardware cloth shall be tightly rolled and firmly tied. Each roll shall carry a tag showing the mesh size, wire size, width, length, ASTM designation A 740, and the name or mark of the manufacturer.

10.2 Packaging for U.S. government-procured hardware cloth shall be designated as either Level A or Commercial.

When Level A packaging is specified, the hardware cloth, packaged as specified in 10.1, shall be palletized in accordance with MIL-STD-147, Load Type XIII. Commercial packaging shall be as specified in 10.1 and MIL-STD-1188.

10.3 Marking for Level A U.S. government shipments shall be in accordance with MIL-STD-129. Marking for commercial U.S. government shipments shall be in accordance with MIL-STD-1188. Other marking shall be as specified in the contract or order.

## 11. Inspection

11.1 Unless otherwise specified in the contract or purchase order the manufacturer is responsible for the performance of all inspection requirements as specified herein. The purchaser, however, reserves the right subsequently to perform any of the inspections set forth to verify that the material is in accordance with this specification.

11.2 When the contract or purchase order stipulates that inspection and tests are to be made by the purchaser's inspector prior to shipment the manufacturer shall afford the purchaser's inspector all reasonable facilities necessary to satisfy him that the material being furnished is in accordance with this specification. Mill inspection by the purchaser shall not interfere unnecessarily with the manufacturer's operations. All tests and inspections shall be made at the place of manufacture, unless otherwise agreed to.

## 12. Certification

12.1 When specified in the purchase order or contract, the manufacturer's or supplier's certification shall be furnished to the purchaser stating that samples representing each lot have been manufactured, tested, and inspected in accordance with this specification and the requirements have been met. When specified in the purchase order or contract, a report of the test results shall be furnished.

## 13. Keywords

13.1 galvanized steel fabric; hardware cloth; steel wire-zinc coated; zinc-coatings-steel wire products

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*This standard is subject to revision at any time by the responsible technical committee and must be reviewed every five years and if not revised, either reapproved or withdrawn. Your comments are invited either for revision of this standard or for additional standards and should be addressed to ASTM International Headquarters. Your comments will receive careful consideration at a meeting of the responsible technical committee, which you may attend. If you feel that your comments have not received a fair hearing you should make your views known to the ASTM Committee on Standards, at the address shown below.*

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# Standard Specification for Zinc-Coated Steel Wire Rope and Fittings for Highway Guardrail<sup>1</sup>

This standard is issued under the fixed designation A 741; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon ( $\epsilon$ ) indicates an editorial change since the last revision or reapproval.

## 1. Scope

1.1 This specification covers  $\frac{3}{4}$  and 1-in. [19 and 25-mm] zinc-coated steel wire rope and fittings for use in the construction of highway guardrail.

1.2 The values stated in inch-pound units are to be regarded as the standard. The values given in brackets are for information only.

## 2. Referenced Documents

### 2.1 ASTM Standards:

A 90/A 90M Test Method for Weight [Mass] of Coating on Iron and Steel Articles with Zinc or Zinc-Alloy Coatings.<sup>2</sup>

A 123/A 123M Specification for Zinc (Hot-Dip Galvanized) Coatings on Iron and Steel Products<sup>2</sup>

A 153/A 153M Specification for Zinc Coating (Hot-Dip) on Iron and Steel Hardware<sup>2</sup>

A 370 Test Methods and Definitions for Mechanical Testing of Steel Products<sup>3</sup>

A 902 Terminology Relating to Metallic Coated Steel Products<sup>2</sup>

B 6 Specification for Zinc<sup>4</sup>

## 3. Terminology

3.1 Definitions—For definitions of terms used in this specification, refer to Terminology A 902.

## 4. Ordering Information

4.1 Orders for wire rope guardrail material purchased to this specification shall include the following:

4.1.1 Diameter of wire rope,

4.1.2 Type of wire rope construction,

4.1.3 Class of zinc coating required (Table 1),

4.1.4 Quantity of wire rope and length per reel, and

4.1.5 ASTM designation and year of issue.

NOTE 1—A typical ordering description is as follows:  $\frac{3}{4}$ -in. [19-mm] diameter, Zinc-Coated Wire Rope for Guardrail, Type 1 Construction, Class A Coating, 80 000 lineal ft [24 300 m] on forty 2 000-ft [608-m] reels, ASTM A 741– .

## 5. Material

5.1 *Base Metal*—The base metal shall be steel made by any process and shall be of such quality that the finished wire rope and the individual zinc-coated wires shall have the properties as prescribed in this specification.

5.2 *Zinc*—The slab zinc when used for the coating shall be any grade of zinc conforming to Specification B 6.

## 6. Mechanical Requirements

6.1 *Breaking Strength*—The zinc-coated steel wire rope shall conform to the mechanical properties in Table 2 when tested in accordance with Test Methods and Definitions A 370 and employing a suitable gripping device as covered in Supplement VII of Test Methods and Definitions A 370.

6.2 *Construction*—The zinc-coated wire rope and individual wires shall conform to the dimension and construction requirements of Table 2.

6.3 *Ductility of Steel*—The individual zinc-coated wires shall be capable of being wrapped two turns in a close helix at a rate not exceeding 15 turns per minute around a cylindrical steel mandrel equal to three times the nominal diameter of the wire under test without cracking or breaking of the wire.

6.4 *Weight of Zinc Coating*—The class of zinc coating shall be specified by the purchaser. The weight of the zinc coating on the individual wires for the specified class and appropriate wire size shall not be less than that specified in Table 1 when tested in accordance with the stripping test of Test Method A 90 /A 90M.

6.5 *Adherence of Coating*—The individual zinc-coated wires shall be capable of being wrapped two turns in a close helix at a rate not exceeding 15 turns per minute around a cylindrical steel mandrel equal to three times the nominal diameter of the wire under test without the coating cracking or flaking to such an extent that any zinc can be removed by rubbing with bare fingers. Loosening or detachment during the adherence test of superficial small particles of zinc formed by mechanical polishing of the surface of zinc-coated wire shall not be considered cause for rejection.

<sup>1</sup> This specification is under the jurisdiction of ASTM Committee A05 on Metallic Coated Iron and Steel Products and is the direct responsibility of Subcommittee A05.12 on Wire Specifications.

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<sup>2</sup> *Annual Book of ASTM Standards*, Vol 01.06.

<sup>3</sup> *Annual Book of ASTM Standards*, Vol 01.03.

<sup>4</sup> *Annual Book of ASTM Standards*, Vol 02.04.

**TABLE 1 Minimum Weight of Coating**

Nominal Diameter of Coated Wire		Weight of Zinc Coating, min					
		oz/ft <sup>2</sup> of Uncoated Wire Surface			g/m <sup>2</sup> of Uncoated Wire Surface		
in.	mm	Class A Coating	Class B Coating	Class C Coating	Class A Coating	Class B Coating	Class C Coating
0.040 to 0.061, incl	1.02 to 1.55, incl	0.40	0.80	1.20	122	244	366
0.062 to 0.079, incl	1.58 to 2.01, incl	0.50	1.00	1.50	152	305	458
0.080 to 0.092, incl	2.03 to 2.34, incl	0.60	1.20	1.80	183	366	549
0.093 to 0.103, incl	2.36 to 2.62, incl	0.70	1.40	2.10	214	427	640
0.104 to 0.119, incl	2.64 to 3.02, incl	0.80	1.60	2.40	244	488	732
0.120 to 0.142, incl	3.05 to 3.61, incl	0.85	1.70	2.55	259	518	778

**TABLE 2 Guard Cable Requirements**

Type	Diameter, min, in. [mm]	Construction (No. of Strands × No. of Wires per Strand)	Breaking Strength, min, lbf [kN]	Length of Lay of Strand, max, in. [mm]	Length of Lay of Wires in Strand, max, in. [mm]	Diameter of Coated Wires in Strand, in. [mm]
I	¾ [19]	3 by 7	25 000 [110]	7.5 [190]	4.5 [114]	0.117 to 0.124 [2.97 to 3.15]
II	¾ [19]	6 by 19 <sup>A</sup> IWRC <sup>B</sup>	42 800 [190]	<sup>C</sup>	<sup>C</sup>	variable
II(a)	¾ [19]	6 by 19 <sup>A</sup> wire strand core	42 800 [190]	<sup>C</sup>	<sup>C</sup>	variable
III	1 [25]	7 by 7	45 000 [200]	10 [254]	4.5 [114]	0.105 to 0.116 [2.67 to 2.84]

<sup>A</sup>6 by 19 classification may have from 15 to 26 wires per strand.

<sup>B</sup>IWRC = independent wire rope core.

<sup>C</sup>Length of lay as specified by the manufacturer.

6.6 *Appearance*—The individual wires shall be cylindrical in form, of uniform quality, and free of imperfections not consistent with good commercial practice. The coating shall be continuous and reasonably uniform.

## 7. Wire Rope

7.1 The wire rope shall be right regular lay, preformed, and of the type of construction shown in Table 2. A right lay is defined as a clockwise twist away from the observer. The type of construction shall be specified by the purchaser.

## 8. Joints and Splices

8.1 *Individual Wires*—The distance between joints in any two individual wires in a strand shall be not less than 18 in. [460 mm]. Joints in individual wires shall be either butt-welded or brazed-lap type. Joints made by butt welding shall have all flash removed. When the brazed-lap type of joint is used, the length of the lap shall be not less than three times the diameter of the wire and the overlapping faces shall be smooth, clean, properly fluxed, and completely covered by the brazing metal. All joints shall be recoated after welding so that the joints shall have protection from corrosion equivalent to the zinc-coated wire itself.

8.2 *Strand or Rope*—Strand or rope splices may only be made when authorized in writing by the purchaser.

## 9. Sampling and Testing

9.1 One wire rope test specimen shall be taken from each lot. A lot shall consist of not more than 20 tons [18 metric tons] of wire rope of one size and type delivered at one time.

9.2 The test specimen shall be of a length to perform conveniently all tests prescribed in this specification.

9.3 A minimum of four wire test specimens shall be cut from each size of main wires in the rope, selected at random for testing for compliance with 6.2, 6.3, 6.4, and 6.5.

9.4 If an individual wire or the rope fails to meet any requirements of this specification, that reel shall be rejected and two additional tests shall be made on samples of wire rope from two different reels in the lot. If failure occurs in either of these tests, the lot of wire rope shall be rejected. The lot may be resubmitted for inspection after testing every reel for the characteristic in which the specimen failed and sorting out the defective reels.

## 10. Inspection

10.1 All tests and inspection shall be made at the place of manufacture unless otherwise specified and shall be so conducted as not to interfere unnecessarily with the operation of the works. The manufacturer shall afford the inspector representing the purchaser all reasonable facilities to satisfy him that the material being furnished is in accordance with this specification. When specified, inspection may be waived and certified copies of test reports furnished. The purchaser reserves the right to test individual wires for compliance to 6.2, 6.3, 6.4, and 6.5 and the zinc-coated wire rope after fabrication.

## 11. Packaging

11.1 Current standard practice is to ship the wire rope on wooden reels. Each reel shall have the length, nominal diameter, type of strand construction, weight of rope, and name or trademark of the manufacturer plainly and indelibly marked on a strong tag, firmly attached, or this information shall be painted on the reel. The wooden reel shall be mountable so that it will revolve and the rope will run off by pulling straight ahead.

## 12. Fittings

12.1 The fittings shall be of the design called for in the plans and shall have the properties necessary to develop the strength of the wire rope.

12.2 Fittings as shown in the plans shall have a uniform coating of zinc conforming to Specifications A 123/A 123M or A 153/A 153M, whichever applies.

### **13. Keywords**

13.1 galvanized wire; steel wire; wire; zinc-coated carbon steel wire

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# Standard Specification for Steel Sheet, Metallic Coated and Polymer Precoated for Corrugated Steel Pipe<sup>1</sup>

This standard is issued under the fixed designation A 742/A 742M; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

*This standard has been approved for use by agencies of the Department of Defense.*

## 1. Scope\*

1.1 This specification covers polymer precoated steel sheet for corrugated steel pipe (CSP) which is coated after metallic coating on continuous lines by coil coating (roller coating or laminating) processes. The metallic coating is either zinc, 55 % aluminum-zinc alloy, or zinc-5 % aluminum-mischmetal alloy. Sheet for this purpose is furnished flat in coils, flat in cut lengths, or corrugated in cut lengths, all being protected by a mill-applied polymer coating on both sides.

1.2 The values stated in either inch-pound units or SI units are to be regarded separately as the standard. Within the text, the SI units are shown in brackets. The values stated in each system are not equivalents; therefore, each system must be used independently of the other.

1.3 The following precautionary caveat refers only to the test method portion, Section 9, of this specification: *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

## 2. Referenced Documents

### 2.1 ASTM Standards:

- A 929/A 929M Specification for Steel Sheet, Metallic-Coated by the Hot-Dip Process for Corrugated Steel Pipe<sup>2</sup>
- D 543 Practices for Evaluating the Resistance of Plastics to Chemical Reagents<sup>3</sup>
- D 658 Test Method for Abrasion Resistance of Organic Coatings by the Air-Blast Abrasion Test<sup>4</sup>
- D 1005 Test Methods for Measurement of Dry-Film Thickness of Organic Coatings Using Micrometers<sup>4</sup>
- D 2794 Test Method for Resistance of Organic Coatings on

the Effects of Rapid Deformation (Impact)<sup>4</sup>

G 22 Practice for Determining Resistance of Plastics to Bacteria<sup>5</sup>

G 23 Practice for Operating Light- and Water-Exposure Apparatus (Carbon-Arc Type) for Exposure of Nonmetallic Materials<sup>3</sup>

G 62 Test Methods for Holiday Detection in Pipeline Coatings<sup>4</sup>

## 3. Terminology

### 3.1 Definitions of Terms Specific to This Standard:

3.1.1 *fabricator*—in this specification, fabricator refers to the producer of the pipe.

3.1.2 *manufacturer*—in this specification, manufacturer refers to the producer of the sheet.

3.1.3 *purchaser*—in this specification, purchaser refers to the purchaser of the finished pipe.

### 3.2 Abbreviations: Abbreviations:

3.2.1 55 Al-Zn—55 % aluminum-zinc.

3.2.2 MM—mischmetal.

3.2.3 Zn-5 Al-MM—zinc-5 % aluminum-mischmetal.

## 4. Classification

4.1 The polymer coating is classified by grade corresponding to the thickness in mils (thousandths inch) on each side in inch-pound units and the thickness in micrometres on each side in SI units.

Grade	Coating Thickness	
	in.	[μm]
10/10 [250/250]	0.010/0.010	[250/250]

4.2 Any combination of polymer coating thickness other than shown above is subject to agreement between the manufacturer and purchaser or fabricator.

## 5. Ordering Information

5.1 The polymer precoated sheet covered by this specification shall be ordered only to the specified thickness listed in Table 1. The specified thickness is based on the thickness of the metallic-coated steel sheet, not including the thickness of the polymer coating.

<sup>1</sup> This specification is under the jurisdiction of ASTM Committee A05 on Metallic Coated Iron and Steel Products and is the direct responsibility of Subcommittee A05.11 on Sheet Specifications.

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<sup>2</sup> Annual Book of ASTM Standards, Vol 01.06.

<sup>3</sup> Annual Book of ASTM Standards, Vol 08.01.

<sup>4</sup> Annual Book of ASTM Standards, Vol 06.01.

<sup>5</sup> Annual Book of ASTM Standards, Vol 14.02.

\*A Summary of Changes section appears at the end of this standard.



**TABLE 1 Thicknesses of Metallic-Coated Steel Sheet<sup>A</sup>**

Specified Thickness, in. [mm]	Metallic Coating		
	Zinc-Coated	55 Al-Zn Alloy Coated	Zn-5 Al-MM Alloy Coated
0.040 [1.02]	X	X	X
0.052 [1.32]	X	X	X
0.064 [1.63]	X	X	X
0.079 [2.01]	X	X	X
0.109 [2.77]	X	X	X
0.138 [3.51]	X	X	X
0.168 [4.27]	X		X

<sup>A</sup>An "X" indicates sheet thicknesses which are available in the corresponding coating type.

5.2 Orders for material to this specification shall include the following information, as necessary, to adequately describe the desired product.

5.2.1 Name of material (polymer precoated steel sheet for CSP),

5.2.2 Type of metallic coating (see 6.1),

5.2.3 ASTM designation and year of issue, as A 742 – \_\_\_ for inch-pound units or A 742M – \_\_\_ for SI units,

5.2.4 Corrugation size, if corrugated (see 6.3),

5.2.5 Substrate dimensions (specified thickness; width, either flat or overall corrugated; and length, if cut length),

5.2.6 Grade of polymer coating (see Section 4), indicating thickness on each side,

5.2.7 Coil size requirements (specify maximum outside diameter (OD), acceptable inside diameter (ID), and maximum weight),

5.2.8 Certification, if required (see 11.1), and

5.2.9 Special requirements.

NOTE 1—Typical ordering descriptions are as follows:

Polymer precoated steel sheet, zinc-coated for CSP, conforming to ASTM A 742 – \_\_\_, 2<sup>2</sup>/<sub>3</sub> by 1/2 -in. corrugations, 0.064 by 25<sup>1</sup>/<sub>2</sub> by 60 in., with Grade 10/10 polymer coating (0.010 in./0.010 in.), certified with test report.

[Polymer precoated steel sheet, aluminum-zinc alloy coated for CSP, conforming to ASTM A 742M – \_\_\_, 2.77 by 700 mm by coil, with Grade 250/250 polymer coating; coil 1200-mm max outside diameter, 600-mm inside diameter, 10 000-kg max coil weight.]

## 6. General Requirements

6.1 The metallic-coated substrate shall conform to all applicable requirements of Specification A 929/A 929M for zinc coating, 55 % aluminum-zinc alloy coating, or zinc-5 % aluminum-mischmetal alloy coating, whichever is stated in the order. If the type of metallic coating is not stated in the order, zinc-coated steel sheet shall be furnished.

6.1.1 The steel sheet shall be thoroughly cleaned of any chromate pretreatment or other passivation using a multi-brush cleaning process. All traces of the caustic cleaning solution shall be immediately rinsed from the sheet following caustic cleaning. After drying, the steel sheet shall be treated with chromic acid solution and heat-cured prior to application of the polymer film. The deposited chromium content shall range from 135 to 190 mg/m<sup>2</sup>.

6.2 The polymer coating shall be a film coating comprised of at least 85 % ethylene acrylic acid copolymer and be capable of being applied to the sheet specified in 6.1. After application, the polymer coating shall be free of holes, tears, and discon-

tinuities, and shall be sufficiently flexible so that it will withstand the corrugating, forming, and lockseaming operations, and punching of holes for rivets or perforations.

6.3 If the polymer-coated sheet is to be furnished with corrugations, the corrugations shall conform to the requirements stated in Specification A 929/A 929M.

## 7. Requirements for Polymer Coating

7.1 *Adhesion*—There shall be no spalling or cracking of the coating, or disbonding of the coating at the cut, when tested in accordance with 9.1.

7.2 *Impact*—There shall be no break in the polymer coating when tested in accordance with 9.2.

7.3 *Thickness of Coating*—The thickness of the polymer coating shall meet the requirements of Section 4, or as specified in the purchase order, when tested in accordance with 9.3. The thicknesses indicated are minimum values at any point not less than 3/8 in. [10 mm] from an edge.

7.4 *Holidays*—The polymer coating on the steel shall be substantially free of holidays when tested in accordance with 9.4. An average of two holidays per square foot [22 holidays per square metre] of actual surface area on the test specimen shall be permitted.

NOTE 2—Holidays are pinholes or voids in the polymer coating that are not visually discernible.

7.5 *Abrasion Resistance*—The average abrasion coefficient when tested in accordance with 9.5, shall be a minimum of 100 (expressed in g/mil of thickness) or 3.9 [expressed in g/μm of thickness].

7.6 *Imperviousness*—There shall be no loosening or separation of the polymer coating from the metallic-coated steel substrate when tested in accordance with 9.6.

7.7 *Freeze-Thaw Resistance*—The specimen shall withstand 100 freeze-thaw cycles, as described in 9.7, without spalling, disbonding, or other detrimental effects.

7.8 *Weatherability*—The specimens shall withstand 100 h of weathering with no observable delamination or cracking, when tested in accordance with 9.8.

7.9 *Resistance to Microbial Attack*— There shall be no effect of microbial attack of the polymer coating when tested in accordance with 9.9.

NOTE 3—Tests 7.1 through 7.4 are suggested as quality control tests. When these tests are used for quality control, they may be run at room temperature only. Tests 7.5 through 7.9 are suggested as qualifying tests. However, the purchaser may use any of the tests listed to verify compliance.

## 8. Sampling and Testing

8.1 The manufacturer shall make adequate tests and measurements to ensure that the material produced complies with this specification.

8.1.1 Test results to show compliance with this specification shall be retained by the manufacturer for seven years and shall be made available to the fabricator and purchaser upon request.

8.2 The fabricator or purchaser shall conduct such tests as are determined necessary to determine the acceptability of the material or to verify the correctness of a certification.

8.3 Flat samples of polymer precoated steel shall be taken by the manufacturer from each coil or in accordance with the sampling procedure as mutually agreed upon between the manufacturer and the purchaser. Each sample shall be at least 24 in. [600 mm] long by the coil width and shall carry an identification to relate it to the coil from which it was taken.

## 9. Test Methods for Polymer Coatings

### 9.1 Adhesion:

9.1.1 *Scope*—This procedure measures the adhesion of the polymer coating to the metallic-coated substrate.

9.1.2 *Significance and Use*—This test indicates the ability of the polymer to withstand forces in fabrication and use tending to disbond the coating from the substrate.

9.1.3 *Procedure*—Cut a 2 by 8-in. [50 by 200-mm] coupon from the sample of precoated steel. Bend the coupon 180° over a 0.5-in. [12.5-mm] diameter mandrel. The surface with the polymer coating to be tested shall be on the outside of the bend. After making bend, make a cut through the polymer coating along an element on the outside of the bend to check for polymer coating adhesion. Perform this test at 0, 77, and 122 ± 2°F [−18, 25, and 50 ± 1°C]. Check for spalling or cracking of the polymer coating, or for disbonding from the metallic-coated substrate.

9.1.4 *Precision and Bias*—No statement is made about either the precision or the bias of the procedure for measuring adhesion since the result merely states whether there is conformance to the criteria for success specified in the procedure.

### 9.2 Impact:

9.2.1 *Scope*—This procedure measures the ability of the polymer coating to withstand impact.

9.2.2 *Significance and Use*—This test provides a measure of the ability of the polymer coating to resist damage by impact, to which it may be subjected in service.

9.2.3 *Procedure*—Cut a 6 by 6-in. [150 by 150-mm] coupon from the sample of precoated steel. Direct impact the coating with an energy of 35 in.-lb [4.0 J] using an impact tester<sup>6</sup> with a 0.625-in. [15.88-mm] diameter punch and with the specimen set on a 0.640-in. [16.26-mm] diameter punch die. Test at approximately 77°F [25°C] (Note 4). Check for breaks in the polymer coating.

NOTE 4—This test procedure is described in detail in Test Method D 2794.

9.2.4 *Precision and Bias*—No statement is made about either the precision or the bias of the procedure for measuring impact resistance since the result merely states whether there is conformance to the criteria for success specified in the process.

9.3 *Thickness of Coating*—Measure polymer coating thickness in accordance with Test Methods D 1005.

9.4 *Holidays*—Test a specimen that is at least 12 in. [300 mm] long and the full coil width in accordance with Practice G 62, Method A, using a nominal voltage of 67½ V.

9.5 *Abrasion Resistance*—Determine the abrasion coefficient in accordance with Test Method D 658 except use a silicon carbide grain passing a No. 140 [106-µm] sieve and retained on a No. 170 [90-µm] sieve, and an air test pressure of 4.82 psi [250 mm Hg] [33.25 kPa].

9.5.1 The modifications to the procedure in Test Method D 658 are not expected to have an effect on the precision and bias as indicated in Test Method D 658.

9.6 *Imperviousness*—Test the polymer coating for imperviousness to chemical reagents in accordance with the applicable sections of Practices D 543 using a 10 % solution of sodium chloride, a 10 % solution of sodium hydroxide, and a 30 % solution of sulfuric acid. Hold each reagent in a separate confined area of the polymer precoated sheet for a period of 48 h. Avoid excessive evaporation of the test solutions.

### 9.7 Freeze-Thaw Resistance:

9.7.1 *Scope*—This procedure evaluates the ability of the polymer coating to resist freeze-thaw cycling.

9.7.2 *Significance and Use*—As pipe fabricated from polymer-coated steel sheet will be exposed to freeze-thaw action while saturated, the procedure will measure ability to withstand such action without damage to the polymer coating.

9.7.3 *Procedure*—Cut a minimum of three 6 by 6-in. [150 by 150-mm] coupons from the sample of precoated metal. Immerse the coupons in water at room temperature for two weeks and then subject them to freeze-thaw cycling. One cycle shall consist of 8 h at 0°F [−18°C] followed immediately by immersion in water at room temperature for 16 h. Cycle time may be interrupted over weekends and holidays, but the specimens shall be maintained in water at room temperature, and such interruptions should be noted. Make observations during the cycling and note any visible changes in the coating, such as spalling, disbonding, etc. After 100 cycles, make a final examination of the effects as a result of freezing and thawing.

9.7.4 *Precision and Bias*—No statement is made about either the precision or the bias of the procedure for measuring freeze-thaw resistance since the result merely states whether there is conformance to the criteria for success specified in the procedure.

9.8 *Weatherability*—Subject coupons of the precoated metal to accelerated weathering in accordance with Practice G 23 using the specimen spray arrangement for Type E, Single Open-Flame Sunshine Carbon-Arc Lamp Apparatus. Test conditions shall consist of a 2-h cycle including 18 min of water spray and a maximum temperature of 140°F [60°C].

9.9 *Resistance to Microbial Attack*—Subject test specimens of the polymer coating to conditions described in Practice G 22, Procedure B. There shall be no visible effects of bacterial attack on the polymer coating after the prescribed incubation period (21 days minimum).

## 10. Rejection

10.1 Material tested by the purchaser and found not conforming to this specification shall be subject to rejection.

## 11. Certification

11.1 When specified in the purchase order or contract, a manufacturer's certification shall be furnished to the fabricator or to the purchaser stating that samples representing each lot

<sup>6</sup> The Gardner-Impact Tester, Variable, Model IG 1120, available from Pacific Scientific Co., Gardner/Neotec Instrument Division, 2431 Linden Lane, Silver Spring, MD 20910, has been found suitable for this purpose.

have been tested and inspected in accordance with this specification and the requirements have been met. When specified in the purchase order or contract, a report of the test results shall be furnished. For results of tests suggested in Section 7 as qualifying tests, the use of typical results is permitted rather than results of tests on the specific lot of material.

## 12. Product Marking

12.1 Each 2 to 5 ft [0.6 to 1.5 m] of sheet in coils or cut lengths shall be identified by marking as follows:

- 12.1.1 Name of sheet producer,
- 12.1.2 Brand name,
- 12.1.3 Specified thickness of metallic-coated sheet,
- 12.1.4 Type of metallic coating,
- 12.1.5 Grade or thickness of polymer coating,
- 12.1.6 Identification symbols relating to a specific heat number and coating lot number, and

12.1.7 ASTM designation.

12.2 The brand shall be removed, obliterated, or the sheet rebranded “Non Specification” on each 2 to 5 ft [0.6 to 1.5 m] of material in a coating lot or heat where control tests, as prescribed herein, show nonconformance to this specification, or where the metallic-coated steel substrate shows nonconformance to the appropriate sheet specification.

## 13. Keywords

13.1 aluminum-mischmetal alloy; aluminum-mischmetal alloy coated; coatings-55 % aluminum-zinc alloy; coatings-metallic; coatings-polymer; coatings-zinc; coatings zinc 5 %; corrugated steel pipe; pipe-corrugated steel; polymer coatings; steel sheet-55 % aluminum-zinc alloy coated; steel sheet-metallic coated; steel sheet-polymer coated; steel sheet-zinc coated; steel sheet-zinc 5 %

## SUMMARY OF CHANGES

This section identifies the location of selected changes to this specification. For the convenience of the user, Committee A05 has highlighted those changes that may impact the use of this specification. This section may also include descriptions of the changes or reasons for the changes, or both.

*A 742/A 742M - 03:*

(1) Added paragraph 6.1.1 and revised paragraph 6.2 to clarify the chemical composition of the polymer film and describe an improved pre-treatment of the steel to improve performance of the coated product.

*A 742/A 742M - 98:*

- (1) Changes were made to 4.1 and Note 1.
- (2) Added a Summary of Changes section.

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# Standard Test Method for Coating Weight (Mass) of Metallic Coatings on Steel by X-Ray Fluorescence<sup>1</sup>

This standard is issued under the fixed designation A 754/A 754M; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon ( $\epsilon$ ) indicates an editorial change since the last revision or reapproval.

## 1. Scope

1.1 This test method covers the use of X-ray fluorescence (XRF) for determining the coating weight (mass) of metallic coatings on steel sheet. The test method is intended to be used for “on-line” measurements of coating on continuous production lines.

1.2 This test method is applicable to the coatings covered by the following ASTM specifications:

A 591/A 591M, A 599/A 599M,

A 623, A 623M, A 653/A 653M, A 792/A 792M, A 875/A 875M, A 879, and A 918. It may be applicable to other coatings, providing that the elemental nature of the coating and substrate are compatible with the technical aspects of XRF such as the absorption coefficient of the system, primary radiation, fluorescent radiation, type of detection.

1.3 This test method includes the procedure for developing a single standard determination of coating weight (mass).

1.4 This test method includes procedures for both X-ray tube and isotope coating weight (mass) measuring instruments.

1.5 The values stated in either inch-pound units or SI units are to be regarded separately as standard. Within the text, the SI units are shown in brackets. The values stated in each system are not exact equivalents; therefore, each system shall be used independently of the other. Combining values from the two systems may result in nonconformance with the specification.

1.6 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

## 2. Referenced Documents

### 2.1 ASTM Standards:

A 591/A591M Specification for Steel Sheet, Electrolytic Zinc-Coated, for Light Coating Mass Applications<sup>2</sup>

<sup>1</sup> This test method is under the jurisdiction of ASTM Committee A05 on Metallic Coated Iron and Steel Products and is the direct responsibility of Subcommittee A05.07 on Methods of Testing.

Current edition approved July 10, 1996. Published September 1996. Originally published as A 754/A 754M – 79. Last previous edition A 754/A 754M – 79 (1990).

<sup>2</sup> *Annual Book of ASTM Standards*, Vol 01.06.

A 599/A599M Specification for Tin Mill Products, Electrolytic Tin-Coated, Cold-Rolled Sheet<sup>2</sup>

A 623 Specification for Tin Mill Products, General Requirements<sup>2</sup>

A 623M Specification for Tin Mill Products, General Requirements [Metric]<sup>2</sup>

A 653/A653M Specification for Steel Sheet, Zinc-Coated (Galvanized) or Zinc-Iron Alloy-Coated (Galvannealed) by the Hot-Dip Process<sup>2</sup>

A 792/A792M Specification for Steel Sheet, 55 % Aluminum-Zinc Alloy-Coated by the Hot-Dip Process<sup>2</sup>

A 875/A875M Specification for Steel Sheet, Zinc-5 % Aluminum Alloy-Coated by the Hot-Dip Process<sup>2</sup>

A 879 Specification for Steel Sheet, Zinc Coated by the Electrolytic Process for Applications Requiring Designation of the Coating Mass on Each Surface<sup>2</sup>

A 902 Terminology Relating to Metallic Coated Steel Products<sup>2</sup>

A 918 Specification for Steel Sheet, Zinc-Nickel Alloy Coated by the Electrolytic Process for Applications Requiring Designation of the Coating Mass on Each Surface<sup>2</sup>

## 3. Terminology

3.1 Definitions—For general definitions of terms relating to metallic-coated steel products, see Terminology A 902.

3.2 *Definitions of Terms Specific to This Standard:*

3.2.1 *averaging time*,  $n$ —the period over which an electronic measuring instrument acquires samples or “counts” prior to each update of coating weight (mass) output; refer to X1.2 for a more detailed explanation.

3.2.2 *response time*,  $n$ —the time required for a coating weight (mass) gage to detect 90 % of a 10 % step change in coating weight (mass).

3.2.3 *sample*,  $n$ —the area of moving sheet that must be measured under standardized conditions to develop a single determination of coating weight (mass).

3.2.4 *standards*,  $n$ —the physical standards, either external or internal, that are used to calibrate the measuring instrument.

3.2.5 *substrate*,  $n$ —the steel sheet upon which the metallic coating is applied.

3.2.6 *time constant*,  $n$ —an electronic filtering term, unique to the design of each type of measuring instrument, that defines the time taken to respond to a step change in coating thickness;

refer to X1.3 for a more detailed explanation.

3.2.7 *X-ray fluorescence, n*—the X-rays emitted by an atom when excited to a higher energy state.

#### 4. Basic Principle

4.1 The measurement of coating thickness by XRF methods is based on the combined interaction of the coating and substrate, with an intense beam of primary radiation from an X-ray or isotope source. This interaction results in the generation of X-rays of well-defined energy. These fluorescent X-rays are detected by a radiation detector that can discriminate between selected energy levels in the secondary beam.

4.1.1 The radiation detector can discriminate between specific fluorescent X-rays because the X-rays generated by the interaction between the primary beam and the surface being fluoresced have energy levels that are unique to each element in the targeted material. Each element fluoresces at an energy that is characteristic of that element alone. Thus the fluoresced radiation can be detected separately for either the elements in a coating or the substrate material.

4.1.2 The detection system includes the radiation detector in conjunction with suitable electronic discriminating circuitry.

4.1.3 The thickness of a coating can be determined because a quantitative relationship exists between the intensity of the secondary radiation captured by the detector and the thickness of the coating material. The thickness of a sample can be established by comparing the measured intensity and that of a series of standards.

4.1.4 The coating weight (mass) can be calculated from the measured coating thickness for a specific coating type. In practice, the electronics are established to report the coating weight (mass) in commonly used units such as oz/ft<sup>2</sup>[g/m<sup>2</sup>].

##### 4.2 Measurement Techniques:

4.2.1 Two measurement techniques are used. The first technique involves direct measurement of the intensity of the fluorescent X-rays emitted by the coating itself. With this method, the coating weight (mass) is correlated with the intensity of the fluorescent X-rays emitted by the coating.

4.2.2 The second technique involves the measurement of the attenuation of the fluorescent X-rays emitted by the substrate as they pass through the coating whose weight (mass) is being determined. The correlation in this case is based on the principle that the intensity of the X-rays from the fluoresced substrate is a function of the weight (mass) of the coating for a specific coating type.

4.2.3 Appendix X2 and Appendix X3 contain a more detailed discussion of these two methods of measuring coating weight (mass).

#### 5. Factors Affecting Accuracy

5.1 The equipment used to make a coating weight (mass) measurement using XRF typically consists of a radiation source, a detector, and an electronic system to process the detected signal. The sample absorbs radiation from the source and produces fluorescent radiation. The detector detects this radiation, and the electronic system converts it into coating weight (mass) information. Since an X-ray measurement is basically an accumulation of random events, the accumulation time must be long enough to produce statistically acceptable

data. The precision of a coating weight (mass) measurement is determined by the equipment and the data collection time. Without a good calibration curve, however, highly precise equipment cannot produce an accurate result. For example, a very thick coating may produce a very precise X-ray fluorescent signal, but it may be outside the range of the equipment. Therefore, the measurement accuracy depends on the equipment, data collection time, and calibration of the instrument. The environment may also influence the measurement accuracy. Since equipment and coating each have unique characteristics, equipment specifications should be reviewed carefully prior to purchase and installation.

5.2 In order to measure coating weight (mass) accurately, the source must have enough strength to produce fluorescent radiation from the entire sample volume of interest. The sample volume of interest varies, depending on the XRF method used. When the coating weight (mass) is measured using fluorescence from the coating, the sample volume is the entire layer of the coating. When fluorescence from the substrate is used, the sample volume of interest is the lesser of the entire substrate or  $5/\mu$  ( $\mu$  is the absorption coefficient of the substrate for the primary beam energy) thickness of the substrate under the coating. The radiated spot size must be large enough to cover a sample area as described in the procedure (refer to Table 1). The range of coating weight (mass) for which the measuring instrument can be used depends on the strength of the source and the coating composition. If a coating is thicker than  $5/\mu$  ( $\mu$  of the coating for the fluorescent beam energy), XRF produced underneath the  $5/\mu$  thickness cannot emerge from the coating due to absorption. A coating thickness of  $5/\mu$  is defined as the critical thickness. If a coating is very thin, there may not be enough signal from the coating.

5.3 The detector must be able to discriminate between signals originating from the coating and the substrate. When the sample contains elements having similar atomic mass or similar X-ray characteristics, detected signals are difficult to discriminate and the measurement accuracy is affected adversely. The measurement accuracy may also be affected adversely when fluorescence from one element influences fluorescence from another. Equipment capable of measuring XRF from several elements simultaneously, including compensating for variations in coating composition, is required when

**TABLE 1 Control Variables to Define a Single Data Point (Single Spot)**

Variable	Value <sup>A</sup>	
	X-Ray Tube	Isotope
Area of fluorescence	1.5 to 5 in. <sup>2</sup> [970 to 3200 mm <sup>2</sup> ]	5 to 14 in. <sup>2</sup> [3200 to 9000 mm <sup>2</sup> ]
Traverse scan speed (traverse mode)	1 in./s [25 mm/s] min	1 in./s [25 mm/s] min
Dwell time (dwell mode)	4 s max	4 s max
Time constant (X-ray) or averaging time (isotope)	min 2.5 in. [25 mm] travel to allow 3 or more "time constants" to elapse	1 to 4 s

<sup>A</sup> Both X-ray tube and isotope coating weight gages, when used for determining conformance to coating weight (mass) specifications, have diminished accuracy above 1.3 oz/ft<sup>2</sup>/side [400 g/m<sup>2</sup>/side] for zinc coatings, 0.066 oz/ft<sup>2</sup>/side [20 g/m<sup>2</sup>/side] for tin coatings, and 0.82 oz/ft<sup>2</sup>/side [250 g/m<sup>2</sup>/side] for aluminum coatings.

the coating composition is unknown (for example, % Zn in Zn-Al or Zn-Ni coating), or the coating contains elements that are present in the substrate (for example, Zn-Fe coating on Fe), or the coating consists of multiple layers of metal or alloy.

5.4 The required data collection time is determined by the strength of the source, sensitivity of the detector, and coating weight (mass). A stronger source and a more sensitive detector typically require a shorter data collection time. The data collection time shall be long enough to achieve the required precision. For example, if  $N$  is the number of counts detected by a counter in a given time interval, the inherent error in radiation detection is equal to  $1/\sqrt{N}$ . As a guideline, the data collection time should be long enough to record 10 000 counts for a desired precision of  $\pm 1\%$ .

5.5 The calibration of the equipment has a very significant impact on the accuracy of the measurement. The coating composition of the material to be measured must be similar to that of the calibration standard. If the substrate has any influence on the X-ray signals, then both substrates must be similar. Significant differences in surface roughness and coating component segregation may also affect the accuracy of the measurement adversely. The coating weight (mass) range of the standards must exceed that of the material to be measured and must be within the useful range of the equipment.

5.6 Additional precautions are necessary for measurements made on-line or in a mill environment.

5.6.1 *Cleanliness*—The measurement instrument window must be kept clean to avoid any interference with the X-ray signal. A film of mill dust containing metal powder is normally more deleterious than that of oil and moisture.

5.6.2 *Stability*—The equipment should be maintained at a steady temperature to avoid any instability due to temperature. The influence of variations in air temperature in the gap between the instrument and the material on X-ray measurements must be compensated. The gap between the instrument and the sheet must be uniform and within the specifications of the equipment. Excessive variations in coating weight (mass) readings may be the result of variability in the strip pass-line due to such conditions as strip off-flatness (for example, wavy edges).

5.6.3 *Averaging Time*—During an on-line measurement, the equipment must be operated using an averaging time suitable for detecting variations in the coating weight (mass) without affecting measurement accuracy adversely. A very long averaging time will mask variations in the coating, resulting in a misleading indication of average coating weight (mass). A very short averaging time will yield unreliable results. (Refer to Table 1 for acceptable combinations.)

## 6. Calibration

6.1 *General*—When taking instrument readings for the purpose of establishing an instrument calibration, exactly the same instrumental conditions should be used as those that will be used on material being measured. The measuring time for calibration standards may be longer than that on material being measured in order to reduce the effect of statistical fluctuations.

6.2 *Standards*—Reliable standards must be used in the calibration of any type of X-ray equipment if accurate results are to be obtained. It should be understood that prolonged

counting periods will not compensate for unreliable standards. Calibration standards that are certified for weight (mass) per unit area are reliable for coatings that have the same composition. The same density is not necessary for weight (mass) per unit area measurement. Calibration standards should be produced using the same material for coatings and substrates and the same coating technique as the material being measured. When correlating to standard weigh-strip-weigh techniques, great care must be exercised in selecting the sample because the coating is destroyed in the weigh-strip-weigh test procedure. Recommended sampling is to choose a uniform area approximately 9 by 9 in. [230 by 230 mm]. This can be measured by using an XRF instrument to find areas of uniform signal, from which five weigh-strip-weigh samples are cut in a cross-like pattern, wherein the center sample is in line with two other samples in the longitudinal direction and with two other samples in the cross-sheet direction. If chemical determinations of the coating weights (masses) of the four “satellite” samples agree to within 3%, the center sample can be assumed to have a coating weight equal to the average of the four samples and can be considered a good calibration standard. If standards representing a particular type of coating and substrate are not available from any reliable source, their preparation may be undertaken, but only if trained personnel are available.

6.3 A minimum of three standard samples covering the range of coatings to be measured should be used for calibration. In general, more standards should be used than there are parameters in the calibration curve. Errors of interpolation may occur between calibration points because the calibration curve is nonlinear. These errors can be minimized by having many closely spaced calibration points. Extrapolation beyond the range of calibration points may also result in serious errors and should not be tolerated.

6.4 The instrument shall be calibrated with weight (mass) standards having the same coating and substrate materials as those being measured.

6.5 The coating of the calibration standards must have the same X-ray emission (or absorption) properties as the coating being measured. If the coating of the standards is under the same conditions as the coating to be measured, the X-ray properties may be assumed to be the same. If the coating on the standard is the same but not produced under conditions known to be the same as the coating being measured, the X-ray properties may be assumed to be the same for weight (mass) per unit area measurements, provided that the specimen properties discussed in 5.3 are verified to be the same for the standard and the specimen.

6.6 If the weight (mass) is to be determined by the X-ray absorption technique, the substrate of the weight (mass) standards shall have the same X-ray emission properties as that of the specimen. This shall be verified by comparing the intensities of the selected characteristic radiations of both uncoated substrate materials.

6.7 In the X-ray absorption technique, the substrate thickness of the specimen and the calibration standards should be the same unless the critical thickness, as defined in 5.2, is exceeded.

6.8 If the curvature of the coating to be measured is such as to preclude calibration on a flat surface, the curvature of the standard and that of the specimen shall be the same.

**7. Procedure**

7.1 Operate each instrument in accordance with the manufacturer’s instructions, heeding the factors listed in Section 5. Calibrate the instrument in accordance with Section 6.

7.2 *Definition of a Single Data Point*—The instrument shall be operated in a manner that meets the requirements of Table 1.

7.2.1 *Area of Fluorescence*—The coating area fluoresced shall be between 1.5 and 5 in.<sup>2</sup> [970 and 3200 mm<sup>2</sup>] for X-ray tube gages and 5 and 14 in.<sup>2</sup> [3200 and 9000 mm<sup>2</sup>] for isotope gages.

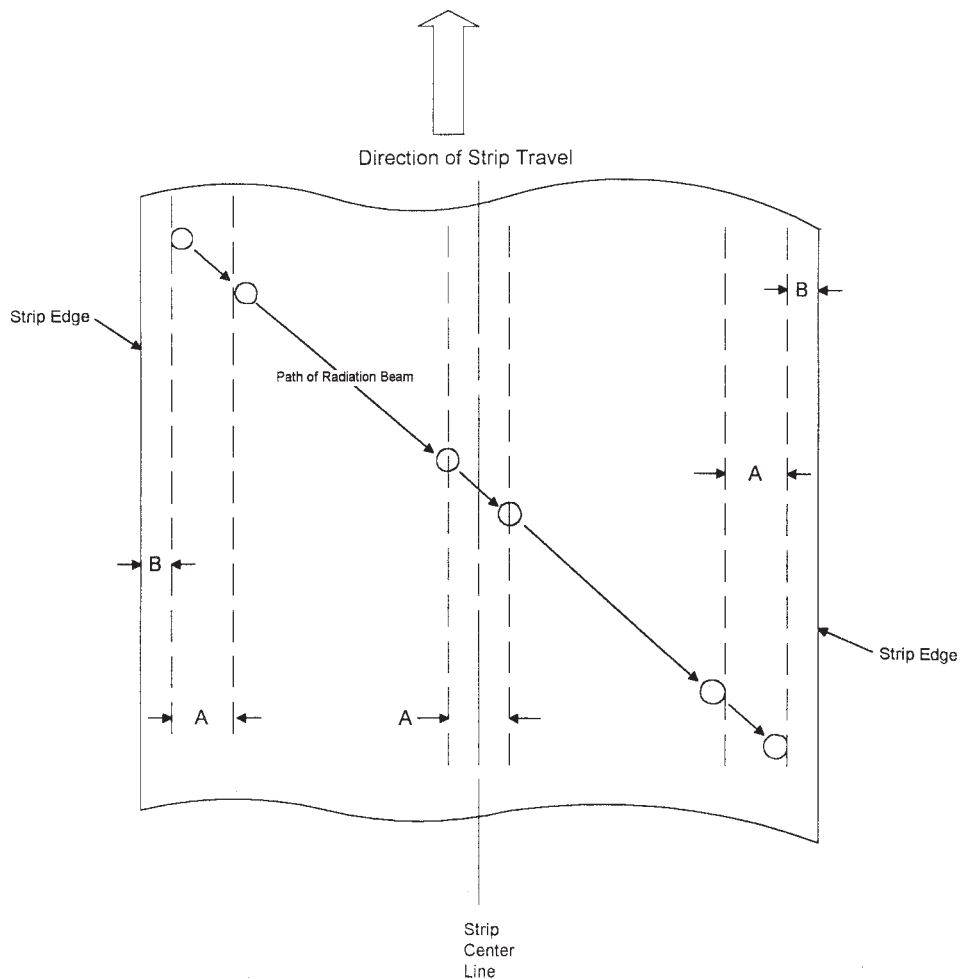
7.2.2 *Traverse Scan Speed*—When the instrument is operated in a traversing mode over a moving strip, the scan speed shall be that speed which will result in less than a 1 % test error, measured over a maximum of 4 in. [100 mm] of strip width (see Fig. 1 for test locations across the strip width), based on a standard test condition. The standard test condition is illustrated in Fig. 2; namely, for a 10 % step in coating weight (mass), the coating weight (mass) value measured and assigned

to the data point shall be the initial value plus a minimum of 90 % of the step value. Conformance to this measurement standard may be determined by calculations based on the time constant being used by the instrument or scan speed or by actual measurement. In no instance shall the traverse scan speed be less than 1 in./s [25 mm/s] nor the elapsed time to determine one data point be longer than 4 s.

7.2.3 *Dwell Time*—When the instrument is operated in the dwell mode, the requirements of the standard test condition of 7.2.2 shall apply and the maximum time used to determine one data point shall be 4 s.

7.3 *Coating Weight (Mass) Sampling Width and Location*—The instrument shall be operated in a manner that meets the requirements of Table 2. The triple spot technique for characterizing coating weight (mass) shall be used and may be acquired in either “scan” or “dwell” mode.

7.3.1 *Sampling Width*—For X-ray gages, the width distance sampled at each of the edge locations by the radiation beam, to obtain a single data point, shall be between 2.5 and 4.0 in. [65 and 100 mm], measured from the outer edges of the beam. The width distance sampled at the center location shall be measured from the center of the beam. In the case of isotope gages, no minimum sampling distance applies, only a maximum of 4 in.



NOTE—(A) Sampling width (2.5 to 4.0 in. [65 to 100 mm]); (B) distance from strip edge (2 in. [50 mm] ± 0.25 in. [6 mm]).

**FIG. 1 Edge, Center, Edge Data Point Locations**

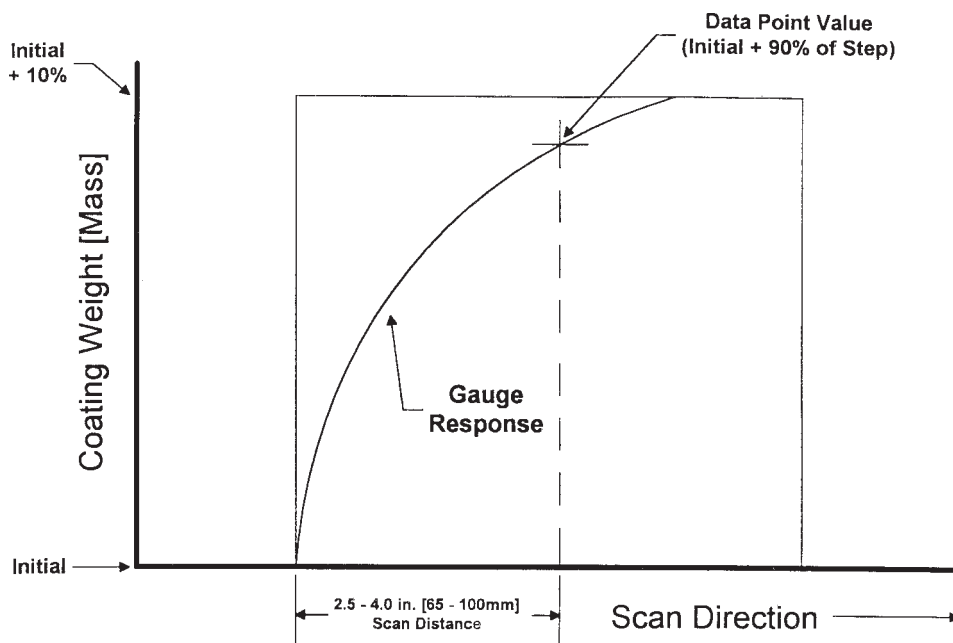


FIG. 2 Gage Response for Standard Test Condition

TABLE 2 Coating Weight (Mass) Sampling Width and Location Specifications

Variable	Value <sup>A</sup>	
Type of Gage	X-Ray Tube	Isotope
Sampling width at Edge	2.5 to 4.0 in.	4.0 in. [100 mm] max
Center Edge positions	[65 to 100 mm]	
Edge readings—distance of beam outer edge from strip edge	2.0 ± 1/4 in. [50 ± 6 mm]	2.0 ± 1/4 in. [50 ± 6 mm]
Center readings—distance from center of strip width	±1 in. [±25 mm]	±1 in. [±25 mm]

<sup>A</sup> Both X-ray tube and isotope coating weight gages, when used for determining conformance to coating weight (mass) specifications, have diminished accuracy above 1.3 oz/ft<sup>2</sup>/side [400 g/m<sup>2</sup>/side] for zinc coatings, 0.066 oz/ft<sup>2</sup>/side [20 g/m<sup>2</sup>/side] for tin coatings, and 0.82 oz/ft<sup>2</sup>/side [250 g/m<sup>2</sup>/side] for aluminum coatings.

[100 mm], with the same sampling locations as for X-ray gages. Refer to Fig. 1 and Table 2.

7.3.2 *Edge Readings*—The outer 2 in. [50 mm] ± 0.25 in. [6 mm] of the strip edges, measured from the outer edge of the

radiation beam, shall not be used for determining coating weight (mass).

7.3.3 *Center Reading*—The midpoint of the center reading shall be within 1 in. [25 mm] of the center of the strip width.

## 8. Precision and Bias

8.1 *Precision*—The precision of the procedure in this test method for “on-line” measurements of coating weight (mass) on steel sheet is being determined.

8.2 *Bias*—Since there is no accepted reference material for determining the bias for the procedure in this test method, bias has not been determined.

## 9. Keywords

9.1 aluminum zinc-coating; coating; coating weight (mass); coatings-metallic; metallic coated; sheet; steel sheet; tin mill products; X-ray fluorescence; zinc coating; zinc-5 % aluminum coating

## APPENDIXES

### (Nonmandatory Information)

#### X1. BASIC PRINCIPLES

X1.1 *Calibration*—There are a number of design parameters unique to each machine and its particular installation or operation practice, or both, that require careful development of calibration curves to establish the correlation between the secondary X-rays being detected and coating weight (mass). Factors that need to be considered include, but are not limited to the following: the apparent absorption coefficient, which

depends on the type of primary radiation and atomic numbers of the coating and substrate, as well as the physical arrangement of the radiation source and detection system; the uniformity of the distance between the specimen and radiation and detection sources; the sample curvature; the lower acceptable limit of the substrate; the effect of very localized coating nonuniformities; and all of the factors that influence the



stability of the X-ray source and detection equipment.

X1.2 *Averaging Time*—Some coating weight (mass) measuring instruments acquire sampling information (“counts”) over a defined period, or averaging time, prior to each update of their output. The “isotope” column of Table 1 establishes the limits when this type of output is used.

X1.3 *Time Constant*—Some coating weight (mass) measuring instruments process their output through an analog filter. The amount of filtering is traditionally quantified by a “time constant.” One time constant is defined as 63 % of the final value when a step input is applied. Refer to Fig. X1.1. The

output approaches 100 % of the input after several time constants. Paragraph 7.2.2 and the “X-ray” column of Table 1 establish the limits when this type of filtering is used.

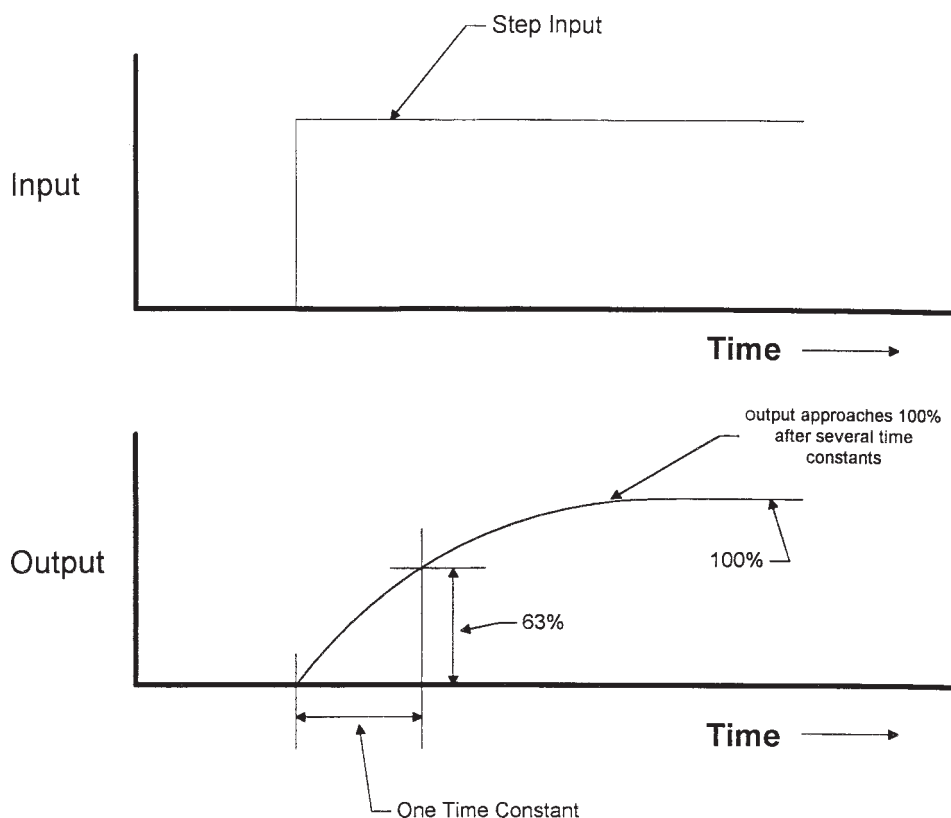


FIG. X1.1 Definition of Time Constant

## X2. WEIGHT (MASS) PER UNIT AREA MEASUREMENTS BY EMISSION OF FLUORESCENT X RAYS OF COATING

X2.1 With this technique, the detection system is set up to count the number of X-rays in an energy region characteristic of X-rays from the coating element. Moreover, a specific, well-defined discrete energy level is usually selected from the various energy levels emitted by the coated element, such as the zinc  $K\alpha$  peak of a zinc (galvanized) coating.

X2.2 If the coating contains more than one element, the detection system is typically set up to count the number of X-rays of a specific energy level from the element that has the highest concentration in the coating. The count rate intensity of the discrete energy level being detected will be at a minimum for a sample of the bare substance, where it consists only of scattered (background) radiation. For a thick sample of the solid coating metal, or for a sample having an “infinite” coating

weight (mass) per unit area, the intensity will have its maximum value for a given set of conditions. For a sample having a coating weight (mass) per unit area less than an infinite weight (mass) per unit area, the intensity will have an intermediate value between the above two end points.

X2.3 In general, the intensity of the emitted secondary X radiation depends on the excitation energy, atomic numbers of the coating and substrate, area of the specimen exposed to the primary radiation, and weight (mass) per unit area of the coating. If all of the other variables are fixed, the intensity of the characteristic secondary radiation is a function of the thickness or weight (mass) per unit of the coating.

X2.4 The exact relationship between the measured intensity

and corresponding coating weight (mass) per unit area must be established by the use of standards having coating and substrate compositions similar to those of the samples to be

measured. In general, the limiting weight (mass) per unit area depends on the atomic number of the coating and the arrangement of the measuring apparatus.

### **X3. WEIGHT (MASS) PER UNIT AREA MEASUREMENTS BY ABSORPTION OF THE FLUORESCENT X-RAYS OF SUBSTRATE**

X3.1 With this technique, the detection system is set up to record the intensity of a selected energy emitted by the substrate material. The intensity will be a maximum for a specimen of the uncoated substrate material and will decrease with increasing coating weight (mass) per unit area. This is because both the exiting and secondary characteristic radiations undergo attenuation in passing through the coating.

X3.2 Depending on the atomic number of the coating, when the coating (mass) per unit area is increased to a certain value, the characteristic radiation of the substrate will disappear, although a certain amount of background radiation will be detected. The measurement of a coating weight (mass) by

X-ray absorption is not applicable if an intermediate coating is present because of the indeterminate absorption effect of the intermediate layer.

X3.3 As for measurement by the emission method, if all of the other variables are fixed, the intensity of the characteristic secondary radiation is a function of the weight (mass) per unit area of the coating.

X3.4 The exact relationship between the measured intensity and corresponding coating weight (mass) must be established by the use of standards having coating and substrate compositions similar to those of the samples to be measured.

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*This standard is subject to revision at any time by the responsible technical committee and must be reviewed every five years and if not revised, either reapproved or withdrawn. Your comments are invited either for revision of this standard or for additional standards and should be addressed to ASTM International Headquarters. Your comments will receive careful consideration at a meeting of the responsible technical committee, which you may attend. If you feel that your comments have not received a fair hearing you should make your views known to the ASTM Committee on Standards, at the address shown below.*

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# Standard Specification for Steel Sheet, Metallic Coated by the Hot-Dip Process and Prepainted by the Coil-Coating Process for Exterior Exposed Building Products<sup>1</sup>

This standard is issued under the fixed designation A 755/A 755M; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reappraisal. A superscript epsilon (ε) indicates an editorial change since the last revision or reappraisal.

*This standard has been approved for use by agencies of the Department of Defense.*

## 1. Scope\*

1.1 This specification covers steel sheet metallic coated by the hot-dip process and coil-coated with organic films for exterior exposed building products. Sheet of this designation is furnished in coils, cut lengths, and formed cut lengths. Building products include corrugated and various types of roll and brake-formed configurations.

1.2 The substrate is available in several different metallic-coated steel sheet products as enumerated in 4.1, depending on the requirements of the purchaser.

1.3 Coating systems supplied under this specification consist of a primer coat covered by various types and thicknesses of top coats. The combination of primer and top coat is classed as either a two-coat thin-film system or as a two-coat (or more) thick-film system. Typical top-coating materials are: polyester, silicone polyester, acrylic, fluoropolymer, plastisol, or polyurethane.

1.4 This specification is applicable to orders in either inch-pound units (as A 755) or SI units [as A 755M]. Values in inch-pound units and SI units are not necessarily equivalent. Within the text, SI units are shown in brackets. Each system shall be used independently of each other.

1.5 Unless the order specifies the “M” designation (SI units) the product shall be furnished to inch-pound units.

1.6 The text of this specification references notes and footnotes that provide explanatory material. These notes and footnotes, excluding those in tables and figures, shall not be considered as requirements of this specification.

1.7 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

## 2. Referenced Documents

### 2.1 ASTM Standards:<sup>2</sup>

- A 463/A 463M Specification for Steel Sheet, Aluminum-Coated, by the Hot-Dip Process
- A 653/A 653M Specification for Steel Sheet, Zinc-Coated (Galvanized) or Zinc-Iron Alloy-Coated (Galvannealed) by the Hot-Dip Process
- A 792/A 792M Specification for Steel Sheet, 55 % Aluminum-Zinc Alloy-Coated by the Hot-Dip Process
- A 875/A 875M Specification for Steel Sheet, Zinc-5 % Aluminum Alloy Coated by the Hot-Dip Process
- A 902 Terminology Relating to Metallic Coated Steel Products
- A 924/A 924M Specification for General Requirements for Steel Sheet, Metallic-Coated by the Hot-Dip Process
- B 117 Practice for Operating Salt Spray (Fog) Apparatus
- D 522 Test Methods for Mandrel Bend Test of Attached Organic Coatings
- D 523 Test Method for Specular Gloss
- D 659 Method for Evaluating Degree of Chalking of Exterior Paints<sup>3</sup>
- D 714 Test Method for Evaluating Degree of Blistering of Paints
- D 822 Practice for Filtered Open-Flame Carbon-Arc Exposures of Paint and Related Coatings
- D 870 Practice for Testing Water Resistance of Coatings Using Water Immersion
- D 1005 Test Method for Measurement of Dry-Film Thickness of Organic Coatings Using Micrometers
- D 1654 Test Method for Evaluation of Painted or Coated Specimens Subjected to Corrosive Environments
- D 1735 Practice for Testing Water Resistance of Coatings Using Water Fog Apparatus

<sup>1</sup> This specification is under the jurisdiction of ASTM Committee A05 on Metallic-Coated Iron and Steel Products and is the direct responsibility of Subcommittee A05.11 on Sheet Specifications.

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<sup>2</sup> For referenced ASTM standards, visit the ASTM website, [www.astm.org](http://www.astm.org), or contact ASTM Customer Service at [service@astm.org](mailto:service@astm.org). For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

<sup>3</sup> Withdrawn.

\*A Summary of Changes section appears at the end of this standard.

- D 2240 Test Method for Rubber Property—Durometer Hardness
- D 2244 Practice for Calculation of Color Tolerances and Color Differences from Instrumentally Measured Color Coordinates
- D 2247 Practice for Testing Water Resistance of Coatings in 100 % Relative Humidity
- D 2370 Test Method for Tensile Properties of Organic Coatings
- D 3359 Test Method for Measuring Adhesion by Tape Test
- D 3363 Test Method for Film Hardness by Pencil Test
- D 4145 Test Method for Coating Flexibility of Prepainted Sheet
- D 4214 Test Methods for Evaluating the Degree of Chalking of Exterior Paint Films
- G 85 Practice for Modified Salt Spray Fog Testing

### 3. Terminology

#### 3.1 Definitions:

3.1.1 *Substrate*—For definitions of terms relating to the substrate, see Terminology A 902.

#### 3.1.2 Coatings:

3.1.2.1 *acrylic, n*—a polymer based on resins prepared from a combination of acrylic and methacrylic esters, acrylic and methacrylic acids, and styrene; they contain one or more functional groups such as amide, hydroxy, or carboxy and form thermosetting systems on baking by cross-linking with themselves, or amino or epoxy resins.

3.1.2.2 *conversion coating, n*—a chemical treatment, normally applied to a metal surface prior to final finishing, which is designed to react with and modify the metal to produce a surface suitable for painting.

3.1.2.3 *epoxy, n*—polymers based on epoxy resins, which are the reaction product of epichlorohydrin and biphenol-A and are cross-linked with amino or urea-formaldehyde resins to form thermosetting systems on baking.

3.1.2.4 *fluorocarbon, n*—polymers based on fluorocarbon resins made by the polymerization of vinyl fluoride monomer (PVF) or vinylidene fluoride monomer (PVF<sub>2</sub>); these resins are formulated into coatings by dispersion of finely divided particles in dispersants and diluents and form thermosetting systems on baking.

3.1.2.5 *plastisol, n*—a dispersion of finely divided vinyl resin in plasticizers; during the baking process, the resin particles are solvated by the plasticizer and fuse into a continuous film.

3.1.2.6 *polyester, n*—a polymer based on the condensation products of polybasic acids and diols (dihydric alcohols), also called oil-alkyds; they are modified by the addition reaction of monomers such as styrene or acrylic esters; polyester resins are cross-linked with amino resins to form thermosetting systems on baking.

3.1.2.7 *polyurethane, n*—a polymer produced by the addition reaction of an acrylic polyol or polyester polyol with an isocyanate-containing compound to produce thermosetting systems on baking.

3.1.2.8 *primer, n*—the first complete layer of paint of a coating system applied to an uncoated surface; the type of primer varies with the type of surface and its condition, the intended purpose, and the coating system being used.

3.1.2.9 *silicone polyester, n*—a polymer which is the reaction product between an organo-siloxane intermediate and an alkyd resin, or a cold blend of a silicone resin and a compatible alkyd resin; these resins are cross-linked with amino resins to form thermosetting systems on baking.

#### 3.1.3 Coating Characteristics:

3.1.3.1 *chalking, v*—the formation on a pigmented coating of a friable powder evolved from the film itself at or just beneath the surface.

3.1.3.2 *fade, v*—a loss in color intensity experienced by pigmented organic coatings over time, generally due to the effect of ultraviolet radiation.

3.1.3.3 *gloss, n*—the luster, shininess, or reflecting ability of a surface.

#### 3.2 Definitions of Terms Specific to This Standard:

3.2.1 *bottom side, n*—the side of prepainted sheet opposite the exposed weathering side.

3.2.2 *coil coating, v*—a continuous process by which paint and other coatings are applied and baked onto a moving strip of steel sheet.

3.2.3 *Discussion*—Rolls are used to pick up, meter, and deposit the liquid coating onto the moving strip and are also used to support the strip through the line. The product of this process is called prepainted steel sheet.

3.2.4 *mil, n*—a unit of length equal to 0.001 in. [25.4 μm], used for describing the thickness of paint coatings.

3.2.5 *paint, n*—of coil coating, an organic liquid, pigmented/nonpigmented, which is converted to a solid film by baking.

3.2.6 *roll former, n*—an apparatus that forms a continuous strip of metal into various shapes by a series of contoured steel rolls.

3.2.7 *top side, n*—the side of the prepainted sheet which is exposed to weathering.

3.2.8 *washcoat, n*—a thin organic coating, usually a polyester, applied to the back or unexposed side of prepainted sheet (also known as a backercoat).

3.2.9 *Discussion*—This pigmented/nonpigmented coating is applied for such reasons as protection of the topcoat while in coil form, interior appearance, and lubrication during roll forming.

### 4. Classification

4.1 The substrate shall conform to all requirements of the appropriate specification for the steel sheet product ordered as follows:

4.1.1 *Zinc-Coated (Galvanized)*—Specification A 653/A 653M.

4.1.2 *Zinc-5 % Aluminum Alloy-Coated*—Specification A 875/A 875M.

4.1.3 *55 % Aluminum-Zinc Alloy-Coated*—Specification A 792/A 792M.

4.1.4 *Aluminum Coated*—Specification A 463/A 463M.

4.1.5 Each of the above-listed metallic-coated sheet specifications describes the range of available coating designations.

The particular designation selected is related to the expected performance of the exterior exposed building product. Although there are exceptions based on the type of environment where the building is erected, the recommended minimum coating mass designations for use in exterior exposed building applications are:

Metallic Coating	Minimum Recommended Coating
A 653/A 653M <i>Zinc-Coated (Galvanized)</i>	G90 [Z275]
A 875/A 875M <i>Zinc-5 % Aluminum Alloy-Coated</i>	GF75 [ZGF225]
A 792/A 792M <i>55 % Aluminum-Zinc Alloy-Coated</i>	AZ50 [AZM150]
A 463/A 463M <i>Aluminum Coated</i>	T2 65 [T2 200]

These minimum coating weight [mass] designations are important to attain the normally expected long-term product life in the application. Exceptions to these minimum designations can be considered when the environmental conditions are of low corrosive potential, such as a very dry climate. In these cases, a lower coating weight [mass], for example, G60 [Z180] may be appropriate. Similarly, for very corrosive environments, the user should consider specifying a coating designation with a heavier coating weight [mass].

4.2 The organic coating typically consists of a primer and a topcoat on the top (exposed) side and washcoat on the bottom (unexposed) side. Typical primers and topcoats are as follows:

4.2.1 *Primers:*

- 4.2.1.1 Epoxy.
- 4.2.1.2 Acrylic.
- 4.2.1.3 Polyurethane.
- 4.2.1.4 Polyester

4.2.2 *Top Coats:*

- 4.2.2.1 Polyester.
- 4.2.2.2 Silicone polyester.
- 4.2.2.3 Acrylic.
- 4.2.2.4 Fluoropolymer.
- 4.2.2.5 Plastisol.
- 4.2.2.6 Polyurethane.

4.2.3 *Washcoats or Backercoats:*

- 4.2.3.1 Polyester.
- 4.2.3.2 Acrylic.

4.3 Other coatings will be specified if agreed upon between the producer and the purchaser (see Note 2).

## 5. Ordering Information

5.1 The coated flat sheet covered by this specification is produced on continuous lines to decimal thickness only. The thickness of the sheet includes the base steel and the metallic coating. The thickness of the organic system is in addition to the substrate (base steel and metallic coating).

5.2 Orders for material under this specification shall include the following information, as applicable, to describe the required product adequately:

- 5.2.1 Product name (prepainted steel sheet),
- 5.2.2 ASTM designation and year of issue, as A 755 – for inch-pound units or A 755M – for SI units,
- 5.2.3 ASTM specification number of metallic coated substrate, steel sheet designation, and, if applicable, type (and grade, if required),
- 5.2.4 Metallic coating type (see 4.1),
- 5.2.5 Metallic coating weight [mass] designation,

5.2.6 Metallic coating finish (such as regular, minimized spangle, extra smooth, or minimized spangle-extra smooth),

5.2.7 Organic coating system designation (see 4.2 or 4.3),

5.2.8 Dry organic film thickness top side and bottom side (the top side will consist of a primer and topcoat and the bottom side will consist of a primer and a washcoat, or the same coating as the topside) (see 7.4.2),

5.2.9 Protection required (waxed or strippable coating),

5.2.10 Dimensions (thickness, width, either flat or formed (overall or cover) and length (if cut length)) and, if applicable, type of formed configuration. The purchaser shall specify the appropriate table of thickness tolerances in Specification A 924/A 924M which applies to the order, that is, the table of thickness tolerances for 3/8-in. [10-mm] edge distance, or the table of thickness tolerances for 1-in. [25- mm] edge distance.

5.2.11 Coil size requirement: maximum outside diameter, acceptable inside diameter, and maximum weight [mass],

5.2.12 Cut length requirement: maximum lift weight [mass],

5.2.13 Special requirements, if any, and

5.2.14 Application (part identification and description).

NOTE 1—A typical ordering description is as follows:

Prepainted steel sheet, ASTM A 755 – \_\_\_ on zinc-coated (galvanized) substrate, ASTM A 653, SS, Grade 40 with G 90 coating, extra smooth, Top Side Primer, 0.25 mil thickness plus Gold Silicone-Polyester, 0.8 mil thickness, Bottom Side Primer, 0.25 mil thickness plus Washcoat, 0.3 mil thickness, 0.019 in. min thickness by 42 in. width by Coil, 24 in. inside diameter, 52 in. max outside diameter, 20 000 pound max weight coil for roll-formed exterior building siding.

[Prepainted steel sheet, ASTM A 755M – \_\_\_ on 55 % aluminum-zinc alloy-coated substrate, ASTM A 792M, CS Type A with AZM150 aluminum-zinc alloy coating, extra smooth, Top Side Primer, 0.006 mm thickness plus White Fluoropolymer, 0.020 mm thickness, Bottom Side Primer, 0.006 mm thickness plus Washcoat, 0.008 mm thickness, 0.80 mm thickness by 1000 mm width by Coil, 600 mm inside diameter, 1320 mm max outside diameter, 4500 kg max coil for roll-formed exterior siding.]

NOTE 2—When specifying the organic coating system designation, instead of using the generic terms listed in 4.2, it is permissible to substitute trade name terminology as published by various coating and prepainted sheet suppliers. These trade name coatings are brand name versions of the generic coatings listed in 4.2 and include a primer and film thickness values.

## 6. Substrate Requirements

6.1 For the purposes of this specification, substrate refers to the steel sheet and metallic coating. The specific requirements for the substrate are contained in the specifications listed in 4.1.

## 7. Organic Coating Requirements

7.1 The application of organic coatings on a continuous coil coating line, when producing products to the requirements of this specification, involves three major steps. These are: the application of a conversion coating, the application of a primer, and the application of one or more topcoats.

7.2 *Conversion Coating*—A conversion coating is a chemical treatment applied to the metal prior to application of the primer. It is designed to react with and modify the metal surface to enable chemical bonding to occur between the metal and the primer thus optimizing adhesion and corrosion resistance.

7.3 *Primer:*

7.3.1 The purpose of the primer is to serve as the bond between the substrate and the topcoat and to offer added corrosion protection for the entire system. For building products, primer thickness is typically 0.2 mil [0.005 mm] (tolerance  $\pm 0.05$  mil [0.001 mm]). Primers with films as thick as 3 mil [0.075 mm] (tolerance  $\pm 0.30$  mil [0.008 mm]) are available for end uses requiring high-performance.

7.3.2 A primer must be compatible with both the conversion coating and the topcoat in order to ensure optimum properties of the coating system. Care must be taken when choosing the primer to obtain the best possible performance for the service environment. For these reasons the primer is specified by the coating supplier or prepainted sheet producer.

7.3.3 See 4.2.1 for examples of typical primers.

**7.4 Topcoat:**

7.4.1 The topcoat provides color and durability and also acts as protection against atmospheric corrosion. Different topcoats are selected based on the performance or appearance requirements desired. For building products, topcoat thickness is nominally 0.8 mil [0.020 mm] (tolerance  $\pm 0.2$  mil [0.005 mm]). High-performance topcoats with films as thick as 12 mil [0.30 mm] (tolerance  $\pm 1.2$  mil [0.03 mm]) are to be specified. Other upgraded systems will specify the application of two or more layers of topcoats.

7.4.2 The topcoat is applied to the top (exposed) side of the sheet and the wash coat or backercoat is applied to the bottom (unexposed) side of the sheet. Upon agreement between the producer and the purchaser, the bottom side will be coated the same as the top side.

7.4.3 See 4.2.2 for examples of typical topcoats.

7.4.4 The selection of a topcoat depends on the performance parameters required such as chalking and fading, plus the corrosion resistance needed, which must take into account the severity of the service environment.

**7.5 Washcoat or Backercoat:**

7.5.1 The washcoat or backercoat is applied to the bottom (unexposed) side of the sheet and is pigmented or not. Its purpose is to provide protection against damage to the top-side coating during shipment and storage and also to provide some additional durability to the unexposed side during the service

life of the product. For building products, washcoat thickness is typically 0.3 mil [0.008 mm] (tolerance  $\pm 0.05$  mil [0.001 mm]).

7.5.2 See 4.2.3 for examples of typical washcoats.

7.6 *Testing Requirements*—The properties of the substrate and the organic coating system, combined with the method of forming, determine the life expectancy and general appearance of the final product. Each coating system has different qualities in regard to gloss, flexibility, fading, chalking, resistance to cracking at bends, abrasion resistance, dirt retention, and resistance to varying atmospheric conditions. All of these factors must be considered in any end application. The test methods used to measure some of these parameters are listed in Annex A1 and are normally considered to be mandatory requirements. The test methods listed in Appendix X1 are used to measure other parameters but are generally considered to be nonmandatory requirements. The specific requirements for each system must be agreed upon between the producer and the purchaser.

**8. Packaging, Marking, and Loading**

8.1 See Specification A 924/A 924M. In addition, coils will be shipped eye vertical to minimize transit abrasion. Roll-formed panels require special packaging. Coil-coated steel is finished material and must be treated as such in handling and storage.

8.2 Proper on-site storage of building panels prior to erection has been found to be important in maintaining the integrity of the coating system. Corrosion failure will result when building panels are not properly protected from water being trapped during storage prior to installation. Pallets must be placed off the ground and at a slight angle for effective drainage. In addition, the use of metal covers or the equivalent is an effective way of keeping pallets dry. Do not use plastic bags to protect the coils or pallets.

**9. Keywords**

9.1 coatings, nonmetallic; coatings, painted; coil-coating process; painted sheet; roofing materials; siding materials; steel sheet

**ANNEX**

**(Mandatory Information)**

**A1. ASTM METHODS FOR TESTING PHYSICAL AND MECHANICAL PROPERTIES OF COIL COATINGS**

A1.1 Requirements for physical and mechanical tests which are mandatory at the time of production are as follows:

Test	ASTM Standard
Elongation of Attached Coating Gloss	D 522 D 523
Color	D 2244
Pencil Hardness	D 3363

Test	ASTM Standard
Dry Film Thickness	...
Solvent Resistance	D 5402
T-Bend	D 4145
Durometer Hardness	D 2240
Tensile Properties	D 2370
Cross Hatch Adhesion	D 3359

**APPENDIX**

**(Nonmandatory Information)**

**X1. ASTM METHODS FOR TESTING THE PERFORMANCE OF COIL COATINGS**

X1.1 Tests for the performance evaluation of coil coatings which are not necessarily mandatory at the time of coating:

Test	ASTM Standard	Test	ASTM Standard
Degree of Blistering	D 714	Weatherometer	D 659
Chalk Resistance	D 4214	Artificial Weathering	D 822
Salt Spray	B 117	Water Immersion	D 870
Modified Salt Spray	G 85, Modified A5	Water Fog	D 1735
		Humidity	D 2247
		Painted Specimens Subjected to Corrosive Environments	D 1654

**SUMMARY OF CHANGES**

Committee A05 has identified the location of selected changes to this standard since the last issue (A 755/A 755M – 01) that may impact the use of this standard.

*A 755/A 755M - 03:*

- (1) In Section 2: deleted reference to NCCA specifications (including footnote 3) and added reference to ASTM standards, D 1005, D 2204, D 2370, D 3359, D 4145, D 4214, and G 85.
- (2) In paragraph 4.2.1: added 4.2.1.4 Polyester.
- (3) In paragraph 5.2.14: changed AZM180 to AZM150.
- (4) In paragraph 7.3.1: changed “High performance primers” to “Primers” and “to be specified” to “available for end uses

requiring high-performance.”

- (5) In paragraph 7.3.2: added “Care must be taken when choosing the primer to obtain the best possible performance for the service environment.”
- (6) In Annex A1: deleted NCCA test and added applicable ASTM tests from Section 2.
- (7) In Appendix X1: added G 85 Method A5.
- (8) Added Summary of Changes section.

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Designation: A 760/A 760M – 01a

American Association State Highway  
and Transportation Officials Standard  
AASHTO No. M 36/M 36M

# Standard Specification for Corrugated Steel Pipe, Metallic-Coated for Sewers and Drains<sup>1</sup>

This standard is issued under the fixed designation A 760/A 760M; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon ( $\epsilon$ ) indicates an editorial change since the last revision or reapproval.

*This standard has been approved for use by agencies of the Department of Defense.*

## 1. Scope

1.1 This specification covers corrugated steel pipe intended for use for storm water drainage, underdrains, the construction of culverts, and similar uses. Pipe covered by this specification is not normally used for the conveyance of sanitary or industrial wastes. The steel sheet used in fabrication of the pipe has a protective metallic coating of zinc (galvanizing), aluminum, 55 % aluminum-zinc alloy, or zinc-5 % aluminum-mischmetal alloy.

1.1.1 Steel sheet with zinc and aramid fiber composite coating may be specified for fabrication of pipe. Pipe made from sheet with this composite coating is always furnished with an asphalt coating. Therefore, the requirements in this specification should be considered as applying to a semifinished pipe; the finished pipe must include provisions of Specification A 849.

NOTE 1—Pipe fabricated with zinc and aramid fiber composite coated sheet and asphalt post coating may be used for sanitary sewers and industrial applications. Petroleum products or similar materials in the sewer effluent may affect the performance of the asphalt coating.

1.2 The several different metallic coatings may not provide equal protection of the base metal against corrosion or abrasion in all environments, or both. Some environments may be so severe that none of the metallic coatings included in this specification will provide adequate protection. Additional protection for corrugated steel pipe can be provided by use of coatings applied after fabrication of the pipe as described in Specification A 849, or by use of polymer precoated corrugated steel pipe as described in Specification A 762/A 762M.

1.3 This specification does not include requirements for bedding, backfill, or the relationship between earth cover load and sheet thickness of the pipe. Experience has shown that the successful performance of this product depends upon the proper selection of sheet thickness, type of bedding and backfill, controlled manufacture in the plant, and care in the installation. The installation procedure is described in Practice A 798.

1.4 This specification is applicable to orders in either inch-pound units as A 760 or in SI units as A 760M. Inch-pound units and SI units are not necessarily equivalent. SI units are shown in brackets in the text for clarity, but they are the applicable values when the material is ordered to A 760M.

## 2. Referenced Documents

### 2.1 ASTM Standards:

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<sup>1</sup> This specification is under the jurisdiction of ASTM Committee A05 on Metallic-Coated Iron and Steel Products and is the direct responsibility of Subcommittee A05.17 on Corrugated Steel Pipe Specifications.

Current edition approved ~~April~~ October 10, 2001. Published ~~June~~ December 2001. Originally published as A 760 – 79. Last previous edition A 760/A 760M – 001.



- A 90/A 90M Test Method for Weight [Mass] of Coating on Iron and Steel Articles with Zinc or Zinc-Alloy Coatings<sup>2</sup>
- A 153/A 153M Specification for Zinc Coating (Hot-Dip) on Iron and Steel Hardware<sup>2</sup>
- A 307 Specification for Carbon Steel Bolts and Studs, 60 000 psi Tensile Strength<sup>3</sup>
- A 428/A 428M Test Method for Weight of Coating on Aluminum-Coated Iron or Steel Articles<sup>2</sup>
- A 449 Specification for Quenched and Tempered Steel Bolts and Studs<sup>3</sup>
- A 563 Specification for Carbon and Alloy Steel Nuts<sup>3</sup>
- A 563M Specification for Carbon and Alloy Steel Nuts [Metric]<sup>3</sup>
- A 762/A 762M Specification for Corrugated Steel Pipe, Polymer Precoated for Sewers and Drains<sup>2</sup>
- A 780 Practice for Repair of Damaged and Uncoated Areas of Hot-Dip Galvanized Coatings<sup>2</sup>
- A 796/A 796M Practice for Structural Design of Corrugated Steel Pipe, Pipe-Arches, and Arches for Storm and Sanitary Sewers and Other Buried Applications<sup>2</sup>
- A 798/A 798M Practice for Installing Factory-Made Corrugated Steel Pipe for Sewers and Other Applications<sup>2</sup>
- A 849 Specification for Post-Applied Coatings, Pavings, and Linings for Corrugated Steel Sewer and Drainage Pipe<sup>2</sup>
- A 885/A 885M Specification for Steel Sheet, Zinc and Aramid Fiber Composite Coated for Corrugated Steel Sewer, Culvert, and Underdrain Pipe<sup>2</sup>
- A 929/A 929M Specification for Steel Sheet, Metallic-Coated by the Hot-Dip Process for Corrugated Steel Pipe<sup>2</sup>
- B 633 Specification for Electrodeposited Coatings of Zinc on Iron and Steel<sup>4</sup>
- B 695 Specification for Coatings of Zinc Mechanically Deposited on Iron and Steel<sup>4</sup>
- C 443 Specification for Joints for Circular Concrete Sewer and Culvert Pipe, Using Rubber Gaskets<sup>5</sup>
- C 443M Specification for Joints for Circular Concrete Sewer and Culvert Pipe, Using Rubber Gaskets [Metric]<sup>5</sup>
- D 1056 Specification for Flexible Cellular Materials— Sponge or Expanded Rubber<sup>6</sup>
- F 568M Specification for Carbon and Alloy Steel Externally Threaded Metric Fasteners<sup>3</sup>
- 2.2 *AASHTO Standards:*
- T241 Test for Helical Continuous Welded Seam Corrugated Steel Pipe<sup>7</sup>
- T249 Test for Helical Lock Seam Corrugated Pipe<sup>7</sup>

### 3. Terminology

#### 3.1 *Definitions of Terms Specific to This Standard:*

- 3.1.1 *fabricator*—the producer of the pipe.
- 3.1.2 *manufacturer*—the producer of the sheet.
- 3.1.3 *minimized coating structure*— a coating characterized by a finer metallurgical coating structure obtained by a treatment designed to restrict the formation of the normal coarse-grain structure formed during solidification of the Zn-5 Al-MM alloy coating.
- 3.1.4 *purchaser*—the purchaser of the finished product.
- 3.1.5 *regular coating structure*— the normal coating structure resulting from unrestricted grain growth during normal solidification of the Zn-5 Al-MM alloy coating.

#### 3.2 *Abbreviations:*

- 3.2.1 *55 Al-Zn*—55 % aluminum-zinc.
- 3.2.2 *MM*—mischmetal.
- 3.2.3 *Zn-5 Al-MM*—zinc-5 % aluminum-mischmetal.

### 4. Classification

- 4.1 The corrugated steel pipe covered by this specification is classified as follows:
- 4.1.1 *Type I*—This pipe shall have a full circular cross section, with a single thickness of corrugated sheet, fabricated with annular (circumferential) or helical corrugations.
- 4.1.2 *Type IA*—This pipe shall have a full circular cross section, with an outer shell of corrugated sheet and an inner liner of smooth (uncorrugated) sheet, fabricated with helical corrugations and lock seams.
- 4.1.3 *Type IR*—This pipe shall have a full circular cross section with a single thickness of smooth sheet, fabricated with helical ribs projecting outwardly.
- 4.1.4 *Type II*—This pipe shall be a Type I pipe which has been reformed into a pipe-arch, having an approximately flat bottom.
- 4.1.5 *Type IIA*—This pipe shall be a Type IA pipe which has been reformed into a pipe-arch, having an approximately flat bottom.

<sup>2</sup> *Annual Book of ASTM Standards*, Vol 01.06.

<sup>3</sup> *Annual Book of ASTM Standards*, Vol 01.08.

<sup>4</sup> *Annual Book of ASTM Standards*, Vol 02.05.

<sup>5</sup> *Annual Book of ASTM Standards*, Vol 04.05.

<sup>6</sup> *Annual Book of ASTM Standards*, Vol 08.01.

<sup>7</sup> Available from American Association of State Highway and Transportation Officials, 444 N. Capitol, Washington DC 20001.

4.1.6 *Type IIR*—This pipe shall be a Type IR pipe which has been reformed into a pipe-arch, having an approximately flat bottom.

4.1.7 *Type III*—This pipe, intended for use as underdrains or for underground disposal of water, shall be a Type I pipe which has been perforated to permit the inflow or outflow of water.

4.1.8 *Type IIIA*—This pipe, intended for use as underdrains, shall consist of a semicircular cross section, having a smooth (uncorrugated) bottom with a corrugated top shield.

4.2 Perforations in Type III pipe are included in three classes as described in 8.3.2.

4.3 Zn-5 Al-MM alloy-coated material is available in two coating classes, or structures, as follows:

4.3.1 *Class A*—Minimized coating structure.

4.3.2 *Class B*—Regular coating structure.

## 5. Ordering Information

5.1 Orders for material to this specification shall include the following information as necessary, to adequately describe the desired product.

5.1.1 Name of material (corrugated steel pipe),

5.1.2 Type of metallic coating (zinc, aluminum, 55 Al-Zn alloy, Zn-5 Al-MM alloy, or zinc and aramid fiber composite coating (see 6.1)).

5.1.2.1 For Zn-5Al-MM coating, the class coating structure (Class A minimized, etc.) (4.3).

5.1.3 ASTM designation and year of issue, as A 760-\_\_\_\_\_ for inch-pound units or as A 760M-\_\_\_\_\_ for SI units.

5.1.4 Type of pipe (4.1),

5.1.5 Diameter of circular pipe (Table 1), or span and rise of pipe-arch section (Tables 2-9),

5.1.6 Length, either total length or length of each piece and number of pieces,

5.1.7 Description of corrugations (7.2),

5.1.8 Sheet thickness (8.1.2),

5.1.9 For Type I and Type II pipe, the pipe fabrication method, whether with annular corrugations or helical corrugations (see 7.1.1),

NOTE 2—Pipe with annular corrugations with spot welded or riveted seams is designed by different criteria compared to pipe with helical corrugations.

**TABLE 1 Pipe Sizes**

Nominal Inside Diameter		Corrugation Sizes <sup>A</sup>							Ribbed Pipe			Minimum Outside Circumference <sup>B</sup>	
in.	mm	1½ by ¼ in.	2¾ by ½ in.	3 by 1 in.	5 by 1 in.	¾ by ¾ by 7½ in.	¾ by 1 by 11½ in.	¾ by 1 by 8½ in.	in.	mm			
4	100	X							11.4	264			
6	150	X							17.7	441			
8	200	X							24.0	598			
10	250	X							30.2	755			
12	300	X	X						36.5	912			
15	375	X	X						46.0	1148			
18	450	X	X			X		X	55.4	1383			
21	500		X			X		X	64.8	1620			
24	600	X	X			X		X	74.2	1854			
27	675		X			X		X	83.6	2091			
30	750		X			X		X	93.1	2483			
33	825		X			X		X	102.5	2561			
36	900		X	X	X	X		X	111.9	2797			
42	1050		X	X	X	X		X	130.8	3269			
48	1200		X	X	X	X		X	149.6	3739			
54	1350		X	X	X	X		X	168.4	4209			
60	1500		X	X	X	X		X	187.0	4675			
66	1650		X	X	X	X		X	205.7	5142			
72	1800		X	X	X	X		X	224.3	5609			
78	1950		X	X	X	X		X	243.0	6075			
84	2100		X	X	X	X		X	261.7	6542			
90	2250			X	X	X		X	280.3	7008			
96	2400			X	X	X		X	299.0	7475			
102	2550			X	X	X		X	317.6	7941			
108	2700			X	X	X	X		336.3	8408			
114	2850			X	X	X		X	355.0	8874			
120	3000			X	X	X		X	373.6	9341			
126	3150			X	X			X	392.3	9807			
132	3300			X	X			X	410.9	10274			
138	3450			X	X			X	429.6	10740			
144	3600			X	X			X	448.3	11207			

<sup>A</sup>An "X" indicates standard corrugation sizes for each nominal diameter of pipe.

<sup>B</sup>Measured in valley of annular corrugations. Not applicable to helically corrugated pipe.

**TABLE 2 Pipe Arch Requirements—2<sup>2</sup>/<sub>3</sub> by 1/2-in. Corrugations (A 760)**

Pipe Arch Size, in.	Equivalent Diameter, in.	Span, <sup>A</sup> in.	Rise, <sup>A</sup> in.	Minimum Corner Radius, in.	Maximum B, <sup>B</sup> in.
17 by 13	15	17	13	3	5¼
21 by 15	18	21	15	3	6
24 by 18	21	24	18	3	7¼
28 by 20	24	28	20	3	8
35 by 24	30	35	24	3	9½
42 by 29	36	42	29	3½	10½
49 by 33	42	49	33	4	11½
57 by 38	48	57	38	5	13½
64 by 43	54	64	43	6	15
71 by 47	60	71	47	7	16½
77 by 52	66	77	52	8	18
83 by 57	72	83	57	9	20

<sup>A</sup> A tolerance of ±1 in. or 2 % of equivalent diameter, whichever is greater, is permissible in span and rise.

<sup>B</sup> B is defined as the vertical dimension from a horizontal line across the widest portion of the arch to the lowest portion of the base.

**TABLE 3 Pipe Arch Requirements—68 by 13-mm Corrugations [A 760M]**

Pipe Arch Size, mm	Equivalent Diameter, mm	Span, <sup>A</sup> mm	Rise, <sup>A</sup> mm	Minimum Corner Radius, mm	Maximum B, <sup>B</sup> mm
430 by 330	375	430	330	75	135
530 by 380	450	530	380	75	155
610 by 460	525	610	460	75	185
710 by 510	600	710	510	75	205
780 by 560	675	780	560	75	225
885 by 610	750	870	630	75	240
970 by 690	825	970	690	75	255
1060 by 740	900	1060	740	90	265
1240 by 840	1050	1240	840	100	290
1440 by 970	1200	1440	970	130	345
1620 by 1100	1350	1620	1100	155	380
1800 by 1200	1500	1800	1200	180	420
1950 by 1320	1650	1950	1320	205	460
2100 by 1450	1800	2100	1450	230	510

<sup>A</sup> A tolerance of ±25 mm or 2 % of equivalent diameter, whichever is greater, is permissible in span and rise.

<sup>B</sup> B is defined as the vertical dimension from a horizontal line across the widest portion of the arch to the lowest portion of the base.

Pipe with annular corrugations must consider seam strength. Therefore, consideration of the method of fabrication is important when pipe is installed under certain conditions of loading.

5.1.10 When zinc and aramid fiber composite coated sheet is used for fabrication of pipe, the type of asphalt coating (1.1.1 and 8.5),

NOTE 3—See Specification A 849 for additional ordering information appropriate to post-coatings on pipe.

5.1.11 Joining systems, including the type of joint from 9.1 and gasket, if required (If no joining system is specified, the fabricator shall select the system.),

5.1.12 For Type III pipe, class of perforations, if other than Class 1 (8.3.2),

5.1.13 Certification, if required (14.1), and

5.1.14 Special requirements.

## 6. Materials and Manufacture

6.1 *Steel Sheet for Pipe*—All pipe fabricated under this specification shall be formed from zinc-coated sheet, aluminum-coated sheet, 55 % aluminum-zinc alloy-coated sheet, zinc-5 % aluminum-mischmetal alloy-coated sheet all conforming to Specification A 929/A 929M, or zinc and aramid fiber composite coated sheet conforming to Specification A 885. If the type of metallic coating is not stated in the order, zinc-coated sheet conforming to Specification A 929/A 929M shall be used. All pipe furnished on the order shall have the same metallic coating, unless otherwise specified.

6.2 *Steel Sheet for Coupling Bands*—The sheet used in fabricating coupling bands shall have the same coating and shall conform to the same specification listed in 6.1 as that used for fabrication of the pipe furnished under the order.

6.3 *Rivets*—The rivets used in riveted pipe shall be of the same material as the base metal specified for the corrugated sheets.

**TABLE 4 Pipe Arch Requirements—3 by 1-in. or 5 by 1-in. Corrugations (A 760)**

Pipe Arch Size, in.	Equivalent Diameter, in.	Span, <sup>A</sup> in.	Rise, <sup>A</sup> in.	Minimum Corner Radius, in.
40 by 31	36	40 – 1.8	31 + 1.8	5
46 by 36	42	46 – 2.1	36 + 2.1	6
53 by 41	48	53 – 2.4	41 + 2.4	7
60 by 46	54	60 – 2.7	46 + 2.7	8
66 by 51	60	66 – 3.0	51 + 3.0	9
73 by 55	66	73 – 3.3	55 + 3.3	12
81 by 59	72	81 – 3.6	59 + 3.6	14
87 by 63	78	87 – 4.4	63 + 4.4	14
95 by 67	84	95 – 4.8	67 + 4.8	16
103 by 71	90	103 – 5.2	71 + 5.2	16
112 by 75	96	112 – 5.6	75 + 5.6	18
117 by 79	102	117 – 5.9	79 + 5.9	18
128 by 83	108	128 – 6.4	83 + 6.4	18
137 by 87	114	137 – 6.9	87 + 6.9	18
142 by 91	120	142 – 7.1	91 + 7.1	18

<sup>A</sup> Negative and positive numbers listed with span and rise dimensions are negative and positive tolerances, no tolerance in opposite direction.

**TABLE 5 Pipe Arch Requirements—75 by 25-mm or 125 by 25-mm Corrugations [A 760M]**

Pipe Arch Size, mm	Equivalent Diameter, mm	Span, <sup>A</sup> mm	Rise, <sup>A</sup> mm	Minimum Corner Radius, mm
1010 by 790	900	1010 – 45	790 + 45	130
1160 by 920	1050	1160 – 55	920 + 55	155
1340 by 1050	1200	1340 – 60	1050 + 60	180
1520 by 1170	1350	1520 – 70	1170 + 70	205
1670 by 1300	1500	1670 – 75	1300 + 75	230
1850 by 1400	1650	1850 – 85	1400 + 85	305
2050 by 1500	1800	2050 – 95	1500 + 95	355
2200 by 1620	1950	2200 – 110	1620 + 110	355
2400 by 1720	2100	2400 – 120	1720 + 120	410
2600 by 1820	2250	2600 – 130	1820 + 130	410
2840 by 1920	2400	2840 – 145	1920 + 145	460
2970 by 2020	2550	2970 – 150	2020 + 150	460
3240 by 2120	2700	3240 – 165	2120 + 165	460
3470 by 2220	2850	3470 – 175	2220 + 175	460
3600 by 2320	3000	3600 – 180	2320 + 180	460

<sup>A</sup> Negative and positive numbers listed with span and rise dimensions are negative and positive tolerances, no tolerance in opposite direction.

They shall be thoroughly galvanized or sherardized. If bolts and nuts are substituted for rivets (see 7.3.1), they shall meet the following requirements:

For A 760 pipe <del>For A 760M pipe</del> For A 760M pipe	Bolts A 449	Nuts A 563, Grade C
-----------------------------------------------------------------	----------------	------------------------

The bolts and nuts shall be hot-dip galvanized in conformance with Specification A 153, or be mechanically galvanized in conformance with Specification B 695, Class 40.

6.4 *Hardware for Joining Systems*—Bolts and nuts for coupling bands shall conform to the following requirements:

For A 760 pipe <del>For A 760M pipe</del> For A 760M pipe	Bolts A 307	Nuts A 563, Grade A
-----------------------------------------------------------------	----------------	------------------------

6.4.1 Bolts, nuts, and other threaded items used with joining systems shall be zinc coated by one of the following processes: hot-dip process as provided in Specification A 153/A 153M; electroplating process as provided in Specification B 633, Class Fe/Zn 8; or mechanical process as provided in Specification B 695, Class 8. Other hardware items used with coupling bands shall be zinc coated by one of the following processes: hot-dip process as provided in Specification A 153/A 153M; electroplating process as provided in Specification B 633, Class Fe/Zn 25; or mechanical process as provided in Specification B 695, Class 25.

6.5 *Gaskets*—If gaskets are used in joining systems, they shall be a band of expanded rubber meeting the requirements of Specification D 1056 for the “RE” closed-cell grades, or O-rings meeting the requirements of Specification C 443 [C 443M].

**TABLE 6 Pipe-Arch Requirements— $\frac{3}{4}$  by  $\frac{3}{4}$  by  $7\frac{1}{2}$ -in. Rib Corrugation**

Pipe-Arch Size, in.	Equivalent Diameter, in.	Span, <sup>A</sup> in.	Rise, <sup>A</sup> in.	Minimum Corner Radius, in.
20 by 16	18	20 – 1.0	16 + 1.0	5
23 by 19	21	23 – 1.0	19 + 1.0	5
27 by 21	24	27 – 1.5	21 + 1.5	5
33 by 26	30	33 – 1.5	26 + 1.5	5
40 by 31	36	40 – 1.8	31 + 1.8	5
46 by 36	42	46 – 2.1	36 + 2.1	6
53 by 41	48	53 – 2.4	41 + 2.4	7
60 by 46	54	60 – 2.7	46 + 2.7	8
66 by 51	60	66 – 3.0	51 + 3.0	9
73 by 55	66	73 – 3.3	55 + 3.3	12
81 by 59	72	81 – 3.6	59 + 3.6	14
87 by 63	78	87 – 3.9	63 + 3.9	14
95 by 67	84	95 – 4.2	67 + 4.2	16
103 by 71	90	103 – 4.5	71 + 4.5	16
112 by 75	96	112 – 4.8	75 + 4.8	18
117 by 79	102	117 – 5.1	79 + 5.1	18

<sup>A</sup>Negative and positive numbers listed with span and rise dimensions are negative and positive tolerances; no tolerance in opposite direction.

**TABLE 7 Pipe-Arch Requirements—19 by 19 by 190-mm Rib Corrugation**

Pipe-Arch Size, mm	Equivalent Diameter, mm	Span, <sup>A</sup> mm	Rise, <sup>A</sup> mm	Minimum Corner Radius, mm
500 by 410	450	500 – 25	410 + 25	130
580 by 490	525	580 – 25	490 + 25	130
680 by 540	600	680 – 40	540 + 40	130
750 by 620	675	750 – 40	620 + 40	130
830 by 670	750	830 – 40	670 + 40	130
900 by 750	825	900 – 45	750 + 45	130
1010 by 790	900	1010 – 45	790 + 45	130
1160 by 920	1050	1160 – 55	920 + 55	155
1340 by 1050	1200	1340 – 60	1050 + 60	180
1520 by 1170	1350	1520 – 70	1170 + 70	205
1670 by 1300	1500	1670 – 75	1300 + 75	230
1850 by 1400	1650	1850 – 85	1400 + 85	305
2050 by 1500	1800	2050 – 90	1500 + 90	355
2200 by 1620	1950	2200 – 100	1620 + 100	355
2400 by 1720	2100	2400 – 105	1720 + 105	410
2600 by 1820	2250	2600 – 115	1820 + 115	410
2840 by 1920	2400	2840 – 120	1880 + 120	450
2920 by 1980	2550	2920 – 130	1980 + 130	450

<sup>A</sup>Negative and positive numbers listed with span and rise dimensions are negative and positive tolerances; no tolerance in opposite direction.

**TABLE 8 Pipe Arch Requirements— $\frac{3}{4}$  by 1 by  $11\frac{1}{2}$ -in. Rib Corrugation**

Pipe Arch Size, in.	Equivalent Diameter, in.	Span, <sup>A</sup> in.	Rise, <sup>A</sup> in.	Minimum Corner Radius, in.
20 by 16	18	20 – 1.0	16 + 1.0	5
23 by 19	21	23 – 1.0	19 + 1.0	5
27 by 21	24	27 – 1.5	21 + 1.5	5
33 by 26	30	33 – 1.5	26 + 1.5	5
40 by 31	36	40 – 1.8	31 + 1.8	5
46 by 36	42	46 – 2.1	36 + 2.1	6
53 by 41	48	53 – 2.4	41 + 2.4	7
60 by 46	54	60 – 2.7	46 + 2.7	8
66 by 51	60	66 – 3.0	51 + 3.0	9

<sup>A</sup>Negative and positive numbers listed with span and rise dimensions are negative and positive tolerances, no tolerance in opposite direction.

## 7. Fabrication

7.1 *General Requirements*—Pipe shall be fabricated in full circular cross section except for Type IIIA pipe which is described in 8.4.

**TABLE 9 Pipe Arch Requirements—19 by 25 by 292-mm Rib  
Corrugation**

Pipe Arch Size, mm	Equivalent Diameter, mm	Span, <sup>A</sup> mm	Rise, <sup>A</sup> mm	Minimum Corner Radius, mm
500 by 410	450	500– 25	410 + 25	130
580 by 490	525	580– 25	490 + 25	130
680 by 540	600	680– 40	540 + 40	130
750 by 620	675	750– 40	620 + 40	130
830 by 670	750	830– 40	670 + 40	130
900 by 750	825	900– 45	750 + 45	130
1010 by 790	900	1010 – 45	790 + 45	130
1160 by 920	1050	1160 – 55	920 + 55	155
1340 by 1050	1200	1340 – 60	1050 + 60	180
1520 by 1170	1350	1520 – 70	1170 + 70	205
1670 by 1300	1500	1670 – 75	1300 + 75	230
1850 by 1400	1650	1850 – 85	1400 + 85	305
2050 by 1500	1800	2050 – 95	1500 + 95	355

<sup>A</sup> Negative and positive numbers listed with span and rise dimensions are negative and positive tolerances, no tolerance in opposite direction.

7.1.1 Type I pipe shall have annular corrugations with lap joints fastened with rivets or resistance spot welds, or shall have helical corrugations with a continuous lock seam or welded seam extending from end to end of each length of pipe. The type of fabrication used shall be the option of the fabricator unless otherwise specified, except that pipe fabricated from zinc and aramid fiber composite-coated sheet shall be fabricated by riveted or lock seam fabrication only.

7.1.2 Type IA pipe shall be fabricated with a smooth liner and helically corrugated shell integrally attached at helical lock seams extending from end to end of each length of pipe. The shell shall have corrugations of nominal 2⅔ or 3-in. [68 or 75-mm] pitch. Zinc and aramid fiber composite-coated sheet shall not be used for fabrication of Type IA pipe.

7.1.3 Type IR pipe shall be fabricated with helical ribs projecting outward with a continuous lock seam extending from end to end of each length of pipe.

7.2 *Corrugations*—The corrugations shall be either annular or helical as provided in 7.1. The direction of the crests and valleys of helical corrugations shall not be less than 60° from the axis of the pipe for pipe diameters larger than 21 in. [525 mm], and not less than 45° from the axis for pipe diameters of 21 in. [525 mm] and smaller.

7.2.1 For Type I and IA pipe, corrugations shall form smooth continuous curves and tangents. The dimensions of the corrugations shall be in accordance with Table 10 for the size indicated in the order, except if the depth measurement of one or more corrugations is less than the minimum depth in Table 10. Then the depth of all corrugations between adjacent seams shall be measured and the values of Table 11 for minimum average depth and minimum corrugation depth shall apply.

NOTE 4—Inspection frequently consists of measurement of the depth of one or a few corrugations. If such measurement indicates insufficient depth, application of the requirements in Table 11 provide for acceptance where greater depth of some corrugations compensates for lack of depth of others. These measurements would normally be made at one location between seams on a length of pipe.

**TABLE 10 Corrugation Requirements for Types I, IA, II, IIA, and III Pipe**

Nominal Size	Maximum Pitch <sup>A</sup>	Minimum Depth <sup>B</sup>	Inside Radius <sup>C</sup>	
			Nominal	Minimum
inches				
1½ by ¼ <sup>D</sup>	1⅞	0.24	⅜	0.25
2⅔ by ½	2⅞	0.48	1⅛	0.5
3 by 1	3¼	0.95	⅝	0.5
5 by 1	5⅝	0.95	1.57	1.4
millimetres				
38 by 6.5 <sup>D</sup>	48	6.0	7	6.5
68 by 13	73	12	17	12
75 by 25	83	24	14	12
125 by 25	135	24	40	36

<sup>A</sup> Pitch is measured from crest to crest of corrugations, at 90° to the direction of the corrugations.

<sup>B</sup> Depth is measured as the vertical distance from a straightedge resting on the corrugation crests parallel to the axis of the pipe to the bottom of the intervening valley. If the depth measurement of one or more corrugations is less than the value indicated herein, the depth of all corrugations between seams shall be measured, and the requirements of Table 11 shall be applied (see 7.2.1).

<sup>C</sup> Minimum inside radius requirement does not apply to a corrugation containing a helical lock seam.

<sup>D</sup> The corrugation size of 1½ by ¼ in. (38 by 6.5 mm) is available only in helically corrugated pipe.

**TABLE 11 Referee Requirements for Corrugation Depth<sup>A</sup>**

Nominal Size	Diameter	Minimum Average	Minimum
		Depth	Corrugation Depth
inches			
1½ by ¼	all	0.24	0.20
2¾ by ½	12 through 21	0.48	0.40
2¾ by ½	over 21	0.49	0.44
3 by 1	all	0.98	0.92
5 by 1	all	0.98	0.92
millimetres			
38 by 6.5	all	6.1	5
68 by 13	300 through 525	12.1	10
68 by 13	over 525	12.4	11
75 by 25	all	24.9	23
125 by 25	all	24.9	23

<sup>A</sup> See 7.2.1 for application of Table 11.

7.2.2 For Type IR pipe, the corrugations shall be essentially rectangular ribs projecting outward from the pipe wall. The dimensions and spacing of the ribs shall be in accordance with Table 12 for the size indicated on the order. For the 11.5-in. [292-mm] rib spacing, if the sheet between the ribs does not include a lock seam, a stiffener shall be included midway between ribs. This stiffener shall have a nominal radius of 0.25 in. [6.4 mm] and a minimum height of 0.20 in. [5.1 mm] toward the outside of the pipe.

NOTE 5—The nominal dimensions and properties for smooth corrugations and for ribs are given in Practice A 796/A 796M.

7.3 *Riveted Seams*—The longitudinal seams shall be staggered to the extent that no more than three thicknesses of sheet are fastened by any rivet. Pipe to be reformed into pipe-arch shape shall have seams meeting the longitudinal seam requirement of 8.2.2.

NOTE 6—Fabrication of pipe without longitudinal seams in 120° of arc, so that the pipe may be installed without longitudinal seams in the invert, is subject to negotiation between the purchaser and the fabricator.

7.3.1 The size of rivets, number per corrugation, and width of lap at the longitudinal seam shall be as stated in Table 13, depending on sheet thickness, corrugation size, and diameter of pipe. For pipe with 1-in. [25-mm] deep corrugations, ½ -in. [metric M12] diameter bolts and nuts may be used instead of rivets on a one-for-one replacement ratio. Circumferential seams shall be riveted using rivets of the same size as for longitudinal seams and shall have a maximum rivet spacing of 6 in. [150 mm], measured on centers, except that six rivets will be sufficient in 12-in. [300-mm] diameter pipe.

7.3.2 All rivets shall be driven cold in such a manner that the sheets shall be drawn tightly together throughout the entire lap. The center of a rivet shall be no closer than twice its diameter from the edge of the sheet. All rivets shall have neat, workmanlike, and full hemispherical heads, or heads of a form acceptable to the purchaser, shall be driven without bending, and shall completely fill the hole.

7.4 *Resistance Spot Welded Seams*—The longitudinal seams shall be staggered to the extent that no more than three thicknesses of sheet are fastened by any spot weld. Pipe to be reformed into pipe-arch shape shall also meet the longitudinal seam requirement of 8.2.2 (Note 4).

7.4.1 The size of spot welds, number per corrugation, and width of lap at the longitudinal seam shall be as stated in Table 12, depending on sheet thickness, corrugation size, and diameter of the pipe. Circumferential seams shall be welded using spot welds of the same size as for longitudinal seams and shall have a maximum weld spacing of 6 in. [150 mm], except that six welds will be sufficient in 12-in. [300-mm] diameter pipe.

**TABLE 12 Rib Requirements for Types IR and IIR Pipe**

Nominal Size	Rib			Bottom Outside Radius, min	Bottom <sup>A</sup> Outside Radius, max, avg	Top Outside Radius, min	Top <sup>A</sup> Outside Radius, max, avg
	Width, <sup>B</sup> min	Depth, <sup>C</sup> min	Spacing, <sup>D</sup> max				
A 760, in.							
¾ by ¾ by 7½	0.68	0.73	7¾	0.10	0.25	0.10 + t	0.25 + t
¾ by 1 by 8½	0.68	0.95	8¾	0.10	0.25	0.10 + t	0.25 + t
¾ by 1 by 11½	0.68	0.95	11¾	0.10	0.25	0.10 + t	0.25 + t
A 760M, mm							
19 by 19 by 180	17	19	197	2.5	6.0	2.5 + t	6.0 + t
19 by 25 by 216	17	24	222	2.5	6.0	2.5 + t	6.0 + t
19 by 25 by 292	17	24	298	2.5	6.0	2.5 + t	6.0 + t

<sup>A</sup>The average of the two top rib radii and of the two bottom rib radii shall be within the minimum and maximum tolerances. The term “outside” refers to the outside surface of the pipe.

<sup>B</sup>Width is a dimension of the inside of the rib but is measured on the outside of the pipe (outside of the rib) and shall meet or exceed the spaced minimum width plus two times the wall thickness (that is, 2t + 0.68 in. [2t + 17 mm]).

<sup>C</sup>Depth is an average of ribs within one sheet width measured from the inside by placing a straightedge across the open rib and measuring to the bottom of the rib.

<sup>D</sup>Spacing is an average of three adjacent ribs spacings for ¾ by ¾ by 7½ pipe and two adjacent rib spacings for the ¾ by 1 by 11½ pipe and ¾ by 1 by 8½ pipe measured center-to-center of the ribs, at 90° to the direction of the ribs.



**TABLE 13 Riveted and Spot Welded Longitudinal Seams**

Specified Sheet Thickness		Nominal Corrugation Size					
		2⅔ by ½ in. <i>A,B</i>		3 by 1 in. <i>C,D</i>		5 by 1 in. <i>D,E</i>	
		Rivet or Spot Weld Diameters, min					
in.	mm	in.	mm	in.	mm	in.	mm
0.052	1.32	⅝	8.0	...	...	...	...
0.064	1.63	⅝	8.0	⅜	9.5	⅜	9.5
0.079	2.01	⅝	8.0	⅜	9.5	⅜	9.5
0.109	2.77	⅜	9.5	⅞	11.0	⅞	11.0
0.138	3.51	⅜	9.5	⅞	11.0	⅞	11.0
0.168	4.27	⅜	9.5	⅞	11.0	⅞	11.0

<sup>A</sup> One rivet or spot weld each valley for pipe diameters 36 in. [900 mm] and smaller. Two rivets or spot welds each valley for pipe diameters 42 in. [1050 mm] and larger.

<sup>B</sup> Minimum width of the lap is 1 ½ in. [38 mm] for pipe diameters 36 in. [900 mm] and smaller, and 3 in. [75 mm] for pipe diameters 42 in. [1050 mm] and larger.

<sup>C</sup> Two rivets or spot welds each valley for all pipe diameters.

<sup>D</sup> Minimum width of the lap is 3 in. [75 mm] for pipe of all diameters.

<sup>E</sup> Two rivets or spot welds each crest and valley for all pipe diameters.

7.4.2 All spot welds shall be made in such a manner that the sheets will be drawn tightly together throughout the lap. The outside edge of each spot weld shall be at least ¼ in. [6.5 mm] from the edge of the sheet. The welding shall be performed in such a manner that the exterior surfaces of 90 % or more of the spot welds on a length of pipe shall show no evidence of melting or burning of the base metal, and the base metal shall not be exposed when the area adjacent to the electrode contact surface area is wire brushed. Discoloration of the spot weld surfaces will not be cause for rejection.

7.4.3 Welding equipment shall be qualified before use, and the qualification shall be verified before each work shift and when changing sheet thickness, all as described in Annex A1. If use of the equipment at the approved machine settings fail to produce satisfactory welds, fabrication shall be stopped until adjustments are made and the equipment is requalified.

7.5 *Helical Lock Seams*—The lock seam for Type I pipe shall be formed in the tangent element of the corrugation profile with its center near the neutral axis of the corrugation profile. The lock seam for Type IA pipe shall be in the valley of the corrugation, shall be spaced not more than 30 in. [760 mm] apart, and shall be formed from both the liner and the shell in the same general manner as Type I helical lock seam pipe. The lock seam for Type IR pipe shall be formed in the flat zone of the pipe wall, midway between two ribs.

7.5.1 The edges of the sheets within the cross section of the lock seam shall lap at least ⅝ in. [4.0 mm] for pipe 10 in. [250 mm] or less in diameter and at least ⅞ in. [7.9 mm] for pipe greater than 10 in. [250 mm] in diameter, with an occasional tolerance of –10 % of lap width allowable. The lapped surfaces shall be in tight contact. The profile of the sheet shall include a retaining offset adjacent to the 180° fold (as described in AASHTO T249) of one sheet thickness on one side of the lock seam, or one-half sheet thickness on both sides of the lock seam, at the fabricator’s option. There shall be no visible cracks in the metal, loss of metal-to-metal contact, or excessive angularity on the interior of the 180° fold of metal at the completion of forming the lock seam.

7.5.2 Specimens cut from production pipe normal to and across the lock seam shall develop the tensile strength as provided in Table 14, when tested according to AASHTO T249. For Type IA pipe, the lock seam strength shall be as tabulated based on the thickness of the corrugated shell.

7.5.3 When the ends of helically corrugated lock seam pipe have been rerolled to form annular corrugations, either with or without a flanged end finish, the lock seam in the rerolled end shall not contain any visible cracks in the base metal and the tensile strength of the lock seam shall be not less than 60 % of that required in 7.5.2.

7.6 *Helical Continuous Welded Seams*—The seam shall be parallel to the corrugations and shall have a continuous weld extending from end to end of each length of pipe. Welding shall be done utilizing ultra high-frequency resistance equipment. Seams shall be welded in such a manner that they will develop the full strength of the pipe and not affect shape or nominal diameter of

**TABLE 14 Lock Seam Tensile Strength**

Specified Sheet Thickness <sup>A</sup>		Lock Seam Tensile Strength, per Unit Width, min	
in.	mm	lbf/in.	kN/m
0.040	1.02	175	30
0.052	1.32	240	42
0.064	1.63	340	60
0.079	2.01	520	91
0.109	2.77	700	122
0.138	3.50	880	154
0.168	4.27	1200	210

<sup>A</sup> For Type 1A pipe, the thickness shall be that of the corrugated shell.



the pipe. Welded seams shall be controlled such that the combined width of weld and adjacent coating burned by welding does not exceed three times the metal thickness. Damage outside this width shall be repaired as required in Section 11. The fabricator shall certify that the welds have been tested and found satisfactory.

7.6.1 Continuous welded seams shall be tested in accordance with Section 3 of AASHTO T241. The welded seam shall be acceptable if the sum of the length of cracks or other defects on either side of the cup does not exceed  $\frac{1}{4}$  in. [6.5 mm], basing the result on the second test if the first shows greater defects. The provisions of the referee test method of Section 4 of AASHTO T241 shall be applicable in the event of disagreement between the purchaser and the fabricator.

7.6.1.1 Tests of continuous welded seams shall be made as follows:

7.6.1.2 Pipe lengths of 24 ft [7.3 m] or less shall be tested on one end of each length, normally the trailing end.

7.6.1.3 If a length of pipe having a diameter greater than 48 in. [1200 mm] and length of 24 ft [7.3 m] or less is rejected, the following length of pipe produced shall be tested on both ends. If the test on either end fails, this entire length shall also be rejected.

7.6.1.4 Pipe lengths greater than 24 ft [7.3 m] shall be tested on each end of each length of pipe. If either end fails, the entire length shall be rejected.

7.6.2 The requirement for conducting quality control tests in accordance with 7.6.1 shall not apply for pipe in which the ends have been rerolled to form annular corrugations. The manufacturer shall maintain visual evaluation of the quality of the weld after rerolling and any indication of weld or base metal failure will be cause for rejection of the pipe.

7.6.3 Any indication of cracks, skips, or deficient welds found through visual inspection will be cause for rejection unless repaired. It is the option of the fabricator to remove the defective portion of the length of pipe or to manually repair defects in the automatically welded seam. Altered or repaired pipe shall meet the applicable requirements of 7.6. Where a manual repair occurs within 16 in. [400 mm] of the end of the length of pipe, a test shall be conducted on both the manually repaired section and on the immediately adjacent automatically welded section. If either test results in failure under the criterion of 7.6.1, the length of pipe shall be rejected.

7.7 *End Finish:*

7.7.1 To facilitate field jointing, the ends of individual pipe sections with helical corrugations or ribs may be rerolled to form annular corrugations extending at least two corrugations from the pipe end, or to form an upturned flange meeting the requirements in 7.7.2, or both. The diameter of ends shall not exceed that of the pipe barrel by more than the depth of the corrugation. All types of pipe ends, whether rerolled or not, shall be matched in a joint such that the maximum difference in the diameter of abutting pipe ends is  $\frac{1}{2}$  in. [13 mm].

7.7.1.1 When pipe with any size helical corrugation or rib is rerolled to form annular corrugations in the ends, the usual size of the annular corrugation is  $2\frac{2}{3}$  by  $\frac{1}{2}$  in. [68 by 13 mm].

7.7.2 If a flanged finish is used on the ends of individual pipe sections to facilitate field jointing, the flange shall be uniform in width, be not less than  $\frac{1}{2}$  in. [13 mm] wide, and shall be square to the longitudinal axis of the pipe.

7.7.3 The ends of all pipe which will form the inlet and outlet of culverts, fabricated of sheets having nominal thicknesses of 0.079 in. [2.01 mm] and less, shall be reinforced in a manner approved by the purchaser, when specified.

## 8. Pipe Requirements

8.1 *Type I, Type IA, and Type IR Pipe:*

8.1.1 *Pipe Dimensions*—The nominal diameter of the pipe shall be as stated in the order, selected from the size listed in Table 1. The size of corrugations which are standard for each size of pipe are also shown in Table 1. The average inside diameter of circular pipe and pipe to be reformed into pipe-arches shall not vary more than 1 % or  $\frac{1}{2}$  in. [13 mm], whichever is greater, from the nominal diameter when measured on the inside crest of the corrugations for Type I pipe, or the inside liner or surface for Type IA and Type IR pipe, respectively. Alternatively, for pipe having annular corrugations, conformance with the inside diameter requirement may be determined by measuring the outside circumference, for which minimum values are given in Table 1.

NOTE 7—The outside circumference of helically corrugated pipe is influenced by the corrugation size and the angle of the corrugations, affecting the number of corrugations crossed, therefore no minimum circumferential measurement can be specified.

8.1.2 *Sheet Thickness*—Sheet thickness shall be as specified by the purchaser from the specified sheet thicknesses listed in Table 15 (Note 8 and Note 9). For Type IA pipe, the thickness of both the shell and the liner shall be given; the thickness of the corrugated shell shall be not less than 60 % of the thickness of the equivalent Type I pipe; the liner shall have a nominal thickness of at least 0.040 in. [1.02 mm]; and the sum of the specified thicknesses of shell and liner shall equal or exceed the specified thickness of an equivalent pipe of identical corrugations as the shell in accordance with the design criteria in Practice A 796/A 796M.

NOTE 8—The sheet thicknesses listed in Table 15 are the thicknesses indicated as available in Specifications A 929/A 929M, for zinc-coated, aluminum-coated, 55 % aluminum-zinc alloy-coated, and zinc-5 % aluminum-mischmetal alloy-coated sheet, and in Specification A 885 for zinc and aramid fiber composite coated sheet.

NOTE 9—The purchaser should determine the required thickness for each of the types of pipe described in 4.1.1 through 4.1.6 in accordance with the design criteria in Practice A 796, or other appropriate guidelines.

8.1.3 When specified by the purchaser, the finished pipe shall be factory elongated to the extent specified. The elongation shall be accomplished by the use of a mechanical apparatus which will produce a uniform deformation throughout the length of the section.

**TABLE 15 Thicknesses of Metallic Coated Steel Sheet<sup>A</sup>**

Specified Thickness		Coating Type				
in.	mm	Zinc Coated	Aluminum Coated	55 Al-Zn Alloy Coated	Zn-5 Al-MM Alloy Coated	Zinc/Aramid Composite Coated
0.040	1.02	x		x	x	
0.052	1.32	x	x	x	x	
0.064	1.63	x	x	x	x	x
0.079	2.01	x	x	x	x	x
0.109	2.77	x	x	x	x	x
0.138	3.51	x	x	x	x	x
0.168	4.27	x			x	x

<sup>A</sup> An "X" indicates sheet thicknesses included in Specification A 929/A 929M or Specification A 885/A 885M for the coating types listed.

## 8.2 Type II, IIA, and IIR Pipe:

8.2.1 *Pipe-Arch Dimensions*—Pipe furnished as Type II, IIA, or IIR shall be made from Type I, IA, or IR pipe, respectively, and shall be reformed to provide a pipe-arch shape. All applicable requirements for Types I, IA, and IR pipe shall be met by finished Types II, IIA, and IIR pipe, respectively. Pipe arches shall conform to the dimensional requirements of Tables 2-9. All dimensions shall be measured from the inside crests of corrugations for Type II pipe or from the inside liner or surface for Types IIA or IIR pipe, respectively.

8.2.2 *Longitudinal Seams*—Longitudinal seams of riveted or spot welded pipe-arches shall not be placed in the corner radius.

8.2.3 Reforming Type IR into Type IIR pipe shall be done in such a manner as to avoid damage to the external ribs.

## 8.3 Type III Pipe:

8.3.1 Type III pipe shall have a full circular cross section and shall conform to the requirements for Type I pipe, and in addition shall contain perforations conforming to one of the classes described in 8.3.2.

8.3.2 *Perforations*—The perforations shall conform to the requirements for Class 1, unless otherwise specified in the order. Class 1 perforations are for pipe intended to be used for subsurface drainage. Class 2 and Class 3 perforations are for pipe intended to be used for subsurface disposal of water, but pipe containing Class 2 and Class 3 perforations may also be used for subsurface drainage.

8.3.2.1 *Class 1 Perforations*—The perforations shall be approximately circular and cleanly cut; shall have nominal diameters of not less than  $\frac{3}{16}$  in. [4.8 mm] nor greater than  $\frac{3}{8}$  in. [9.5 mm]; and shall be arranged in rows parallel to the axis of the pipe. The perforations shall be located on the inside crests or along the neutral axis of the corrugations, with one perforation in each row for each corrugation. Pipe connected by couplings or bands may be unperforated within 4 in. [100 mm] of each end of each length of pipe. The rows of perforations shall be arranged in two equal groups placed symmetrically on either side of a lower unperforated segment corresponding to the flow line of the pipe. The spacing of the rows shall be uniform. The distance between the center lines of rows shall be not less than 1 in. [25 mm]. The minimum number of longitudinal rows of perforations, the maximum heights of the centerlines of the uppermost rows above the bottom of the invert, and the inside chord lengths of the unperforated segments illustrated in Fig. 1 shall be as specified in Table 16.

NOTE 10—Pipe with Class 1 perforations is generally available in diameters from 4 to 21 in. [100 to 525 mm] inclusive, although perforated pipe in larger sizes may be obtained.

8.3.2.2 *Class 2 Perforations*—The perforations shall be circular holes with nominal diameters of  $\frac{5}{16}$  to  $\frac{3}{8}$  in. [8.0 to 9.5 mm], or slots with nominal width of  $\frac{3}{16}$  to  $\frac{5}{16}$  in. [4.8 to 8.0 mm] and not to exceed  $\frac{1}{2}$  in. [13 mm]. The perforations shall be uniformly spaced around the full periphery of the pipe. The perforations shall provide an opening area of not less than 3.3 in.<sup>2</sup>/ft<sup>2</sup> [230 cm<sup>2</sup>/m<sup>2</sup>] of pipe surface based on nominal diameter and length of pipe.

NOTE 11—Thirty perforations  $\frac{3}{8}$  in. in diameter, per square foot [323 perforations, 9.5 mm in diameter, per square metre] satisfies this requirement.

8.3.2.3 *Class 3 Perforations*—The perforations shall be slots with a width of  $0.10 \pm 0.04$  in. [ $2.5 \pm 1.0$  mm] and length of  $1.0 \pm 0.25$  in. [ $25 \pm 6.5$  mm], spaces  $1\frac{3}{4}$  to  $2\frac{1}{2}$  in. [45 to 65 mm] on centers around the circumference and staggered on the outside crests of the corrugations of the pipe. No metal shall be removed in making the slot. Slots shall be made from the inside of the pipe.

## 8.4 Type IIIA Pipe:

8.4.1 Type IIIA pipe shall be fabricated of an unperforated semicircular bottom section with a top shield of corrugated steel, both of nominal 0.052-in. [1.32-mm] thickness or greater. The smooth semicircular bottom section shall be approximately  $4\frac{5}{8}$  in. [120 mm] in diameter and shall have a continuous lip extending outward along each side; the corrugated top shield shall be approximately  $6\frac{3}{8}$  in. [160 mm] wide including a  $\frac{3}{4}$ -in. [19-mm] sloping overhang on each side and shall be secured to the lip of the bottom section by integral tabs spaced at about  $3\frac{1}{2}$  in. [90 mm] center to center. The top shield shall have corrugations approximately  $\frac{7}{8}$ -in. [22 mm] center to center and approximately  $\frac{5}{16}$ -in. [9.0-mm] depth.

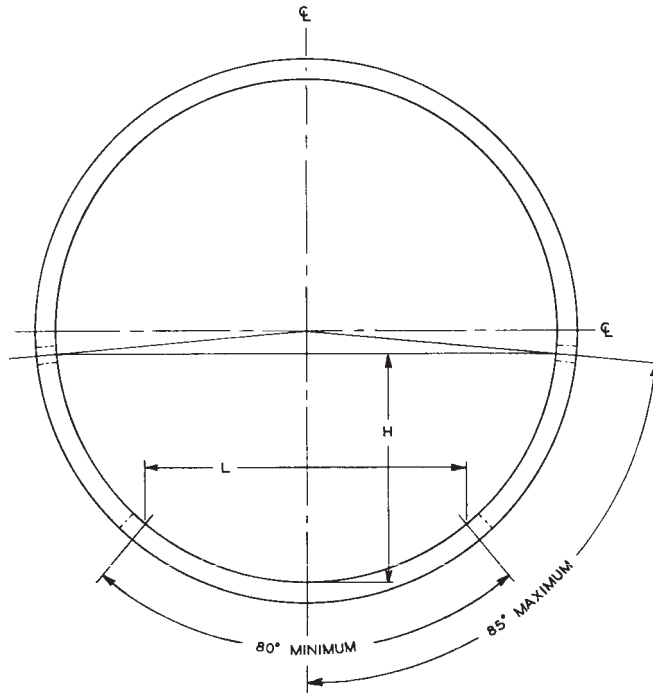


FIG. 1 Requirements for Perforations

TABLE 16 Rows of Perforations, Height *H* of the Centerline of the Uppermost Rows Above the Invert, and Chord Length *L* of Unperforated Segment, for Class 1 Perforations

Internal Diameter of Pipe		Rows of Perforations <sup>A</sup>	<i>H</i> , max <sup>B</sup>		<i>L</i> , min <sup>B</sup>	
in.	mm		in.	mm	in.	mm
4	100	2	1.8	46	2.6	64
6	150	4	2.8	69	3.8	96
8	200	4	3.7	92	5.1	128
10	250	4	4.6	115	6.4	160
12	300	6 <sup>C</sup>	5.5	138	7.7	192
15	375	6 <sup>C</sup>	6.9	172	9.6	240
18	450	6 <sup>C</sup>	8.3	207	11.5	288
21	525	6	9.7	241	13.4	336
24 and larger	600 and larger	8	<sup>D</sup>	<sup>D</sup>	<sup>D</sup>	<sup>D</sup>

<sup>A</sup> Minimum number of rows. A greater number of rows for increased inlet area shall be subject to agreement between the purchaser and the fabricator. Note that the number of perforations per unit length (perforations per foot [metre]) in each row (and inlet area) is dependent on the corrugation pitch.

<sup>B</sup> See Fig. 1 for location of dimensions *H* and *L*.

<sup>C</sup> Minimum of 4 rows permitted in pipe with 1½ by ¼-in. [38 by 6.5-mm] corrugations.

<sup>D</sup>  $H$  (max) = 0.46*D*;  $L$  (min) = 0.64*D*, where *D* = internal diameter of pipe, inches or millimetres as appropriate.

8.5 *Pipe Fabricated from Zinc and Aramid Fiber Composite Coated Sheet*—Pipe which has been fabricated from zinc and aramid fiber composite coated sheet shall be coated with asphalt as described in Specification A 849, Class B, fully coated. If full or partial smooth lining is desired, it shall be specified by the purchaser. (See 1.1.1 and Specification A 849.)

## 9. Joining Systems

9.1 *Types of Joining Systems*—Joining systems shall be of the following types, depending upon the configuration of the steel band joining the pipe together. If required, the joining system shall incorporate a flat, o-ring, or profile gasket. The corrugations at the ends of pipe sections being joined shall conform to one of the corrugations detailed in Practice A 796/A 796M.

9.1.1 *Corrugated Bands*—Bands with either annular or helical corrugations. The band corrugation shall match that of the pipe sections being joined or the annular rerolled ends of those pipe sections.

9.1.2 *Partially Corrugated Bands*—Flat bands with a minimum of one corrugation formed along each circumferential edge of the band. These bands are intended for use with helically corrugated pipe with its ends rerolled to a 2⅔-in.-by-½-in. [68-mm-13-mm] corrugation

9.1.3 *Bands with Projections*—Flat bands with projections, such as dimples, are used to join pipe with either helical or annular corrugations. The bands shall be formed with the projections in annular rows with one projection for each corrugation of helical pipe engaged by the band. Bands 10½ in. [265 mm] or 12 in. [300 mm] wide shall have two annular rows of projections, and bands 16¼ in. [415 mm] or wider shall have four annular rows of projections.

9.1.4 *Channel Bands*—Channel bands that incorporate a connector formed into a channel (hat) shape, shall be used only with pipe having upturned flanges on the pipe ends. Channel bands shall conform with the requirements of 9.3.3.

9.1.5 *Flat Bands*—When specified by the purchaser, flat bands shall be used with helical corrugated pipe, annular corrugated pipe, or pipe with helical corrugations on which the ends have been rerolled to form annular corrugations.

9.1.6 *Sleeve Couplers*—When specified by the purchaser, the joining system shall incorporate a push-on type coupler designed to properly interface with the pipes being joined. Sleeve couplers generally do not have any external device for tightening around the pipe. Sleeve couplers shall provide a centering device so the coupler laps equally on both pipe being joined. Sleeve couplers for pipe diameters less than 12 in. [300 mm] shall have a minimum stab depth of 3 in. [75 mm]. The minimum stab depth for larger sizes 12 in. [300 mm] through 42 in. [1050 mm] diameters, shall be 6 in. [150 mm]. When sleeve couplers are used with pipes other than Type III or 8% of the Type IIIA, pipe diameter, which ever is greater, with annular corrugations or re-rolled ends shall be used. Sleeve couplers are not intended for pipe diameters larger than 42 in. [1050 mm].

9.1.7 *Bell and Spigot*—Bell and spigot configurations incorporate an integral bell that is permanently installed at the factory to one end of the pipe, while the other end of the pipe serves as a spigot. The bell shall be affixed to the pipe by welding or with mechanical fasteners. The steel in the bell shall meet the thickness requirements of 9.3.1. The bell and spigot configuration shall be classified in accordance with 9.2. The spigot end of the pipe shall be re-rolled or provide annular corrugations to allow placement of a gasket if required. The bell shall provide a minimum stab depth of 6 in. [150 mm], or 8% of the pipe diameter, which ever is greater.

9.1.8 *Special Design*—Other joining systems that meet the requirements of 9.3, 9.4 (if required), and 9.5 (if required), and are specified by the purchaser, shall be used on the project for which they are specified.

9.2 *Joining Systems: Significance and Use*—Joining systems are classified as standard or gasketed, based on the ability of the system to control infiltration and/or exfiltration. These classifications of standard and gasketed systems are covered in 9.2.1 and 9.2.2. When site conditions near the pipe are such that movement or differential settlement is possible at the joint, the joining system shall have structural requirements that conform with 9.4.

#### 9.2.1 *Standard Systems*

9.2.1.1 Standard joining systems for corrugated steel pipe are intended to control the infiltration of soil into the pipe. Standard joining systems are used in the majority of CSP installations. The gradation and plasticity of the backfill materials around the pipe are important factors in the selection of a joining system. The greater the concentration of very fine particles, such as silts which pass the #200 [75 µm] sieve, the greater the possibility of soil infiltration. Additionally, when the water table is above the pipe or where the backfill is otherwise saturated and the flow level in the pipe varies rapidly, soil infiltration is more likely to occur.

9.2.1.2 External bands conforming with 9.1.1-9.1.3, or 9.1.5, when used with annular pipe or with helical pipe with rerolled ends, generally provide adequate control of infiltration of soil particles. Properly installed, these bands provide continuous metal-to-metal contact with the periphery of the annular portion of the pipe. Where these bands do not provide adequate soil infiltration control, a geotextile wrap around the exterior of the joining system and the adjacent pipe will inhibit the movement of silt and larger soil particles into the pipe.

#### 9.2.2 *Gasketed Systems*

9.2.2.1 Gasketed joining systems are used to limit the flow of water from the pipe interior to the backfill, to limit the flow of ground water into the pipe, and where necessary, to provide further control of soil particle infiltration. Joining systems such as those described in 9.1.4, 9.1.6, and 9.1.7 require gaskets to adequately control soil particle infiltration, except where the pipe is used in underdrain applications. Gaskets used in all joining systems shall conform to the requirements of 6.5 and 9.5.

9.2.2.2 Sites where excessive water infiltration is expected or where the pipe will carry hazardous pollutants require a gasketed joining system. In these cases, the joining system shall be tested to establish a leakage rate not to exceed 200 gal per diameter inch per mile per day [18.5 L per millimeter of diameter per kilometre per day] with no pressure applied to the pipe or joining system. The joining system shall be tested at the pipe fabricator's plant or a laboratory, with the pipe in straight alignment. The test shall be witnessed and certified by an approved laboratory.

9.3 *Requirements*—Joining systems shall be fabricated in a manner that ensures that the band or coupler extends over each pipe section an equal length. The joining system shall be fabricated in such a way that proper installation will result in performance conforming with 9.2.1 or 9.2.2 as required for the project.

9.3.1 *Band, Sleeve, or Bell Thickness and Width*—The band, sleeve coupler, or bell portion of the joining system shall be sufficiently strong to resist the forces to which it is subjected. Table 17 provides minimum steel thickness requirements for bands, sleeves, or bells based on the steel thickness of the pipes being connected. Table 17 does not apply to channel (hat) bands, which are covered under 9.3.3. The width of coupling bands (9.1.1-9.1.3, and 9.1.5) shall be equal to or greater than the minimum widths shown in Tables 18 and 19.

9.3.2 *Band Connectors*—The bands shall be connected in a manner approved by the purchaser with hardware that has been suitably galvanized to provide durability. This hardware includes angles and integrally or separately formed and attached flanges

**TABLE 17 Band, Sleeve, or Bell Thickness<sup>A,B</sup>**

Nominal Pipe Thickness		Minimum Band Sleeve or Bell Thickness
in.		in.
0.109	and thinner	0.052
0.138		0.064
0.168		0.079

<sup>A</sup>For annular corrugated pipe or helically corrugated pipe with 2<sup>3</sup>/<sub>8</sub>-by-1/2-in. [68-by-13-mm] annular rerolled ends.

<sup>B</sup>Applies to joining systems covered by 9.1.1-9.1.3, 9.1.5, 9.1.7, and 9.1.6, when the coupler is 12 in. [300 mm] or larger and made from steel.

**TABLE 18 Band Width Requirements for Pipe with Annular Corrugated Ends<sup>A,B</sup>**

Nominal Pipe Diameter	Minimum Band Width
in.	in.
12 to 36	7
42 to 144	10 1/2

<sup>A</sup>For annular pipe or helical pipe with 2<sup>3</sup>/<sub>8</sub>-by-1/2-in. [68-by-13-mm] rerolled ends.

<sup>B</sup>Applies to joining systems covered by 9.1.1-9.1.3, and 9.1.5

**TABLE 19 Band Width Requirements for Helically Corrugated Pipe**

in.	Nominal Corrugation [mm]	Nominal Pipe Diameter in.	Minimum Band Width in.
1 1/2 by 1/4		4 to 18	7
2 3/8 by 1/2		12 to 84	12
3 by 1		36 to 144	14
5 by 1		36 to 144	22

NOTE 1—Corrugation of band shall match that pipe

NOTE 2—Band shall be centered on pipes being joined

NOTE 3—Applies to joining systems covered by 9.1.1-9.1.3, and 9.1.5.

that will be connected together with galvanized or cadmium-plated bolts, bars and straps, wedge locks, and straps or lugs. Bands shall be connected with the bolts in accordance with Table 20.

9.3.3 *Channel Bands*—Pipe sections provided with flanges on the ends will be connected by interlocking the flanges of two pipes with a channel (hat) band or other band incorporating an interlocking channel, not less than 3/4 in. [19 mm] in width. The depth of the channel shall be not less than 1/2 in. [13 mm]. The channel band shall have a minimum thickness of 0.064 in. [1.62 mm].

9.3.4 *Sleeve Couplers*—Sleeve couplers for pipes less than 12 in. [300 mm] in diameter shall be made from steel with a minimum thickness of 0.040 in. [1.02 mm]. The steel thickness for larger sizes shall conform to Table 17. Alternatively the coupler shall be a plastic sleeve with adequate strength to maintain the in-service pipe alignment and meet the requirements of 9.2.1.

9.4 *Structural Properties*—Joining systems that are subject to forces created by differential soil movement or settlement require certain structural properties to withstand the applied forces. Minimum values for these structural properties are shown in Table 21. These values for a joining system are determined by either a rational analysis or a suitable physical test.

9.4.1 *Shear Strength*—The shear strength required of the joining system is expressed as a percentage of the calculated shear strength of the pipe at a typical cross section at a location other than a rerolled end.

9.4.2 *Moment Strength*—The moment strength required of a joining system is expressed as a percent of the calculated moment strength of the pipe at a typical cross section at a location other than a rerolled end.

9.4.3 *Tensile Strength*—Where pull-apart (tensile) strength is required to control disjuncting in slope drains and similar applications, corrugated, partially corrugated, or channel bands shall be specified. When special requirements exist, joining systems shall provide tensile strength levels of 5,000 lb [22kN] for 42 in. [1050 mm] and smaller sizes and 10,000 lb [46 kN] for larger sizes.

9.5 *Gaskets*—Where infiltration or exfiltration is a concern, as defined in 9.2.2, the joining system shall incorporate gaskets. Rubber gaskets shall meet the requirements of 6.5 and shall be flat, o-ring, or have a profile shape. Flat gaskets shall be continuous

**TABLE 20 Band Connector Bolt Size**

Pipe Diameter	Bolt Diameter [mm]
in.	in.
≤ 8	3/8
≥ 21	1/2
Type III and IIIA	5/16

**TABLE 21 Structural Properties of Joining System**

	Minimum Value
Shear strength (% of barrel strength)	2
Moment strength (% of barrel strength)	5
Tensile (pull-apart) strength	none

or have a lap joint and be approximately 7 in. [18 mm] wide and approximately  $\frac{3}{8}$  in. [9.5 mm] thick. O-ring gaskets shall be  $\frac{1}{16}$ -in. [20 mm] or  $\frac{7}{8}$  in. [22 mm] in diameter for pipe diameters of 36 in. [900 mm] and smaller, or  $\frac{7}{8}$  in. [22 mm] diameter for larger diameters of pipe fabricated with a  $\frac{1}{2}$  in. [13 mm] deep corrugation. O-ring gaskets shall be  $1\frac{3}{8}$  in. [35 mm] in diameter when used on pipes having a 1 in. [25 mm] or deeper corrugation. Other types of gaskets may be used, including profile gaskets, that meet the specific requirements of the joining system.

## 10. Workmanship, Finish, and Appearance

10.1 The completed pipe shall show careful, finished workmanship in all particulars. Pipe which has been damaged, either during fabrication or in shipping, may be rejected unless repairs are made which are satisfactory to the purchaser. Among others, the following defects shall be considered as constituting poor workmanship:

- 10.1.1 Variation from a straight centerline.
- 10.1.2 Elliptical shape in pipe intended to be round.
- 10.1.3 Dents or bends in the metal.
- 10.1.4 Metallic coating which has been bruised, broken, or otherwise damaged.
- 10.1.5 Lack of rigidity.
- 10.1.6 Illegible markings on the steel sheet.
- 10.1.7 Ragged or diagonal sheared edges.
- 10.1.8 Uneven laps in riveted or spot welded pipe.
- 10.1.9 Loose, unevenly lined, or unevenly spaced rivets.
- 10.1.10 Defective spot welds or continuous welds.
- 10.1.11 Loosely formed lockseams.

## 11. Repair of Damaged Coatings

11.1 Pipe on which the metallic coating has been burned by welding beyond the limits provided in 7.4.2 and 7.6, or has been otherwise damaged in fabricating or handling, shall be repaired. The repair shall be done so that the completed pipe shall show careful finished workmanship in all particulars. Pipe which, in the opinion of the purchaser, has not been cleaned or coated satisfactorily may be rejected. If the purchaser so elects, the repair shall be done in his presence.

11.2 The damaged area shall be repaired in conformance with Practice A 780 (Note 12), except as described herein. The damaged area shall be cleaned to bright metal by blast cleaning, power disk sanding, or wire brushing. The cleaned area shall extend at least  $\frac{1}{2}$  in. [13 mm] into the undamaged section of the coating. The cleaned area shall be coated within 24 h and before any rusting or soiling.

NOTE 12—While Practice A 780 specifically refers to repair of damaged zinc coatings, the same procedures are applicable to repair of other metallic coatings except as described in this section.

NOTE 13—Repair of asphalt coating is described in Specification A 849.

11.3 *Paints Containing Zinc Dust*—Paints containing zinc dust, as described in the Materials section of Practice A 780, shall be applied to a dry film thickness of at least 0.005 in. [0.13 mm] over the damaged section and surrounding cleared area. Paints containing zinc dust shall be used for repair to all types of metallic coatings such as zinc, aluminum, and alloys of zinc and aluminum.

11.4 *Metallizing Coating*—The damaged area shall be cleaned as described in 11.2, except it shall be cleaned to the near-white condition. The repair coating applied to the cleaned section shall have a thickness of not less than 0.005 in. [0.13 mm] over the damaged section and shall taper off to zero thickness at the edges of the cleaned undamaged section.

11.4.1 Where zinc coating is to be metallized, it shall be done with zinc wire containing not less than 99.98 % zinc.

11.4.2 Where aluminum coating is to be metallized, it shall be done with aluminum wire containing not less than 99 % aluminum.

11.4.3 Where 55 % aluminum-zinc alloy coating is to be metallized, it shall be done using the materials described in 11.4.1 or 11.4.2, or by using an alloy wire of 55 % aluminum and 45 % zinc by weight.

11.4.4 Where Zn-5 Al-MM alloy coating is to be metallized, it shall be done using the materials described in 11.4.1, or by using an alloy wire of 85 % zinc and 15 % aluminum by weight.

11.5 Pipe on which zinc and aramid fiber composite coating is damaged by welding during fabrication of fittings or otherwise damaged during handling or shipping shall be repaired in accordance with 11.2 through 11.4.

## 12. Inspection

12.1 The purchaser or his representative shall have free access to the fabricating plant for inspection, and every facility shall

be extended to him for this purpose. This inspection shall include an examination of the pipe for the items in 10.1 and the specific requirements of this specification applicable to the type of pipe and method of fabrication.

12.2 On a random basis, samples may be taken for chemical analysis and metallic coating measurements for check purposes. These samples will be secured from fabricated pipe or from sheets or coils of the material used in fabrication of the pipe. The weight [mass] of metallic coating shall be determined in accordance with Test Method A 90/A 90M for zinc, 55 % aluminum-zinc alloy, and zinc-5 % aluminum-mischmetal alloy coatings, and in accordance with Test Method A 428/A 428M for aluminum coating.

### 13. Rejection

13.1 Pipe failing to conform to the specific requirements of this specification, or that shows poor workmanship, may be rejected. This requirement applies not only to the individual pipe, but to any shipment as a whole where a substantial number of pipe are defective. If the average deficiency in length of any shipment of pipe is greater than 1 %, the shipment may be rejected.

### 14. Certification

14.1 When specified in the purchase order or contract, a manufacturer’s or fabricator’s certification, or both, shall be furnished to the purchaser stating that samples representing each lot have been tested and inspected in accordance with this specification and have been found to meet the requirements for the material described in the order. When specified in the order, a report of the test results shall be furnished.

### 15. Keywords

15.1 corrugated steel pipe; drainage pipe; metallic coated pipe; sewer pipe

## ANNEX

### (Mandatory Information)

#### A1. QUALIFICATION OF RESISTANCE SPOT WELDING EQUIPMENT

A1.1 *General*—Welding equipment shall be of sufficient capacity, of such design, and in such condition as to make possible the production of first-class welds. Before being permitted to perform welding on corrugated steel pipe, resistance spot welding machines and operators shall be qualified by means of the test prescribed in A1.2. Tests shall be performed by the fabricator’s shop or by a recognized independent laboratory at no expense to the purchaser. Qualification tests performed by the fabricator’s shop shall be made in the presence of the representative of the purchaser.

A1.2 *Qualification*—Perform three tension shear tests representing each thickness of sheet to be used in the fabrication of the pipe. Prepare specimens by lapping two strips of corrugated steel sheet 1½-in. [38-mm] minimum width by 5-in. [125-mm] minimum length and joining them together by a single spot weld duplicating the size to be used in production. The length of lap shall be 1½ in. [38 mm]. The longer axis of the specimen shall be parallel to the direction of rolling. Test the specimens in tension to destruction in a standard calibrated testing machine. The minimum shear strength in pounds-force [kilonewtons] as determined by this test shall be not less than that shown in Table A1.1 for the nominal thickness of sheet used in the test.

A1.3 *Verification*—After a machine and operator have been qualified by the foregoing procedure, to ensure that qualification is maintained, make three tension shear tests at the start of each work shift, and make three tension shear tests for each change in sheet thickness.

A1.4 *Machine Settings*—One copy of the approved machine setting shall be posted on the machine for use by the machine operator. No settings shall be varied, except weld phase shift and pressure which may be varied by ±10 %.

**TABLE A1.1 Shear Strength of Spot Welds**

Specified Sheet Thickness		Minimum Shear Strength	
in. (A 760)	mm	lbf (A 760)	kN
0.064	1.63	4 100	18.2
0.079	2.01	5 200	23.1
0.109	2.77	7 000	31.1
0.138	3.51	8 500	37.8
0.168	4.27	10 000	44.5

 **A 760/A 760M – 01a**

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# Standard Specification for Corrugated Steel Structural Plate, Zinc-Coated, for Field- Bolted Pipe, Pipe-Arches, and Arches<sup>1</sup>

This standard is issued under the fixed designation A 761/A 761M; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

*This standard has been approved for use by agencies of the Department of Defense.*

## 1. Scope\*

1.1 This specification covers corrugated steel structural plate, zinc-coated, used in the construction of pipe, pipe-arches, arches, underpasses, and special shapes for field assembly. Appropriate fasteners and accessory materials are also described. The pipe, arches, and other shapes are generally used for drainage purposes, pedestrian and vehicular underpasses, and utility tunnels.

1.2 This specification does not include requirements for bedding, backfill, or the relationship between earth cover load and plate thickness of the pipe. Experience has shown that the successful performance of this product depends upon the proper selection of plate thickness, type of bedding and backfill, manufacture in the plant, and care in the installation. The purchaser must correlate the preceding factors and also the corrosion and abrasion requirements of the field installation with the plate thickness. The structural design of corrugated steel structural plate pipe and the proper installation procedures are described in Practices A 796/A 796M and A 807/A 807M.

1.3 This specification is applicable to orders in either inch-pound units (as A 761) or SI units (as A 761M). Inch-pound units and SI units are not necessarily equivalent. SI units are shown in brackets in the text, but they are the applicable values when the material is ordered to A 761M.

1.4 This specification references notes and footnotes which provide explanatory material. These notes and footnotes (excluding those in tables and figures) shall not be considered as requirements of this specification.

## 2. Referenced Documents

### 2.1 ASTM Standards:<sup>2</sup>

- A 36/A 36M Specification for Carbon Structural Steel
- A 90/A 90M Test Method for Weight [Mass] of Coating on

- Iron and Steel Articles with Zinc or Zinc-Alloy Coatings
  - A 123/A 123M Specification for Zinc (Hot-Dip Galvanized) Coatings on Iron and Steel Products
  - A 153/A 153M Specification for Zinc Coating (Hot-Dip) on Iron and Steel Hardware
  - A 307 Specification for Carbon Steel Bolts and Studs, 60 000 psi Tensile Strength
  - A 370 Test Methods and Definitions for Mechanical Testing of Steel Products
  - A 449 Specification for Quenched and Tempered Steel Bolts and Studs
  - A 563 Specification for Carbon and Alloy Steel Nuts
  - A 563M Specification for Carbon and Alloy Steel Nuts [Metric]
  - A 751 Test Methods, Practices, and Terminology for Chemical Analysis of Steel Products
  - A 754 Test Method for Coating Thickness by X-ray Fluorescence
  - A 780 Practice for Repair of Damaged Hot-Dip Galvanized Coatings
  - A 796/A 796M Practice for Structural Design of Corrugated Steel Pipe, Pipe-Arches, and Arches for Storm and Sanitary Sewers and Other Buried Applications
  - A 807/A 807M Practice for Installing Corrugated Steel Structural Plate Pipe for Sewers and Other Applications
  - A 902 Terminology Relating to Metallic Coated Steel Products
  - B 6 Specification for Zinc (Slab Zinc)
  - B 695 Specification for Coatings of Zinc Mechanically Deposited on Iron and Steel
  - E 29 Practice for Using Significant Digits in Test Data to Determine Conformance with Specifications
  - E 376 Practice for Measuring Coating Thickness by Magnetic-Field or Eddy-Current (Electromagnetic) Test Methods
  - F 568 Specification for Carbon and Alloy Steel Externally Threaded Metric Fasteners
- ### 2.2 ANSI Standards:<sup>3</sup>

<sup>1</sup> This specification is under the jurisdiction of ASTM Committee A05 on Metallic Coated Iron and Steel Products and is the direct responsibility of Subcommittee A05.17 on Corrugated Steel Pipe Specifications.

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<sup>2</sup> For referenced ASTM standards, visit the ASTM website, [www.astm.org](http://www.astm.org), or contact ASTM Customer Service at [service@astm.org](mailto:service@astm.org). For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

<sup>3</sup> Available from American National Standards Institute (ANSI), 25 W. 43rd St., 4th Floor, New York, NY 10036.

\*A Summary of Changes section appears at the end of this standard.

- B18.2.1 Square and Hex Bolts and Screws, Inch Series
- B18.2.2 Square and Hex Nuts
- B18.2.3.6M Bolts, Metric Heavy Hex
- B18.2.4.6M Hex Nuts, Heavy, Metric
- 2.3 AASHTO Standard:<sup>4</sup>  
Standard Specifications for Highway Bridges, Division I

### 3. Terminology

- 3.1 *Definitions*—See Terminology A 902 for definitions of general terminology relating to metallic-coated steel products.
- 3.2 *Definitions of Terms Specific to This Standard:*
  - 3.2.1 *arch, n*—a part circle shape spanning an open invert between the footings on which it rests.
  - 3.2.2 *box culvert, n*—a rectangular box with a long-radius crown and short radius corners, and having either a full invert or footings.
  - 3.2.3 *fabricator, n*—the producer of the components for the finished product.
  - 3.2.4 *flat plate, n*—sheet or plate used to fabricate structural plate.
  - 3.2.5 *manufacturer, n*—the producer of the flat plate and accessories.
  - 3.2.6 *pipe, n*—a conduit having full circular shape; also, in a general context, all structure shapes covered by this specification.
  - 3.2.7 *pipe-arch, n*—an arch shape with an approximate semicircular crown, small-radius, corners, and large-radius invert.
  - 3.2.8 *pipe, horizontal ellipse, n*—an elliptically shaped pipe with the horizontal diameter approximately 25 % greater than the nominal diameter.
  - 3.2.9 *pipe, vertically elongated, n*—an elliptically shaped pipe with the vertical diameter up to 10 % greater than the nominal diameter.
  - 3.2.10 *purchaser, n*—the person or agency that purchases the finished pipe structure.
  - 3.2.11 *special shape, n*—a shape, other than described elsewhere in this section, suitable for fabrication with structural plate.
  - 3.2.12 *structural plate, n*—a corrugated and curved plate which is field assembled with other structural plates to form the required structure.

3.2.13 *vehicular underpass, n*—a high arch shape with an approximate semicircular crown, large-radius sides, small-radius corners between sides and invert, and large-radius invert.

### 4. Ordering Information

- 4.1 Orders for material under this specification shall include the following information as necessary to adequately describe the desired product:
  - 4.1.1 Name of material (corrugated steel structural plate and accessories),
  - 4.1.2 Description of structure (see Section 3),
  - 4.1.3 Number of structures,
  - 4.1.4 ASTM designation and year of issue, as A 761– \_\_\_\_ for inch-pound units or A 761M – \_\_\_\_ for SI units.
  - 4.1.5 Dimensions of structure (diameter or span and rise, and length, and so forth) (see 8.2 and Note 7),
  - 4.1.6 Thickness of plate (see 8.1), and for the 6 by 2-in. [150 by 50-mm] corrugation, the type of steel in accordance with 5.1.3 and Table 1,
  - 4.1.7 Description of corrugations (see 6.2),
  - 4.1.8 End treatment (bevel, skew, grade or slope corrections, or other special provision if required by the project plans or specifications),
  - 4.1.9 Seam bolt size and number per corrugation, if different than the minimums specified (see 6.3 and Table 2 and Table 3),
  - 4.1.10 Special requirements (including reinforcement locations, shapes, and thicknesses), if required, and
  - 4.1.11 Certification, if required (see 12.1).

NOTE 1—Typical ordering descriptions are as follows: (1) Structural plates and fasteners for two corrugated steel structural plate pipes, in accordance with ASTM A 761 – \_\_\_\_, 180-in. diameter, 0.168-in. plate thickness, 6 by 2-in. corrugations, each 140-ft nominal centerline length with end treatment as shown on plans; (2) Structural plates and fasteners for one corrugated steel structural plate pipe-arch, in accordance with ASTM A 761M – \_\_\_\_, 3860-mm span by 2460-mm rise, 5.54-mm plate thickness, 150 by 50-mm corrugations, 27.0-m nominal centerline length with square ends, longitudinal seams with four M20 bolts per corrugation.

### 5. Materials

- 5.1 *Flat Plate:*
  - 5.1.1 *Manufacture*—The base steel shall be made by any of the following processes: open-hearth, basic-oxygen, or electric-furnace.
  - 5.1.2 *Chemical Composition*—The base metal heat analysis shall conform to the chemical requirements of Table 4. The

<sup>4</sup> Available from American Association of State Highway and Transportation Officials (AASHTO), 444 N. Capitol St., NW, Suite 249, Washington, DC 20001.

**TABLE 1 Mechanical Requirements for Flat Plate<sup>A</sup>**

Corrugation Size in. [mm]	Yield Strength <sup>B</sup> , min. ksi [MPa]	Tensile Strength <sup>B</sup> , min. ksi [MPa]	Elongation in 2 in. [50 mm], <sup>C</sup> min, %
6 by 2 [150 by 50]			
Type 33	28.0 [190]	42.0 [290]	25
Type 38	33.0 [225]	45.0 [310]	25
15 by 5½ [380 by 140] and 16 by 6 [400 by 150]	40.0 [275]	55.0 [380]	25

<sup>A</sup>To determine conformance with this specification, round each value for tensile strength and for yield strength to the nearest 0.1 ksi [1 MPa] and each value for elongation to the nearest 1 %, both in accordance with the rounding method of Practice E 29.

<sup>B</sup>Yield strength and tensile strength are based on thickness of the base metal. If tests are made after coating, determine the base metal thickness after stripping the coating from the ends of the specimen contacting the grips of the tension testing machine.

<sup>C</sup>Elongation requirement does not apply to material tested after corrugating.

**TABLE 2 Bolt and Nut Requirements**

	Bolts <sup>A</sup>	Nuts
General dimensions <sup>B</sup>	A 761 (in.) ANSI B18.2.1 Heavy Hex	ANSI B18.2.2 Heavy Hex
Seam bolts and nuts <sup>C</sup>	A 449	A 563 Grade C
Anchorage bolts and nuts	A 307	A 563 Grade A
Zinc coating	A 153 or B 695, Class 55	A 153 or B 695, Class 55
Nominal diameter, min, in. <sup>D</sup>	3/4	3/4
General dimensions <sup>B</sup>	A 761M [mm] ANSI B18.2.3.4M Heavy Hex	ANSI B18.2.4.6M Heavy Hex
Seam bolts and nuts <sup>C</sup>	F 568 Class 8.8	A 563M Class 12
Anchorage bolts and nuts	F 568 Class 4.6	A 563M Class 5
Zinc coating	A 153 or B 695, Class 55	A 153 or B 695, Class 55
Nominal diameter, min, metric size <sup>D</sup>	M20	M20

<sup>A</sup>Bolts with a special hemispherical base under the head are only available in inch sizes. They are also intended for use with metric plate.

<sup>B</sup>See 5.4.1 for requirements for bolt and nut bearing surfaces.

<sup>C</sup>Bolts and nuts also used for connecting arch plates to bearings and structural reinforcement to structural plates.

<sup>D</sup>Bolt size of 7/8 in. or 1 in. [M22, M24, or M27] shall be furnished when specified in the order (see 5.4 and Note 4).

requirements of this specification shall be met in continuous mass production during which the manufacturer has made analysis of individual heats so as to ensure that material is controlled within the specified limits.

**5.1.3 Mechanical Requirements**—The mechanical properties of the flat plate material prior to corrugating shall conform to the requirements in Table 1. For the 6 by 2-in. [150 by 50-mm] corrugation, either Type 33 or Type 38 must be specified.

NOTE 2—The properties given in Table 1 for the flat plate normally provide the minimum yield strength of 33 ksi [230 MPa] for Type 33 material and 38 ksi [265 MPa] for Type 38 material (used in structural design for pipe with 6 by 2-in. [150 by 50-mm] corrugations), or 44 ksi [300 MPa] (used in structural design for pipe with 15 by 5 1/2-in. [380 by 140-mm] and 16 by 6-in. [400 by 150-mm] corrugations), after the plate is corrugated.

**5.2 Bearings for Arches**—When specified, metal bearings for arches shall be cold-formed channels made from flat plate material conforming to 5.1, and not less than 0.188 in. [4.78 mm] in specified thickness.

**5.3 Members for Structural Reinforcement**—Steel members for circumferential or longitudinal stiffeners, or secondary structural components, shall be fabricated from rolled shapes conforming to Specification A 36/A 36M, or from flat plate material conforming to 5.1.

NOTE 3—When used, steel transverse structural reinforcing members are part of long span or box corrugated steel structural plate structures. Members of these types of structures can be designed using Practice A 796. The structural design of long-span structures is given in AASHTO Standard Specifications for Highway Bridges, Division I, Section 12.6. The structural design of beams is under development by AASHTO.

**5.4 Assembly Fasteners**—Except as provided in 5.4.1, bolts and nuts shall conform to the requirements specified in Table 2 (Note 4). Bolts shall have sufficient length to provide at least “full nut” engagement when tightened in place. The number of bolts furnished shall be 2 % in excess of the theoretical number required to erect the structure or structures.

5.4.1 Bolts and nuts for use with 6 by 2-in. [150 by 50-mm] and 16 by 6-in. [400 by 150-mm] corrugations shall have the bearing surface of both bolt and nut shaped to a 1-in. [25-mm] radius spherical surface, or shall be standard-type bolts and nuts with special washers providing comparable bearing surface. Bolts and nuts for use with 15 by 5 1/2-in. [380 by 140-mm] corrugations shall have either standard bearing surfaces or bearing surfaces shaped to a 1-in. [25-mm] spherical radius.

NOTE 4—The purchaser should determine the appropriate bolt size and number of bolts per corrugation for longitudinal seams in accordance with the design criteria in Practice A 796/A 796M or other appropriate guidelines. Bolts of larger diameter than specified in Table 2 may be required with thicker plates.

**5.5 Head Wall and Bearing Anchorage**—Bolts and nuts for head wall anchorage and for anchoring arch bearings to foundations shall be fabricated as shown on the plans and shall conform to the requirements specified in Table 2.

## 6. Fabrication

**6.1 Structural Plates**—Structural plates shall be fabricated from flat sheets or plates, corrugated in accordance with 6.2, punched for bolted lap seams in accordance with 6.3, and curved to the required radius.

**6.2 Corrugations**—Corrugations shall form smooth continuous curves and tangents. Corrugations shall form annular rings (complete or partial) about the axis of the structure. The dimensions of the corrugations shall be in accordance with Table 5 for the size specified in the order.

**6.3 Bolt Holes (General)**—The bolt holes shall be punched so that all plates having like dimensions, curvature, and same size and number of bolts per foot of seam shall be interchangeable. Except as otherwise specified, the location and number of seam bolt holes shall conform to the requirements of Table 3 for the size of bolts indicated in Table 2 (see Note 4). Holes shall be provided as required for connecting headwall anchors, structural reinforcement, and miscellaneous attachments.

6.3.1 For 6 by 2-in. [150 by 52-mm] corrugations, the diameter of the bolt holes in the longitudinal seams shall not exceed the bolt diameter by more than 1/8 in. [3 mm] except those in plate corners. Bolt holes in circumferential seams, including plate corners, shall be round holes with the diameter not exceeding the bolt diameter by more than 1/4 in. [6 mm], or shall be slotted holes with a width equal to the bolt diameter plus 1/8 in. [3 mm] and a length equal to the bolt diameter plus 3/8 in. [10 mm].

6.3.2 For 15 by 5 1/2-in. [380 by 140-mm] corrugations, the diameter of the bolt holes in the longitudinal and circumferential seams shall not exceed the bolt diameter by more than 1/4 in. [6 mm]. Bolt holes for the attachment of circumferential reinforcing, where required, shall be slotted with a width not greater than the bolt diameter plus 1/4 in. [6 mm] and a length not greater than the bolt diameter plus 1/2 in. [12 mm].

6.3.3 For 16 by 6-in. [400 by 150-mm] corrugations, the diameter of bolt holes in the longitudinal seams shall not exceed the bolt diameter by more than 1/4 in. [6 mm], except for those in the plate corners and two other locations (aligned with the center hole of the group of three corner holes, and in

**TABLE 3 Bolt Hole Patterns in Structural Plate<sup>A</sup>**

Corrugation Size, in. [mm]	6 by 2 [150 by 50]	15 by 5½ [380 by 140]	16 by 6 [400 by 150]
<i>Longitudinal seams:</i>			
Number of rows	2	3	3
Holes per corrugation, each row, min:			
plates less than 0.310 [7.87] thick	1 <sup>B</sup>	2 <sup>C</sup>	2 <sup>C</sup>
plates 0.310 [7.87] and thicker	2	2 <sup>C</sup>	2 <sup>C</sup>
Spacing between rows, min, in. [mm]	2 [50]	3 [75]	4 [100]
<i>Circumferential seams:</i>			
Number of rows	1	1	1
Spacing in rows, max, in. [mm]	10 [250]	16 [400]	16.75 [425]
<i>Arch anchorage seams:</i>			
Number of rows	1	1	1
Spacing in rows, nominal max, in. [mm]	24 [600]	15 [380]	16 [400]

<sup>A</sup>All bolt holes shall be located 1.75 bolt diameters, minimum, center of hole to edge of sheet.

<sup>B</sup>For minimum of one hole per corrugation, holes shall be staggered with holes in one row in valleys and holes in the other row in crests of corrugations.

<sup>C</sup>One hole each crest and valley of all corrugations for each row.

**TABLE 4 Chemical Composition By Heat Analysis**

Corrugation Size in. [mm]		Composition, %	Tolerance Over the Maximum Limit by Product Analysis, %
6 by 2 [150 by 50]	Sulfur, max	0.05	+0.01
	Sum of carbon, manganese, phosphorus, silicon, and sulfur, max	0.75	+0.04
15 by 5½ [380 by 140] and 16 by 6 [400 by 150]	Sulfur, max	0.04	+0.01
	Sum of carbon, manganese, phosphorus, silicon, and sulfur, max	1.86	+0.13

**TABLE 5 Corrugation Requirements**

Nominal Size	Maximum Pitch <sup>A</sup>	Minimum Depth <sup>B</sup>	Minimum Inside Radius
<i>A 761 (in.)</i>			
6 by 2	6.25	1.90	1.0
15 by 5½	15.5	5.23	2.7
16 by 6	16.3	5.67	2.9
<i>A 761M (mm)</i>			
150 by 50	158	48	25
380 by 140	394	133	68
400 by 150	413	144	74

<sup>A</sup>Pitch is measured from crest to crest of corrugations, at 90° to the direction of the corrugations.

<sup>B</sup>Depth is measured as the vertical distance from a straight-edge resting on the corrugation crests parallel to the axis of the pipe to the bottom of the intervening valley.

adjacent corrugations) which will be the same as the circumferential holes. The bolt holes in the circumferential seams shall be slotted holes with a width not greater than the bolt diameter plus 3/16 in. [5 mm] and a length not greater than the bolt diameter plus 3/8 in. [110 mm].

**6.3.4 Bolt Holes in Bearings for Arches**—Bolt holes for anchoring bearings to foundation shall be punched as shown on the plans, with a spacing that is a multiple of the structural plate pitch, but not more than 24 in. [600 mm] on centers. Bolt holes shall be punched in the vertical leg of bearings to match corresponding bolt holes in the bottom arch plate.

**6.4 Special Plates**—Plates for forming skewed ends, beveled ends, or curved alignment shall be accurately cut to fit the order plans. Cut edges of plates shall be free of notches, gouges, or burrs, and shall present a workmanlike finish.

Legible identification shall be placed on each special plate to designate its proper position in the finished structure and reference to the approved erection drawings.

**6.5 Structural Reinforcement**—Members for longitudinal or circumferential reinforcing, if required, shall be as sized and located on the order plans and fabricated from materials described in 5.3.

## 7. Zinc Coating

**7.1** All structural plates, including fittings and cut ends, shall be zinc coated after cutting, corrugating, punching of holes, and welding (when required). The structural plates are permitted to be curved to the required radius either before or after zinc coating when it has been demonstrated that the zinc coating is not damaged using the specific tooling and fabrication equipment. All arch bearings and structural reinforcement shall be zinc coated after all fabrication is completed. The zinc used for the coating shall conform to Specification B 6 and shall be at least equal to the grade designated as “prime western”.

**7.2 Coating Weight [Mass] (Plates)**—Plates shall be zinc coated to provide an average coating weight [mass] of 3.0 oz/ft<sup>2</sup> [910 g/m<sup>2</sup>] of sheet (total both surfaces), and a minimum coating weight [mass] for any single specimen of 2.7 oz/ft<sup>2</sup> [820 g/m<sup>2</sup>] of sheet (total both surfaces).

**7.2.1** To determine conformance with this specification, each single value for coating weight [mass] and the average of all values, shall be rounded to the nearest 0.1 oz/ft<sup>2</sup> [10 g/m<sup>2</sup>] in accordance with the rounding method of Practice E 29.

7.3 *Coating Weight [Mass] (Structural Reinforcement and Arch Bearings)*—Members fabricated from rolled shapes shall be zinc-coated to conform to Specification A 123. Members fabricated from plate material shall be zinc-coated in accordance with 7.2.

7.4 *Repair of Damaged Zinc Coating*—Plate or accessory material on which the metallic coating has been burned by welding, or has been otherwise damaged in fabricating or handling, shall be repaired. The repair shall be done so that the completed material shall show careful finished workmanship in all particulars. Material which, in the opinion of the purchaser, has not been cleaned or coated satisfactorily shall be subject to rejection. If the purchaser so elects, the repair shall be done in his presence.

7.4.1 The damaged area shall be cleaned to bright metal by blast cleaning, power disk sanding, or wire brushing. The cleaned area shall extend at least ½ in. [13 mm] into the undamaged section of the coating. The cleaned area shall be coated within 24 h and before any rusting or soiling, using either the procedure in 7.4.2 or 7.4.3, unless specified otherwise.

7.4.2 *Zinc-Rich Paint Coating*—Zinc-rich paint shall be applied to a dry film thickness of at least 0.005 in. [0.013 mm] over the damaged section and surrounding cleaned area.

7.4.3 *Metallizing Coating*—The damaged area shall be cleaned as described in 7.4.1, except it shall be cleaned to the near-white condition. The repair coating applied to the cleaned section shall have a thickness of not less than 0.005 in. [0.13 mm] over the damaged section and shall taper off to zero thickness at the edges of the cleaned undamaged section. Metallizing shall be performed using zinc wire containing not less than 99.98 % zinc.

NOTE 5—Practice A 780 contains additional information on repair of damaged zinc coatings.

7.5 *Coating Adherence*—The coating shall adhere to the base metal so that no peeling or flaking occurs during normal handling.

## 8. Dimensions and Tolerances

8.1 *Plate Thickness*—Plate thickness shall conform to the requirements of Table 6 as specified by the purchaser from the

specified plate thicknesses listed in that table (see Note 6). For corrugated plate, the thickness shall be measured on the tangents of the corrugations. The thickness shall include both the base metal and the coating.

NOTE 6—The purchaser should determine the required thickness according to the design criteria in Practice A 796/A 796M or other appropriate guidelines.

8.2 *Cross-Section Dimensions*—Cross-section dimensions, such as diameter, span and rise, and radius of curvature, shall be measured to the inside crest of corrugations. Tolerances herein specified apply to the as-erected shape before backfill placement. The diameter of circular pipe, based on the average of two measurements at 90° to each other, shall not vary by more than ±2 % from the calculated inside diameter shown in Table 7, Table 8, and Table 9. The span and rise of pipe-arch, arch, underpass, and other noncircular structures shall be as specified within ±2 %.

NOTE 7—The purchaser should consult the fabricator to determine the standard dimensions for the various types of structures, other than circular structures.

## 9. Workmanship

9.1 Plates, fasteners, and accessories shall be of uniform quality consistent with good manufacturing and inspection practices.

## 10. Sampling and Testing

10.1 Sampling and testing of plate for chemical composition shall be in accordance with Test Methods A 751, and for mechanical requirements shall be in accordance with the procedure for sheet-type specimens in Test Methods and Definitions A 370. The manufacturer or steel supplier shall make adequate tests and measurements to ensure that the material produced complies with this specification.

10.2 *Coating Weight [Mass] Determination*—Determine the coating weight [mass] in accordance with one of the procedures described in 10.2.1, 10.2.2, or 10.2.3. The average coating weight [mass] shall be the average of three or more single-spot tests, each taken from different plates in the order. In case of dispute, results of testing in accordance with 10.2.1 shall govern.

**TABLE 6 Thickness for Zinc-Coated Plates<sup>A</sup>**

Corrugated Size in. [mm]	Specified Thickness		Minimum Thickness	
	in.	[mm]	in.	[mm]
6 by 2 [150 by 50] and 15 by 5½ [380 by 140]	0.111	[2.82]	0.099	[2.51]
	0.140	[3.56]	0.128	[3.25]
	0.170	[4.32]	0.158	[4.01]
	0.188	[4.78]	0.176	[4.47]
	0.218	[5.54]	0.206	[5.23]
	0.249	[6.32]	0.237	[6.02]
	0.280	[7.11]	0.268	[6.81]
	0.310	[7.87]	0.295	[7.49]
16 by 6 [400 by 150]	0.380	[9.65]	0.358	[9.09]
	0.118	[3.0]	0.106	[2.70]
	0.157	[4.0]	0.146	[3.70]
	0.197	[5.0]	0.185	[4.70]
	0.236	[6.0]	0.224	[5.70]
	0.276	[7.0]	0.264	[6.70]

<sup>A</sup>Thickness is measured at any point on the plate not less than ⅜ in. [10 mm] from an edge, and if corrugated, on the tangents of corrugations. There is no limit on over-thickness.

**TABLE 7 Diameter of Circular Pipe, 6 by 2-in. [150 by 50-mm] Corrugation**

Nominal Diameter Specified in. [mm]	Calculated Inside Diameter in. [mm]
60 [1500]	58.9 [1475]
66 [1650]	65.0 [1626]
72 [1800]	71.1 [1775]
78 [1950]	77.3 [1935]
84 [2100]	83.4 [2085]
90 [2250]	89.5 [2240]
96 [2400]	95.6 [2390]
102 [2550]	101.7 [2545]
108 [2700]	107.8 [2695]
114 [2850]	113.9 [2850]
120 [3000]	120.0 [3000]
126 [3150]	126.1 [3155]
132 [3300]	132.3 [3310]
138 [3450]	138.4 [3460]
144 [3600]	144.5 [3615]
150 [3750]	150.6 [3765]
156 [3900]	156.7 [3920]
162 [4050]	162.8 [4070]
168 [4200]	168.9 [4225]
174 [4350]	175.0 [4375]
180 [4500]	181.2 [4530]
186 [4650]	187.3 [4685]
192 [4800]	193.4 [4835]
198 [4950]	199.5 [4990]
204 [5100]	205.6 [5140]
210 [5250]	211.7 [5295]
216 [5400]	217.8 [5445]
222 [5550]	223.9 [5600]
228 [5700]	230.0 [5750]
234 [5850]	236.2 [5905]
240 [6000]	242.3 [6060]
246 [6150]	248.4 [6210]
252 [6300]	254.5 [6365]
258 [6450]	260.6 [6515]
264 [6600]	266.7 [6670]
270 [6750]	272.8 [6820]
276 [6900]	278.9 [6975]
282 [7050]	285.0 [7125]
288 [7200]	291.2 [7280]
294 [7350]	297.3 [7435]
300 [7500]	303.4 [7585]
306 [7650]	309.5 [7740]
312 [7800]	315.6 [7890]

10.2.1 Test for zinc coating weight [mass] in accordance with Test Method A 90/A 90M, using a specimen with an area of 5 in.<sup>2</sup> [3000 mm<sup>2</sup>] or greater. Calculate the coating weight [mass] in accordance with the procedure for zinc-coated sheet.

10.2.2 Test for zinc coating thickness using a magnetic coating-thickness gage, suitably checked and demonstrated for accuracy (Note 8). Total the coating thickness on the two surfaces of the plate, and convert to coating weight [mass] per unit area of sheet (total both surfaces) using the following relationship: 1 mil (0.001 in. = 0.59 oz/ft<sup>2</sup>) [1 μm = 7.1 g/m<sup>2</sup>].

10.2.3 Test for zinc coating weight [mass] using the X-ray fluorescence procedure of Test Method A 754.

NOTE 8—Several magnetic and electromagnetic types of coating-thickness gages are commercially available and are a satisfactory basis for

**TABLE 8 Diameter of Circular Pipe, 15 by 5.5-in. [380 by 140-mm] Corrugation**

Nominal Diameter Specified in. [mm]	Calculated Inside Diameter in. [mm]
240 [6000]	238.5 [5965]
255 [6380]	253.7 [6345]
270 [6750]	269.0 [6725]
285 [7130]	284.3 [7110]
300 [7500]	299.6 [7490]
315 [7880]	314.8 [7870]
330 [8250]	330.1 [8255]
345 [8630]	345.4 [8635]
360 [9000]	360.7 [9018]
375 [9380]	376.0 [9400]
390 [9750]	391.2 [9780]
405 [10130]	406.5 [10165]
420 [10500]	421.8 [10545]
435 [10880]	437.1 [10930]
450 [11250]	452.4 [11310]
465 [11630]	467.6 [11690]
480 [12000]	482.9 [12080]
495 [12380]	498.2 [12455]
510 [12750]	513.5 [12840]
525 [13130]	528.7 [13220]
540 [13500]	544.0 [13600]
555 [13880]	559.3 [13990]
570 [14250]	574.6 [14365]
585 [14630]	589.9 [14750]
600 [15000]	605.1 [15130]
615 [15380]	620.4 [15510]
630 [15750]	635.7 [15990]
645 [16130]	651.0 [16275]
660 [16500]	666.3 [16660]
675 [16880]	681.5 [17040]
690 [17250]	696.8 [17420]
705 [17630]	712.1 [17810]
720 [18000]	727.4 [18185]
735 [18380]	742.7 [18570]
750 [18750]	757.9 [18950]

acceptance when properly calibrated just prior to inspection use (see Practice E 376).

10.3 Determine the mechanical properties on plate prior to corrugating or other fabrication, except testing by the purchaser after fabrication is permitted for tensile and yield strengths.

10.4 Test results including chemical composition and mechanical properties shall be maintained by the steel manufacturer or supplier for seven years. Test results for coating weight [mass] or other tests, and a copy of the steel manufacturer or supplier's certified test results for chemical composition and mechanical properties, shall be maintained by the fabricator for seven years. Such results shall be made available to the purchaser upon request.

## 11. Rejection and Rehearing

11.1 Material that fails to conform to the requirements of this specification is subject to rejection. Rejection shall be reported to the manufacturer, supplier or fabricator promptly and in writing. In case of dissatisfaction with the results of the test, the manufacturer, supplier or fabricator shall make claim for a rehearing.

**TABLE 9 Diameter of Circular Pipe, 16 by 6-in. [400 by 150-mm] Corrugation**

Nominal Diameter Specified in. [mm]	Calculated Inside Diameter in. [mm]
245 [6225]	239.2 [6075]
256 [6495]	249.8 [6345]
266 [6765]	260.4 [6615]
277 [7035]	271.1 [6885]
288 [7305]	281.7 [7155]
298 [7575]	292.3 [7425]
309 [7845]	303.0 [7695]
319 [8115]	313.6 [7965]
330 [8385]	324.2 [8235]
341 [8660]	335.0 [8510]
352 [8930]	345.7 [8780]
362 [9200]	356.3 [9050]
373 [9470]	366.9 [9320]
383 [9740]	377.6 [9590]
394 [10010]	388.2 [9860]
405 [10280]	398.8 [10130]
415 [10550]	409.4 [10400]
426 [10825]	420.3 [10675]
437 [11095]	430.9 [10945]
447 [11365]	441.5 [11215]
458 [11635]	452.2 [11485]
469 [11905]	462.8 [11755]
479 [12175]	473.4 [12025]
490 [12445]	484.1 [12295]
501 [12715]	494.7 [12565]
511 [12985]	505.3 [12835]
522 [13260]	516.1 [13110]
533 [13530]	526.8 [13380]
543 [13800]	537.4 [13650]
554 [14070]	548.0 [13920]
565 [14340]	558.7 [14190]
575 [14610]	569.3 [14460]
586 [14880]	579.9 [14730]
596 [15150]	590.6 [15000]
607 [15420]	601.2 [15270]
618 [15695]	612.0 [15545]
629 [15965]	622.6 [15815]

## 12. Certification

12.1 When specified in the purchase order or contract, a steel manufacturer or supplier's certification or fabricator's certification, or both, shall be furnished to the purchaser stating that samples representing each lot have been tested and inspected in accordance with this specification and have been found to meet the requirements for the material described in the order. When specified in the purchase order or contract, a report of the test results shall be furnished.

## 13. Product Marking

13.1 Each plate shall be identified by showing the following:

13.1.1 Name of fabricator,

13.1.2 Specified zinc-coated plate thickness,

13.1.3 Specified coating weight [mass],

13.1.4 Identification showing heat number and coating lot number. The heat number is not required if the fabricator's records tie the coating lot number to a specific heat number and manufacturer, and

13.1.5 ASTM designation.

13.2 The marking shall be so placed that when the structure is erected, the identification will appear on the inside.

## 14. Keywords

14.1 corrugated steel pipe; drainage pipe; pipe—corrugated steel; steel pipe—corrugated; steel structural plate; structural plate pipe

**SUMMARY OF CHANGES**

This section identifies the location of selected changes to this specification. For the convenience of the user, Committee A05 has highlighted those changes that may impact the use of this specification. This section may also include descriptions of the changes or reasons for the changes, or both.

*A 761/A 761M - 04:*

(1) Added two steel grades to plate size “6 by 2 in. [150 by 50 mm].” The revisions were made in 4.1.6, 5.1.3, Note 2, and Table 1.

*A 761/A 761M - 03:*

Specification modified to update material properties and current fabrication practice for 15 by 5 ½-in. [380 by 140 mm] corrugated plate.

- (1) Note 2 in 5.1.3 revised to reflect higher design yield strength.
- (2) Revised 5.4.1 to add provision for standard or spherical bearing surfaces on bolts and nuts.
- (3) Added 6.3.2 to update bolt hole fabrication information.
- (4) Table 3 updated.
- (5) Table 4 updated.
- (6) Added Summary of Changes section.

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# Standard Specification for Corrugated Steel Pipe, Polymer Precoated for Sewers and Drains<sup>1</sup>

This standard is issued under the fixed designation A 762/A 762M; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

*This standard has been approved for use by agencies of the Department of Defense.*

## 1. Scope

1.1 This specification covers polymer precoated corrugated steel pipe intended for use for storm water drainage, underdrains, the construction of culverts, and similar uses. Pipe covered by this specification is not normally used for the conveyance of sanitary or industrial wastes. The steel sheet used in fabrication of the pipe has a polymer protective coating over a metallic coating of zinc, 55 % aluminum-zinc alloy, or zinc-5 % aluminum-mischmetal alloy.

1.2 The polymer precoating provides extra protection of the base metal against corrosion or abrasion, or both, in addition to that provided by the metallic coating. Some severe environments may cause corrosion problems to accessory items such as rivets or coupling band hardware that does not have a polymer coating. Additional protection for polymer precoated corrugated steel pipe can be provided by use of coatings applied after fabrication of the pipe as described in Specification A 849.

1.3 This specification does not include requirements for bedding, backfill, or the relationship between earth cover load and sheet thickness of the pipe. Experience has shown that the successful performance of this product depends upon the proper selection of sheet thickness, type of bedding and backfill, controlled manufacture in the plant, and care in the installation. The installation procedure is described in Practice A 798.

1.4 This specification is applicable to orders in either inch-pound units as A 762, or in SI units as A 762M. Inch-pound units and SI units are not necessarily equivalent. SI units are shown in brackets in the text for clarity, but they are the applicable values when the material is ordered to A 762M.

## 2. Referenced Documents

### 2.1 ASTM Standards:

A 90/A 90M Test Method for Weight [Mass] of Coating on Iron and Steel Articles with Zinc or Zinc-Alloy Coatings<sup>2</sup>

A 153/A 153M Specification for Zinc Coating (Hot-Dip) on Iron and Steel Hardware<sup>2</sup>

A 307 Specification for Carbon Steel Bolts and Studs, 60 000 psi Tensile Strength<sup>3</sup>

A 449 Specification for Quenched and Tempered Steel Bolts and Studs<sup>3</sup>

A 493 Specification for Stainless and Heat-Resisting Steel Wire for Cold Heading and Cold Forging<sup>4</sup>

A 563 Specification for Carbon and Alloy Steel Nuts<sup>3</sup>

A 563M Specification for Carbon and Alloy Steel Nuts [Metric]<sup>3</sup>

A 742/A 742M Specification for Steel Sheet, Metallic-Coated, and Polymer Precoated for Corrugated Steel Pipe<sup>2</sup>

A 760/A 760M Specification for Corrugated Steel Pipe, Metallic Coated for Sewers and Drains<sup>5</sup>

A 780 Practice for Repair of Damaged and Uncoated Areas of Hot-Dip Galvanized Coatings<sup>2</sup>

A 796/A 796M Practice for Structural Design of Corrugated Steel Pipe, Pipe-Arches, and Arches for Storm and Sanitary Sewers and Other Buried Applications<sup>2</sup>

A 798/A 798M Practice for Installing Factory-Made Corrugated Steel Pipe for Sewers and Other Applications<sup>2</sup>

A 849 Specification for Post-Applied Coatings, Pavings, and Linings for Corrugated Steel Sewer and Drainage Pipe<sup>2</sup>

A 929/A929M Specification for Steel Sheet, Metallic-Coated by the Hot-Dip Process for Corrugated Steel Pipe<sup>2</sup>

B 633 Specification for Electrodeposited Coatings of Zinc on Iron and Steel<sup>6</sup>

B 695 Specification for Coatings of Zinc Mechanically Deposited on Iron and Steel<sup>6</sup>

C 443 Specification for Joints for Circular Concrete Sewer and Culvert Pipe, Using Rubber Gaskets<sup>7</sup>

D 1005 Test Methods for Measurement of Dry-Film Thickness of Organic Coatings Using Micrometers<sup>5</sup>

D 1056 Specification for Flexible Cellular Materials—Sponge or Expanded Rubber<sup>8</sup>

<sup>1</sup> This specification is under the jurisdiction of ASTM Committee A05 on Metallic Coated Iron and Steel Products and is the direct responsibility of Subcommittee A05.17 on Corrugated Steel Pipe Specifications.

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<sup>2</sup> *Annual Book of ASTM Standards*, Vol 01.06.

<sup>3</sup> *Annual Book of ASTM Standards*, Vol 15.08.

<sup>4</sup> *Annual Book of ASTM Standards*, Vol 01.03.

<sup>5</sup> *Annual Book of ASTM Standards*, Vol 06.01.

<sup>6</sup> *Annual Book of ASTM Standards*, Vol 02.05.

<sup>7</sup> *Annual Book of ASTM Standards*, Vol 04.05.

<sup>8</sup> *Annual Book of ASTM Standards*, Vol 09.02.

F 568M Specification for Carbon and Alloy Steel Externally Threaded Metric Fasteners<sup>3</sup>

2.2 AASHTO Standard:

T 249 Test for Helical Lock Seam Corrugated Pipe<sup>9</sup>

### 3. Terminology

3.1 *Definitions of Terms Specific to This Standard:*

3.1.1 *fabricator, n*—the producer of the pipe.

3.1.2 *manufacturer, n*—the producer of the sheet.

3.1.3 *minimized coating structure, n*—a coating characterized by a finer metallurgical coating structure obtained by a treatment designed to restrict the formation of the normal coarse grain structure formed during solidification of the Zn-5 Al-MM alloy coating.

3.1.4 *purchaser, n*—the purchaser of the finished product.

3.1.5 *regular coating structure, n*—the normal coating structure resulting from unrestricted grain growth during normal solidification of the Zn-5 Al-MM alloy coating.

3.2 Abbreviations:

55 Al-Zn—55 % aluminum-zinc.

Zn-5 Al-MM—zinc-5 % aluminum-mischmetal.

MM—mischmetal.

### 4. Classification

4.1 The corrugated steel pipe covered by this specification is classified as follows:

4.1.1 *Type I*—This pipe shall have a full circular cross-section, with a single thickness of corrugated sheet, fabricated with annular (circumferential) or helical corrugations.

4.1.2 *Type IA*—This pipe shall have a full circular cross-section, with an outer shell of corrugated sheet and an inner liner of smooth (uncorrugated) sheet, fabricated with helical corrugations and lock seams.

4.1.3 *Type IR*—This pipe shall have a full circular cross-section with a single thickness of smooth sheet, fabricated with helical ribs projecting outwardly.

4.1.4 *Type II*—This pipe shall be a Type I pipe which has been reformed into a pipe arch, having an approximately flat bottom.

4.1.5 *Type IIA*—This pipe shall be a Type IA pipe which has been reformed into a pipe arch, having an approximately flat bottom.

4.1.6 *Type HR*—This pipe shall be a Type IR pipe which has been reformed into a pipe-arch, having an approximately flat bottom.

4.1.7 *Type III*—This pipe, intended for use as underdrains or for underground disposal of water, shall be a Type I pipe which has been perforated to permit the in-flow or out-flow of water.

4.1.8 *Type IIIA*—This pipe, intended for use as underdrains, shall consist of a semicircular cross section, having a smooth (uncorrugated) bottom with a corrugated top shield.

4.2 Perforations in Type III pipe are included in two classes as described in 8.3.2.

4.3 Zn-5 Al-MM alloy coated material is available in two coating classes, or structures, as follows:

4.3.1 *Class A*—Minimized coating structure, and

4.3.2 *Class B*—Regular coating structure.

### 5. Ordering Information

5.1 Orders for material to this specification shall include the following information as necessary, to adequately describe the desired product.

5.1.1 Name of material (polymer-coated corrugated steel pipe),

5.1.2 Grade of polymer coating indicating thickness on inside and outside (6.1),

5.1.3 Type of metallic coating (zinc, aluminum, 55 Al-Zn alloy, or Zn-5 Al-MM alloy) (6.1),

5.1.4 ASTM designation and year of issue, as A 762-\_\_ for inch-pound units or as A 762M-\_\_ for SI units,

5.1.5 Type of pipe (4.1),

5.1.6 Diameter of circular pipe, Table 1, or span and rise of pipe-arch section, Table 2 [Table 3] or Table 4 [Table 5],

5.1.7 Length, either total length or length of each piece and number of pieces,

5.1.8 Description of corrugations (7.2),

5.1.9 Sheet thickness (8.1.2),

5.1.10 For Type I and Type II pipe, the pipe fabrication method, whether with annular corrugations or helical corrugations (7.1.1),

NOTE 1—Pipe with annular corrugations with spot welded or riveted seams is designed by different criteria compared to pipe with helical corrugations. Pipe with annular corrugations must consider seam strength. Therefore, consideration of the method of fabrication is important when pipe is installed under certain conditions of loading.

5.1.11 Coupling bands, number, and type (9.1) if special type is required,

5.1.12 Gaskets for coupling bands, if required (9.3),

5.1.13 For Type III pipe, class of perforations, if other than Class 1 (8.3.2),

5.1.14 Certification, if required (14.1), and

5.1.15 Special requirements.

### 6. Materials and Manufacture

6.1 *Steel Sheet for Pipe*—All pipe fabricated under this specification shall be formed from polymer precoated sheet conforming to Specification A 742/A 742M.

6.1.1 The grade of coating shall be stated in the order, and the polymer thickness on both inside and outside of the pipe. The polymer coating is classified by grade corresponding to the thickness in mils (thousandths inch) on each side in inch-pound units, and the thickness in micrometres on each side in SI units.

Grade	Coating Thickness	
	in.	µm
10/10 [250/250]	0.010/0.010	250/250

6.1.1.1 Any combination of polymer coating thickness other than shown in 6.1.1 is subject to agreement between the manufacturer and the purchaser or fabricator.

6.1.2 The polymer coating is applied to steel sheet having a metallic coating of zinc, 55 % aluminum-zinc alloy, or zinc-5 % aluminum-mischmetal alloy, as described in Specifications A 929/A 929M. The type of metallic coating should be stated in the order, consistent with thickness availability as shown in

<sup>9</sup> Available from American Association of State Highway and Transportation Officials, 444 N. Capitol, Washington, DC 20001.

**A 762/A 762M**

**TABLE 1 Pipe Sizes**

Nominal Inside Diameter		Corrugation Sizes <sup>A</sup>					Ribbed Pipe			Minimum Outside Circumference <sup>B</sup>	
							1½ by ¾ in. [38 by 6.5 mm]	2⅔ by ½ in. [68 by 13 mm]	3 by 1 in. [75 by 25 mm]	5 by 1 in. [125 by 25 mm]	¾ by ¾ by 7½ in. [19 by 19 by 190 mm]
in.	mm										
4	100	X							11.4	264	
6	150	X							17.7	441	
8	200	X							24.0	598	
10	250	X							30.2	755	
12	300	X	X						36.5	912	
15	375	X	X						46.0	1148	
18	450	X	X			X		X	55.4	1383	
21	500		X			X		X	64.8	1620	
24	600		X			X		X	74.2	1854	
27	675		X			X		X	83.6	2091	
30	750		X			X		X	93.1	2483	
33	825		X			X		X	102.5	2561	
36	900		X	X	X	X		X	111.9	2797	
42	1050		X	X	X	X		X	130.8	3269	
48	1200		X	X	X	X		X	149.6	3739	
54	1350		X	X	X	X		X	168.4	4209	
60	1500		X	X	X	X		X	187.0	4675	
66	1650		X	X	X	X		X	205.7	5142	
72	1800		X	X	X	X		X	224.3	5609	
78	1950		X	X	X	X		X	243.0	6075	
84	2100		X	X	X	X		X	261.7	6542	
90	2250			X	X	X		X	280.3	7008	
96	2400			X	X	X		X	299.0	7475	
102	2550			X	X		X	X	317.6	7941	
108	2700			X	X		X	X	336.3	8408	
114	2850			X	X			X	355.0	8874	
120	3000			X	X			X	373.6	9341	
126	3150			X	X			X	392.3	9807	
132	3300			X	X			X	410.9	10274	
138	3450			X	X			X	429.6	10740	
144	3600			X	X			X	448.3	11207	

<sup>A</sup>An "X" indicates standard corrugation sizes for each nominal diameter of pipe.  
<sup>B</sup>Measured in valley of annular corrugations. Not applicable to helically corrugated pipe.

**TABLE 2 Pipe Arch Requirements 2⅔by ½-in. Corrugations (A 762)**

Pipe Arch Size, in.	Equivalent Diameter, in.	Span, <sup>A</sup> in.	Rise, <sup>A</sup> in.	Minimum Corner Radius, in.	Maximum, B, <sup>B</sup> in.
17 by 13	15	17	13	3	5¼
21 by 15	18	21	15	3	6
24 by 18	21	24	18	3	7¼
28 by 20	24	28	20	3	8
35 by 24	30	35	24	3	9½
42 by 29	36	42	29	3½	10½
49 by 33	42	49	33	4	11½
57 by 38	48	57	38	5	13½
64 by 43	54	64	43	6	15
71 by 47	60	71	47	7	16½
77 by 52	66	77	52	8	18
83 by 57	72	83	57	9	20

<sup>A</sup>A tolerance of ±1 in. or 2 % of equivalent diameter, whichever is greater, is permissible in span and rise.  
<sup>B</sup>B is defined as the vertical dimension from a horizontal line across the widest portion of the arch to the lowest portion of the base.

**TABLE 3 Pipe Arch Requirements 68 by 13-mm Corrugations (A 762M)**

Pipe Arch Size, mm	Equivalent Diameter, mm	Span, <sup>A</sup> mm	Rise, <sup>A</sup> mm	Minimum Corner Radius, mm	Maximum B, <sup>B</sup> mm
430 by 330	375	430	330	75	135
530 by 380	450	530	380	75	155
610 by 460	525	610	460	75	185
710 by 510	600	710	510	75	205
780 by 560	675	780	560	75	225
885 by 610	750	870	630	75	240
970 by 690	825	970	690	75	255
1060 by 740	900	1060	740	90	265
1240 by 840	1050	1240	840	100	290
1440 by 970	1200	1440	970	130	345
1620 by 1100	1350	1620	1100	155	380
1800 by 1200	1500	1800	1200	180	420
1950 by 1320	1650	1950	1320	205	460
2100 by 1450	1800	2100	1450	230	510

<sup>A</sup>A tolerance of 25 mm or 2 % of equivalent diameter, whichever is greater, will be permissible in span and rise.  
<sup>B</sup>B is defined as the vertical dimension from a horizontal line across the widest portion of the arch to the lowest portion of the base.

Table 6. If the type of metallic coating is not stated, zinc-coated sheet conforming to Specification A 929/A 929M shall be used. All pipe furnished on the order shall have the same metallic coating unless otherwise specified.

6.2 *Steel Sheet for Coupling Bands*—The sheet used in fabricating coupling bands shall conform to Specification A 742/A 742M with the same polymer coating grade as that used for fabrication of the pipe furnished under the order, and

having the same metallic coating.

6.2.1 As an alternative, the steel sheet used in fabricating coupling bands shall conform to Specification A 929/A 929M with the same metallic coating as that used for the fabrication of the pipe, with the sheet having a bituminous coating

**TABLE 4 Pipe Arch Requirements 3 by 1-in. or 5 by 1-in. Corrugations (A 762)**

Pipe Arch Size, in.	Equivalent Diameter, in.	Span, <sup>A</sup> in.	Rise, <sup>A</sup> in.	Minimum Corner Radius, in.
40 by 31	36	40 - 1.8	31 + 1.8	5
46 by 36	42	46 - 2.1	36 + 2.1	6
53 by 41	48	53 - 2.4	41 + 2.4	7
60 by 46	54	60 - 2.7	46 + 2.7	8
66 by 51	60	66 - 3.0	51 + 3.0	9
73 by 55	66	73 - 3.3	55 + 3.3	12
81 by 59	72	81 - 3.6	59 + 3.6	14
87 by 63	78	87 - 4.4	63 + 4.4	14
95 by 67	84	95 - 4.8	67 + 4.8	16
103 by 71	90	103 - 5.2	71 + 5.2	16
112 by 75	96	112 - 5.6	75 + 5.6	18
117 by 79	102	117 - 5.9	79 + 5.9	18
128 by 83	108	128 - 6.4	83 + 6.4	18
137 by 87	114	137 - 6.9	87 + 6.9	18
142 by 91	120	142 - 7.1	91 + 7.1	18

<sup>A</sup>Negative and positive numbers listed with span and rise dimensions are negative and positive tolerances, no tolerance in opposite direction.

**TABLE 5 Pipe Arch Requirements 75 by 25-mm or 125 by 25-mm Corrugations (A 762M)**

Pipe Arch Size, mm	Equivalent Diameter, mm	Span, <sup>A</sup> mm	Rise, <sup>A</sup> mm	Minimum Corner Radius, mm
1010 by 790	900	1010 - 45	790 + 45	130
1160 by 920	1050	1160 - 55	920 + 55	155
1340 by 1050	1200	1340 - 60	1050 + 60	180
1520 by 1170	1350	1520 - 70	1170 + 70	205
1670 by 1300	1500	1670 - 75	1300 + 75	230
1850 by 1400	1650	1850 - 85	1400 + 85	305
2050 by 1500	1800	2050 - 95	1500 + 95	355
2200 by 1620	1950	2200 - 110	1620 + 110	355
2400 by 1720	2100	2400 - 120	1720 + 120	410
2600 by 1820	2250	2600 - 130	1820 + 130	410
2840 by 1920	2400	2840 - 145	1920 + 145	460
2970 by 2020	2550	2970 - 150	2020 + 150	460
3240 by 2120	2700	3240 - 165	2120 + 165	460
3470 by 2220	2850	3470 - 175	2220 + 175	460
3600 by 2320	3000	3600 - 180	2320 + 180	460

<sup>A</sup>Negative and positive numbers listed with span and rise dimensions are negative and positive tolerances, no tolerance in opposite direction.

**TABLE 6 Thickness of Metallic Coated Steel Sheet<sup>A</sup>**

Specified Thickness		Metallic Coating Type		
in.	mm	Zinc Coated	55 Al-Zn Alloy Coated	Zn-5 Al-MM Alloy Coated
0.040	1.02	X	X	X
0.052	1.32	X	X	X
0.064	1.63	X	X	X
0.079	2.01	X	X	X
0.109	2.77	X	X	X
0.138	3.51	X	X	X
0.168	4.27	X		X

<sup>A</sup>An "X" indicates sheet thicknesses for the different metallic coating types included in Specification A 742/A 742M. The specified thickness is the thickness of the metallic-coated sheet and does not include the thickness of the polymer coating.

according to Specification A 849, except the requirement for the thickness of bituminous coating shall not apply.

6.2.2 When specifically permitted by the purchaser, coupling bands shall be made of steel sheet conforming to Specification A 929/A 929M with the same metallic coating as that used for the fabrication of the pipe, without bituminous coating.

6.3 *Rivets*—The rivets used in riveted pipe shall be of the same material as the base metal specified for the corrugated sheets. They shall be thoroughly galvanized or sherardized. If bolts and nuts are substituted for rivets (see 7.3.1), they shall meet the following requirements:

	Bolts	Nuts
For A 762 pipe	A 449	A 563, Grade C
[For A 762M pipe]	[F 568, Class 8.8]	[A 563M, Class 12]

The bolts and nuts shall be hot-dip galvanized in conformance with Specification A 153, or be mechanically galvanized in conformance with Specification B 695, Class 40.

6.3.1 When specified in the order, rivets used in riveted pipe to be installed in severely corrosive environments shall be made of stainless steel conforming to any of the S3xxx designations in Specification A 493. Stainless steel rivets may be substituted for those described in 6.3 at the fabricator's option.

NOTE 2—Some polymer-precoated pipe in a severe environment is reported to have failed due to corrosion of rivets conforming to 6.3, while the sheet was essentially unaffected. The use of stainless steel rivets is recommended to overcome such problems.

6.4 *Hardware for Coupling Bands*—Bolts and nuts for coupling bands shall conform to the following requirements:

	Bolts	Nuts
For A 762 pipe	A 307	A 563, Grade A
[For A 762M pipe]	[F 568, Class 4.6]	[A 563M, Class 5]

6.4.1 Bolts, nuts, and other threaded items used with coupling bands shall be zinc coated by one of the following processes: hot-dip process as provided in Specification A 153; electroplating process as provided in Specification B 633, Class Fe/Zn 8; or mechanical process as provided in Specification B 695, Class 8. Other hardware items used with coupling bands shall be zinc coated by one of the following processes: hot-dip process as provided in Specification A 153; electroplating process as provided in Specification B 633, Class Fe/Zn 25; or mechanical process as provided in Specification B 695, Class 25.

6.5 *Gaskets*—If gaskets are used in couplings, they shall be a band of expanded rubber meeting the requirements of Specification D 1056 for the "RE" closed cell grades, or O-rings meeting the requirements of Specification C 443.

## 7. Fabrication

7.1 *General Requirements*—Pipe shall be fabricated in full circular cross section except for Type IIIA pipe which is described in 8.4.

7.1.1 Type I pipe shall have annular corrugations with lap joints fastened with rivets or shall have helical corrugations with a continuous lock seam extending from end to end of each length of pipe. The type of fabrication used shall be the option of the fabricator unless otherwise specified.

7.1.2 Type IA pipe shall be fabricated with a smooth liner and helically corrugated shell integrally attached at helical lock seams extending from end to end of each length of pipe. The shell shall have corrugations of nominal 2<sup>2</sup>/<sub>3</sub> or 3-in. [68 or 75-mm] pitch.

7.1.3 Type IR pipe shall be fabricated with helical ribs projecting outward with a continuous lock seam extending

from end to end of each length of pipe.

**7.2 Corrugations**—The corrugations shall be either annular or helical as provided in 7.1. The direction of the crests and valleys of helical corrugations shall not be less than 60° from the axis of the pipe for pipe diameters larger than 21 in. [525 mm], and not less than 45° from the axis for pipe diameters of 21 in. [525 mm] and smaller.

**7.2.1** For Type I and IA pipe, corrugations shall form smooth continuous curves and tangents. The dimensions of the corrugations shall be in accordance with Table 7 for the size indicated in the order, except if the depth measurement of one or more corrugations is less than the minimum depth in Table 7. Then the depth of all corrugations between adjacent seams shall be measured and the values of Table 8 for minimum average depth and minimum corrugation depth shall apply.

**NOTE 3**—Inspection frequently consists of measurement of the depth of one or a few corrugations. If such measurement indicates insufficient depth, application of the requirements in Table 8 provide for acceptance where greater depth of some corrugations compensates for lack of depth of others. These measurements would normally be made at one location between seams on a length of pipe.

**7.2.2** For Type IR pipe, the corrugations shall be essentially rectangular ribs projecting outward from the pipe wall. The dimensions and spacing of the ribs shall be in accordance with Table 9 for the size indicated on the order. For the 11.5 in. [292 mm] rib spacing, if the sheet between the ribs does not include a lock seam, a stiffener shall be included midway between ribs. This stiffener shall have a nominal radius of 0.25 in. [6.4 mm] and a minimum height of 0.20 in. [5.1 mm] toward the outside of the pipe.

**NOTE 4**—The nominal dimensions and properties for smooth corrugations and for ribs are given in Practice A 796.

**7.3 Riveted Seams**—The longitudinal seams shall be staggered to the extent that no more than three thicknesses of sheet are fastened by any rivet. Pipe to be reformed into pipe-arch

**TABLE 7 Corrugation Requirements for Types I, IA, II, IIA, and III Pipe**

Nominal Size	Maximum Pitch <sup>A</sup>	Minimum Depth <sup>B</sup>	Inside Radius <sup>C</sup>	
			Nominal	Minimum
A 762, in.				
1½ by ¼ <sup>D</sup>	1⅞	0.24	⅞ <sub>32</sub>	0.25
2⅝ by ½	2⅞	0.48	1¼ <sub>16</sub>	0.5
3 by 1	3¼	0.95	⅞ <sub>16</sub>	0.5
5 by 1	5⅞ <sub>16</sub>	0.95	1.57	1.4
A 762M, mm				
38 by 6.5 <sup>D</sup>	48	6.0	7	6.5
68 by 13	73	12	17	12
75 by 25	83	24	14	12
125 by 25	135	24	40	36

<sup>A</sup>Pitch is measured from crest to crest of corrugations, at 90° to the direction of the corrugations.

<sup>B</sup>Depth is measured as the vertical distance from a straightedge resting on the corrugation crests parallel to the axis of the pipe, to the bottom of the intervening valley. If the depth measurement of one or more corrugations is less than the value indicated herein, the depth of all corrugations between seams shall be measured, and the requirements of Table 2 shall be applied. (see 7.2.1).

<sup>C</sup>Minimum inside radius requirement does not apply to a corrugation containing a helical lock seam.

<sup>D</sup>The corrugation size of 1½ by ¼ in. [38 by 6.5 mm] is available only in helically corrugated pipe.

**TABLE 8 Referee Requirements for Corrugation Depth<sup>A</sup>**

Nominal Size	Diameter	Minimum Average Depth	Minimum Corrugation Depth
Inches			
1½ by ¼	all	0.24	0.20
2⅝ by ½	12 through 21	0.48	0.40
2⅝ by ½	over 21	0.49	0.44
3 by 1	all	0.98	0.92
5 by 1	all	0.98	0.92
Millimetres			
38 by 6.5	all	6.1	5
68 by 13	300 through 525	12.1	10
68 by 13	over 525	12.4	11
75 by 25	all	24.9	23
125 by 25	all	24.9	23

<sup>A</sup>See 7.2.1 for application of Table 2.

shape shall have seams meeting the longitudinal seam requirement of 8.2.2.

**NOTE 5**—Fabrication of pipe without longitudinal seams in 120° of arc, so that the pipe may be installed without longitudinal seams in the invert, is subject to negotiation between the purchaser and the fabricator.

**7.3.1** The size of rivets, number per corrugation, and width of lap at the longitudinal seam shall be as stated in Table 10, depending on sheet thickness, corrugation size, and diameter of pipe. For pipe with 1-in. [25-mm] deep corrugations, ½-in. [Metric M12] diameter bolts and nuts may be used in place of rivets on a one-for-one replacement ratio. Circumferential seams shall be riveted using rivets of the same size as for longitudinal seams and shall have a maximum rivet spacing of 6 in. [150 mm], measured on centers, except that six rivets will be sufficient in 12-in. [300-mm] diameter pipe.

**7.3.2** All rivets shall be driven cold in such a manner that the sheets shall be drawn tightly together throughout the entire lap. The center of a rivet shall be no closer than twice its diameter from the edge of the sheet. All rivets shall have neat, workmanlike, and full hemispherical heads or heads of a form acceptable to the purchaser, shall be driven without bending, and shall completely fill the hole.

**7.4 Helical Lock Seams**—The lock seam for Type I pipe shall be formed in the tangent element of the corrugation profile with its center near the neutral axis of the corrugation profile. The lock seam for Type IA pipe shall be in the valley of the corrugation, shall be spaced not more than 30 in. [760 mm] apart, and shall be formed from both the liner and the shell in the same general manner as Type I helical lock seam pipe. The lock seam for Type IR pipe shall be formed in the flat zone of the pipe wall, midway between two ribs.

**7.4.1** The edges of the sheets within the cross section of the lock seam shall lap at least ⅝<sub>32</sub>in. [4.0 mm] for pipe 10 in. [250 mm] or less in diameter and at least ⅝<sub>16</sub> in. [7.9 mm] for pipe greater than 10 in. [250 mm] in diameter, with an occasional tolerance of -10 % of lap width allowable. The lapped surfaces shall be in tight contact. The profile of the sheet shall include a retaining offset adjacent to the 180° fold (as described in AASHTO T 249 ) of one sheet thickness on one side of the lock seam, or one-half sheet thickness on both sides of the lock seam, at the fabricator's option. There shall be no visible cracks in the metal, loss of metal-to-metal contact, or excessive

**TABLE 9 Rib Requirements for Types IR and IIR Pipe**

Nominal Size Rib	Rib			Bottom Outside Radius, min	Bottom <sup>A</sup> Outside Radius, max avg.	Top Outside Radius, min	Top <sup>A</sup> Outside Radius, max avg.
	Width <sup>B</sup> , min	Depth <sup>C</sup> , min	Spacing <sup>D</sup> , max				
A 762, in.							
¾ by ¾ by 7½	0.68	0.73	7¾	0.10	0.25	0.10+t	0.25+t
¾ by 1 by 8½	0.68	0.95	8¾	0.10	0.25	0.10+t	0.25+t
¾ by 1 by 11½	0.68	0.95	11¾	0.10	0.25	0.10+t	0.25+t
A 762M, mm							
19 by 19 by 180	17	19	197	2.5	6.0	2.5+t	6.0+t
19 by 25 by 216	17	24	222	2.5	6.0	2.5+t	6.0+t
19 by 25 by 292	17	24	298	2.5	6.0	2.5+t	6.0+t

<sup>A</sup>The average of the two top rib radii and of the two bottom rib radii shall be within the minimum and maximum tolerances. The term "outside" refers to the outside surface of the pipe.

<sup>B</sup>Width is a dimension of the inside of the rib but is measured on the outside of the pipe (outside of the rib) and shall meet or exceed the spaced minimum width plus two times the wall thickness (that is,  $2t + 0.68$  in. [ $2t + 17$  mm]).

<sup>C</sup>Depth is an average of ribs within one sheet width measured from the inside by placing a straightedge across the open rib and measuring to the bottom of the rib.

<sup>D</sup>Spacing is an average of three adjacent ribs spacings for ¾ by ¾ by 7½ pipe and two adjacent rib spacings for the ¾ by 1 by 11½ pipe and ¾ by 1 by 8½ pipe measured center-to-center of the ribs, at 90° to the direction of the ribs.

**TABLE 10 Riveted Longitudinal Seams**

Specified Sheet Thickness	Nominal Corrugation Size							
	2⅝ by ½ in. [68 by 13 mm] <sup>A,B</sup>		3 by 1 in. [75 by 25 mm] <sup>C,D</sup>		5 by 1 in. [125 by 25 mm] <sup>D,E</sup>			
	Rivet diameters, min							
in.	mm	in.	mm	in.	mm	in.	mm	
0.052	1.32	⅝	8.0	...	...	...	...	
0.064	1.63	⅝	8.0	⅜	9.5	⅜	9.5	
0.079	2.01	⅝	8.0	⅜	9.5	⅜	9.5	
0.109	2.77	⅜	9.5	7/16	11.0	7/16	11.0	
0.138	3.51	⅜	9.5	7/16	11.0	7/16	11.0	
0.168	4.27	⅜	9.5	7/16	11.0	7/16	11.0	

<sup>A</sup>One rivet each valley for pipe diameters 36 in. [900 mm] and smaller. Two rivets each valley for pipe diameters 42 in. [1050 mm] and larger.

<sup>B</sup>Minimum width of lap is 1½ in. [38 mm] for pipe diameters 36 in. [900 mm] and smaller, and 3 in. [75 mm] for pipe diameters 42 in. [1050 mm] and larger.

<sup>C</sup>Two rivets each valley for all pipe diameters.

<sup>D</sup>Minimum width of lap is 3 in. [75 mm] for pipe of all diameters.

<sup>E</sup>Two rivets each crest and valley for all pipe diameters.

angularity on the interior of the 180° fold of metal at the completion of forming the lock seam.

7.4.2 Specimens cut from production pipe normal to and across the lock seam shall develop the tensile strength as provided in Table 11, when tested according to AASHTO T 249. For Type IA pipe, the lock seam strength shall be as tabulated based on the thickness of the corrugated shell.

7.4.3 When the ends of helically corrugated lock seam pipe have been rerolled to form annular corrugations, either with or without a flanged end finish, the lock seam in the rerolled end shall not contain any visible cracks in the base metal and the tensile strength of the lock seam shall be not less than 60 % of that required in 7.4.2.

**TABLE 11 Lock Seam Tensile Strength**

Specified Sheet Thickness <sup>A</sup>		Lock Seam Tensile Strength, per Unit Width, min	
in.	mm	lbf/in.	kN/m
0.040	1.02	175	30
0.052	1.32	240	42
0.064	1.63	340	60
0.079	2.01	520	91
0.109	2.77	700	122
0.138	3.50	880	154
0.168	4.27	1200	210

<sup>A</sup>For Type 1A pipe, the thickness shall be that of the corrugated shell.

### 7.5 End Finish:

7.5.1 To facilitate field jointing, the ends of individual pipe sections with helical corrugations may be rerolled to form annular corrugations extending at least two corrugations from the pipe end or to form an upturned flange meeting the requirements in 7.5.2, or both. The diameter of ends shall not exceed that of the pipe barrel by more than the depth of the corrugation. All types of pipe ends, whether rerolled or not, shall be matched in a joint such that the maximum difference in the diameter of abutting pipe ends is ½ in. [13 mm].

7.5.1.1 When pipe with any size helical corrugation (except 1-½ by ¼ in. [38 by 6.5 mm]) or rib is rerolled to form annular corrugations in the ends, the usual size of the annular corrugation is 2-⅔ by ½ in. [68 by 13 mm].

7.5.2 If a flanged finish is used on the ends of individual pipe sections to facilitate field jointing, the flange shall be uniform in width, be not less than ½ in. [13 mm] wide, and shall be square to the longitudinal axis of the pipe.

7.5.3 The ends of all pipe which will form the inlet and outlet of culverts, fabricated of sheets having nominal thicknesses of 0.079 in. [2.01 mm] and less, shall be reinforced in a manner approved by the purchaser, when specified.

## 8. Pipe Requirements

### 8.1 Type I, Type IA, and Type IR Pipe:

8.1.1 *Pipe Dimensions*—The nominal diameter of the pipe shall be as stated in the order, selected from the sizes listed in Table 1. The size of corrugations which are standard for each size of pipe are also shown in Table 1. The average inside diameter of circular pipe and pipe to be reformed into pipe arches shall not vary more than 1 % or ½ in. [13 mm], whichever is greater, from the nominal diameter when measured on the inside crest of the corrugations. Alternatively, for pipe having annular corrugations, conformance with the inside diameter requirement may be determined by measuring the outside circumference, for which minimum values are given in Table 1.

NOTE 6—The outside circumference of helically corrugated pipe is influenced by the corrugation size and the angle of the corrugations, affecting the number of corrugations crossed, therefore no minimum circumferential measurement can be specified.

8.1.2 *Sheet Thickness*—Sheet thickness shall be as specified

by the purchaser from the specified sheet thicknesses listed in Table 6 (Note 7 and Note 8). For Type IA pipe, the thickness of both the shell and the liner shall be given; the thickness of the corrugated shell shall be not less than 60 % of the equivalent Type I pipe; the liner shall have a nominal thickness of at least 0.040 in. [1.02 mm]; and the sum of the specified thicknesses of shell and liner shall equal or exceed the specified thickness of an equivalent pipe of identical corrugations as the shell according to the design criteria in Practice A 796.

NOTE 7—The sheet thicknesses indicated in Table 6 are the thicknesses listed as available in Specification A 742/A 742M. The specified thickness is based on the thickness of the metallic-coated sheet, not including the thickness of polymer coating.

NOTE 8—The purchaser should determine the required thickness for Types I, IA or IR pipe, or Types I, IA or IR pipe to be reformed into Types II, IIA, or IIR pipe according to the design criteria in Practice A 796 or other appropriate guidelines.

8.1.3 When specified by the purchaser, the finished pipe shall be factory elongated to the extent specified. The elongation shall be accomplished by the use of a mechanical apparatus which will produce a uniform deformation throughout the length of the section.

**8.2 Type II, IIA and IIR Pipe:**

8.2.1 *Pipe-Arch Dimensions*—Pipe furnished as Type II, IIA, or IIR shall be made from Type I, IA, or IR pipe, respectively, and shall be reformed to provide a pipe-arch shape. All applicable requirements for Types I, IA, and IR pipe shall be met by finished Types II, IIA, and IIR pipe respectively. Pipe arches shall conform to the dimensional requirements of Table 2 [Table 3], Table 4 [Table 5], or Table 12 [Table 13]. All dimensions shall be measured from the inside crests of corrugations for Type II pipe or from the inside liner or surface for Types IIA or IIR pipe, respectively.

8.2.2 *Longitudinal Seams*—Longitudinal seams of riveted pipe-arches shall not be placed in the corner radius.

8.2.3 Reforming Type IR into Type IIR pipe shall be done in such a manner as to avoid damage to the external ribs.

**8.3 Type III Pipe:**

8.3.1 Type III pipe shall have a full circular cross section and shall conform to the requirements for Type I pipe, and in addition shall contain perforations conforming to one of the classes described in 8.3.2.

8.3.2 *Perforations*—The perforations shall conform to the requirements for Class 1, unless otherwise specified in the

**TABLE 12 Pipe Arch Requirements— $\frac{3}{4}$  by  $\frac{3}{4}$  by 7 $\frac{1}{2}$ -in. or  $\frac{3}{4}$  by 1 by 11 $\frac{1}{2}$ -in. Rib Corrugations**

Pipe Arch Size, in.	Equivalent Diameter, in.	Span, <sup>A</sup> in.	Rise, <sup>A</sup> in.	Minimum Corner Radius, in.
20 by 16	18	20-1.0	16 + 1.0	5
23 by 19	21	23-1.0	19 + 1.0	5
27 by 21	24	27-1.5	21 + 1.5	5
33 by 26	30	33-1.5	26 + 1.5	5
40 by 31	36	40-1.8	31 + 1.8	5
46 by 36	42	46-2.1	36 + 2.1	6
53 by 41	48	53-2.4	41 + 2.4	7
60 by 46	54	60-2.7	46 + 2.7	8
66 by 51	60	66-3.0	51 + 3.0	9

<sup>A</sup>Negative and positive numbers listed with span and rise dimensions are negative and positive tolerances, no tolerance in opposite direction.

**TABLE 13 Pipe Arch Requirements—19 by 19 by 190-mm or 19 by 25 by 292-mm Rib Corrugations**

Pipe Arch Size, mm	Equivalent Diameter, mm	Span, <sup>A</sup> mm	Rise, <sup>A</sup> mm	Minimum Corner Radius, mm
500 by 400	450	500-25	400 + 25	125
550 by 450	500	550-25	450 + 25	125
680 by 530	600	680-40	530 + 40	125
770 by 630	700	770-40	630 + 40	126
880 by 690	800	880-40	690 + 40	125
1000 by 770	900	1000-50	770 + 50	125
1100 by 850	1000	1100-50	850 + 50	150
1330 by 1030	1200	1330-50	1030 + 50	175
1550 by 1200	1400	1550-70	1200 + 70	200
1780 by 1360	1600	1780-85	1360 + 85	300

<sup>A</sup>Negative and positive numbers listed with span and rise dimensions are negative and positive tolerances, no tolerance in opposite direction.

order. Class 1 perforations are for pipe intended to be used for subsurface drainage. Class 2 perforations are for pipe intended to be used for subsurface disposal of water, but pipe containing Class 2 perforations may also be used for subsurface drainage.

8.3.2.1 *Class 1 Perforations*—The perforations shall be approximately circular and cleanly cut; shall have nominal diameters of not less than  $\frac{3}{16}$  in. [4.8 mm] nor greater than  $\frac{3}{8}$  in. [9.5 mm]; and shall be arranged in rows parallel to the axis of the pipe. The perforations shall be located on the inside crests or along the neutral axis of the corrugations, with one perforation in each row for each corrugation. Pipe connected by couplings or bands may be unperforated within 4 in. [100 mm] of each end of each length of pipe. The rows of perforations shall be arranged in two equal groups placed symmetrically on either side of a lower unperforated segment corresponding to the flow line of the pipe. The spacing of the rows shall be uniform. The distance between the center lines of rows shall be not less than 1 in. [25 mm]. The minimum number of longitudinal rows of perforations, the maximum heights of the centerlines of the uppermost rows above the bottom of the invert, and the inside chord lengths of the unperforated segments illustrated in Fig. 1 shall be as specified in Table 14.

NOTE 9—Pipe with Class 1 perforations is generally available in diameters from 4 to 21 in. [100 to 525 mm] inclusive, although perforated pipe in larger sizes may be obtained.

8.3.2.2 *Class 2 Perforations*—The perforations shall be circular holes with nominal diameters of  $\frac{5}{16}$  to  $\frac{3}{8}$  in. [8.0 to 9.5 mm], or slots with nominal width of  $\frac{3}{16}$  to  $\frac{5}{16}$  in. [4.8 to 8.0 mm] and not to exceed  $\frac{1}{2}$  in. [13 mm] in length. The perforations shall be uniformly spaced around the full periphery of the pipe. The perforations shall provide an opening area of not less than 3.3 in.<sup>2</sup>/ft<sup>2</sup> [230 cm<sup>2</sup>/m<sup>2</sup>] of pipe surface based on nominal diameter and length of pipe.

NOTE 10—Thirty perforations,  $\frac{3}{8}$ -in. diameter, per square foot [323 perforations, 9.5-mm diameter, per square metre] satisfies this requirement.

8.4 *Type IIIA Pipe*—Type IIIA pipe shall be fabricated of an unperforated semicircular bottom section with a top shield of corrugated steel, both of nominal 0.052 in. [1.32 mm] thickness or greater. The smooth semicircular bottom section shall be approximately 4 $\frac{5}{8}$  in. [120 mm] in diameter and shall have a

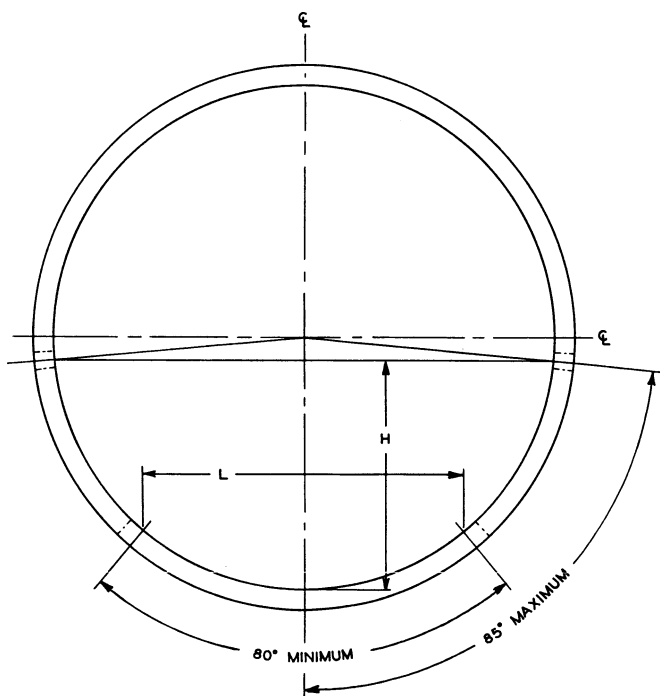


FIG. 1 Requirements for Perforations

TABLE 14 Rows of Perforations, Height *H* of the Centerline of the Uppermost Rows Above the Invert, and Chord Length *L* of Unperforated Segment, for Class 1 Perforations

Internal Diameter of Pipe		Rows of Perforations <sup>A</sup>	<i>H</i> , max <sup>B</sup>		<i>L</i> , min <sup>B</sup>	
in.	mm		in.	mm	in.	mm
4	100	2	1.8	46	2.6	64
6	150	4	2.8	69	3.8	96
8	200	4	3.7	92	5.1	128
10	250	4	4.6	115	6.4	160
12	300	6 <sup>C</sup>	5.5	138	7.7	192
15	375	6 <sup>C</sup>	6.9	172	9.6	240
18	450	6 <sup>C</sup>	8.3	207	11.5	288
21	525	6	9.7	241	13.4	336
24 and larger	600 and larger	8	<i>D</i>	<i>D</i>	<i>D</i>	<i>D</i>

<sup>A</sup>Minimum number of rows. A greater number of rows for increased inlet area shall be subject to agreement between the purchaser and the fabricator. Note that the number of unit length in each row (and inlet area) is dependent on the corrugation pitch.

<sup>B</sup>See Fig. 1 for location of dimensions *H* and *L*.

<sup>C</sup>Minimum of 4 rows permitted in pipe with 1½ by ¼-in. [38 by 6.5-mm] corrugations.

<sup>D</sup>*H*(max) = 0.46*D*; *L*(min) = 0.64*D*, where *D* = internal diameter of pipe, inches or millimetres as appropriate.

continuous lip extending outward along each side; the corrugated top shield shall be approximately 6¾ in. [160 mm] wide including a ¾-in. [19-mm] sloping overhang on each side and shall be secured to the lip of the bottom section by integral tabs spaced at about 3½ in. [90 mm] center to center. The top shield shall have corrugations approximately 7/8 in. [22 mm] center to center and approximately 5/16-in. [8.0-mm] depth.

## 9. Coupling Bands

9.1 *Types of Coupling Bands*—Field joints for each type of corrugated steel pipe shall maintain pipe alignment during construction and prevent infiltration of fill material during the

life of the installation. Coupling bands may be of the following types: bands with annular corrugations; bands with helical corrugations; bands with projections (dimples); channel bands for upturned flanges, with or without annular corrugations; flat bands; and smooth sleeve-type couplers. Except as provided in 9.1.1 through 9.1.4, the type of coupling furnished shall be the option of the fabricator unless the type is specified in the order.

NOTE 11—Bands are classified according to their ability to resist shear, moment, and tensile forces as described in Practice A 798 and identified as “standard joints” and “special joints.” The first four types of bands listed in 9.1, and meeting the requirements of 9.2, are expected to meet the requirements for “standard joints.” Some may also be able to meet the requirements for “special joints,” but such capability should be determined by analysis or test.

9.1.1 *Annular Corrugations*—Coupling bands with annular corrugations shall be used only with pipe with annular corrugations, or helical pipe in which the ends have been rerolled to form annular corrugations. The corrugations in the band shall have the same dimensions as the corrugations in the pipe end, or may be of a special design to engage either the first or second corrugation from the end of each pipe. The band may also include a U-shaped channel to accommodate upturned flanges on the pipe.

9.1.2 *Helical Corrugations*—Coupling bands with helical corrugations shall be used only with pipe with helically corrugated ends. The corrugations in the bands shall be designed to properly mesh with the corrugations in the pipe.

9.1.3 *Projections*—Coupling bands with projections (dimples) may be used with pipe with either annular or helical corrugations. The bands shall be formed with the projections in annular rows with one projection for each corrugation of helical pipe. Bands 10½ or 12 in. [265 or 300 mm] wide shall have two annular rows of projections, and bands 16¼ or 22 in. [415 or 560 mm] wide shall have four annular rows of projections.

9.1.4 *Channel Bands*—Channel bands may be used only with pipe having upturned flanges on the pipe ends.

9.1.5 *Smooth Sleeve-Type*—Smooth sleeve-type couplers and flat bands may be used with Types III and IIIA pipe of 12-in. [300-mm] diameter or smaller.

9.1.6 *Flat Bands*—When specified by the purchaser, flat bands may be used on pipe with helically corrugated ends, annular corrugated pipe, or helical pipe on which the ends have been rerolled to form annular corrugations.

9.2 *Requirements*—Coupling bands shall be fabricated to lap on an equal portion of each of the pipe sections to be connected. The ends of the bands shall lap or be fabricated to form a tightly closed joint upon installation. Coupling band thickness shall conform to the requirements in Table 15 based on the sheet thickness of the pipe to be connected, except as provided in 9.2.4 and 9.2.5. The band width shall be not less

TABLE 15 Coupling Band Thickness

Nominal Pipe Thickness		Nominal Coupling Band Thickness, Minimum	
in.	mm	in.	mm
0.109 and thinner	2.77 and thinner	0.052	1.32
0.138	3.51	0.064	1.63
0.168	4.27	0.079	2.01



than as shown in Table 16. The bands shall be connected in a manner approved by the purchaser with suitable galvanized devices such as: angles, or integrally or separately formed and attached flanges, bolted with galvanized or cadmium-plated bolts; bars and straps; wedge lock and straps; or lugs. Coupling bands shall be fastened with the following size of bolts:

9.2.1 Pipe diameters 18 in. [450 mm] and less, 3/8-in. [Metric M10] diameter.

9.2.2 Pipe diameters 21 in. [525 mm] and greater, 1/2-in. [Metric M12] diameter.

9.2.3 Type IIIA pipe, 5/16-in. [Metric M8] diameter.

9.2.4 If flanges are provided on the pipe ends, the coupling may also be made by interlocking the flanges with a preformed channel band or other band incorporating a locking channel not less than 3/4 in. [19 mm] in width. The depth of the channel shall be not less than 1/2 in. [13 mm]. The channel band shall have a minimum nominal thickness of 0.079 in. [2.01 mm].

9.2.5 Smooth sleeve-type couplings and flat bands shall be steel having a nominal thickness of not less than 0.040 in. [1.02 mm], or as an option, may be a plastic sleeve to provide equivalent strength. The coupling shall be close-fitting, to hold the pipe firmly in alignment without the use of sealing compounds or gaskets. The coupling or flat band shall contain a device so that the band or coupling will lap equally on the two pipes being joined. The overall length of the coupling shall be equal to or greater than the nominal diameter of the pipe.

9.3 *Gaskets*—Where infiltration or exfiltration is a concern, the couplings may be required to have gaskets. The closed-cell expanded rubber gaskets shall be a continuous band, approximately 7 in. [180 mm] wide and approximately 3/8 in. [9.5 mm] thick. Rubber O-ring gaskets shall be 13/16-in. [20-mm] diameter for pipe diameters of 36 in. [900 mm] or smaller, and 7/8-in.

[22-mm] diameter for large pipe diameters, having 1/2-in. [13-mm] deep end corrugations. Rubber O-ring gaskets shall be 1 3/8 in. [35 mm] in diameter for pipe having 1-in. [25-mm] deep end corrugations.

NOTE 12—Riveted pipe is not watertight, having small openings at the intersection of longitudinal and circumferential seams. Therefore this type of fabrication should not be used where watertightness is a concern unless the pipe is bituminous coated or lined prior to installation.

9.4 Other types of coupling bands or fastening devices which are equally effective as those described, and which comply with the joint performance criteria of Practice A 798 may be used when approved by the purchaser.

### 10. Workmanship, Finish, and Appearance

10.1 The completed pipe shall show careful, finished workmanship in all particulars. Pipe which has been damaged, either during fabrication or in shipping, may be rejected unless repairs are made which are satisfactory to the purchaser. Among others, the following defects shall be considered as constituting poor workmanship:

- 10.1.1 Variation from a straight centerline.
- 10.1.2 Elliptical shape in pipe intended to be round.
- 10.1.3 Dents or bends in the metal.
- 10.1.4 Polymer coating or metallic coating which has been bruised, broken, disbonded, or otherwise damaged.
- 10.1.5 Lack of rigidity.
- 10.1.6 Illegible markings on the steel sheet.
- 10.1.7 Ragged or diagonal sheared edges.
- 10.1.8 Uneven laps in riveted pipe.
- 10.1.9 Loose, unevenly lined, or unevenly spaced rivets.
- 10.1.10 Loosely formed lockseams.

### 11. Repair of Damaged Coatings

11.1 Pipe on which either the polymer coating or the underlying metallic coating has been damaged in fabricating or handling shall be repaired. Damage to the metallic coating shall be repaired as described in 11.2 through 11.4. Damage to the polymer coating shall be repaired as described in 11.5. The repair shall be done so that the completed pipe shall show careful finished workmanship in all particulars. Pipe which, in the opinion of the purchaser, has not been cleaned or coated satisfactorily may be rejected. If the purchaser so elects, the repair shall be done in his presence.

11.2 Damage to the metallic coating shall be repaired as provided in Practice A 780 (Note 13), except as described herein. The damaged area shall be cleaned to bright metal by blast cleaning, power disk sanding, or wire brushing. The cleaned area shall extend at least 1/2 in. [13 mm] into the undamaged section of the coating. The cleaned area shall be coated within 24 h and before any rusting or soiling.

NOTE 13—While Practice A 780 specifically refers to repair of damaged zinc coatings, the same procedures are applicable to repair of 55 Al-Zn alloy and Zn-5 Al-MM alloy coatings except as described in this section.

11.3 *Paints Containing Zinc Dust*—Paints containing zinc dust as described in the Materials section of Practice A 780 shall be applied to a dry film thickness of at least 0.005 in. [0.13 mm] over the damaged section and surrounding cleared

**TABLE 16 Coupling Band Width Requirements**

Nominal Corrugation Size <sup>A</sup>	Nominal Pipe Inside Diameter <sup>B</sup>	Coupling Band Width, min		
		Annular Corrugated Bands	Helically Corrugated Bands	Bands With Projections
Specification A 762, in.				
1 1/2 by 1/4	4 to 18	10 1/2	7	10 1/2
2 2/3 by 1/2	12 to 36	7	12	10 1/2
	42 to 72	10 1/2	12	10 1/2
3 by 1	78 to 84 <sup>C</sup>	10 1/2	12	16 1/4
	36 to 72	12	14	10 1/2
5 by 1	78 to 120	12	14	16 1/4
	36 to 72	20	22	12
	78 to 120	20	22	22
Specification A 762M, mm				
38 by 6.5	100 to 450	265	180	265
68 by 13	300 to 900	180	300	265
	1050 to 1800	265	300	265
	1950 to 2100 <sup>C</sup>	265	300	415
75 by 25	900 to 1800	300	350	265
	1950 to 3600	300	350	415
125 by 25	900 to 1800	500	560	300
	1950 to 3600	500	560	560

<sup>A</sup>For helically corrugated pipe with rerolled ends, the nominal corrugation size refers to the dimensions of the end corrugations in the pipe. When pipe with helical corrugations 2 2/3 by 1/2, 3 by 1, or 5 by 1 in. (68 by 13, 75 by 25, or 125 by 25 mm) are rolled to form annular corrugations in the ends, the usual size of the annular corrugations is 2 2/3 by 1/2 in. (68 by 13 mm).

<sup>B</sup>Equivalent diameter for Type II pipe.

<sup>C</sup>Diameters through 144 in. (3600 mm) for annular corrugated bands used on rerolled ends of helically corrugated pipe.

area. Paints containing zinc dust shall be used for repair of damage to all types of metallic coatings such as zinc and alloys of zinc and aluminum.

11.4 *Metallizing Coating*—The damaged area shall be cleaned as described in 11.2, except it shall be cleaned to the near-white condition. The repair coating applied to the cleaned section shall have a thickness of not less than 0.005 in. [0.13 mm] over the damaged section and shall taper off to zero thickness at the edges of the cleaned undamaged section.

11.4.1 Where zinc coating is to be metallized, it shall be done with zinc wire containing not less than 99.98 % zinc.

11.4.2 Where 55 % aluminum-zinc alloy coating is to be metallized, it shall be done using zinc wire containing not less than 99.98 % zinc, aluminum wire containing not less than 99 % aluminum, or an alloy wire of 55 % aluminum and 45 % zinc by weight.

11.4.3 Where Zn-5 Al-MM alloy coating is to be metallized, it shall be done using zinc wire containing not less than 99.98 % zinc or an alloy wire of 85 % zinc and 15 % aluminum by weight.

11.5 Areas of damaged polymer coating shall be repaired with a polymer coating similar and compatible with respect to durability, adhesion, and appearance of the original polymer coating.

11.5.1 Polymer coating damaged during shipping or installation may be repaired using materials as described in 11.5 or by the application of a protective coating material conforming to Specification A 849.

## 12. Inspection

12.1 The purchaser or representative shall have free access to the fabricating plant for inspection, and every facility shall be extended for this purpose. This inspection shall include an

examination of the pipe for the items in 10.1 and the specific requirements of this specification applicable to the type of pipe and method of fabrication.

12.2 On a random basis, samples may be taken for chemical analysis and metallic and polymer coating measurements for check purposes. These samples will be secured from fabricated pipe or from sheets or coils of the material used in fabrication of the pipe. The weight [mass] of metallic coating shall be determined in accordance with Test Method A 90/A 90M. The thickness of polymer coating shall be measured according to Test Method D 1005.

## 13. Rejection

13.1 Pipe failing to conform to the specific requirements of this specification, or that shows poor workmanship, may be rejected. This requirement applies not only to the individual pipe, but to any shipment as a whole where a substantial number of pipes are defective. If the average deficiency in length of any shipment of pipe is greater than 1 %, the shipment may be rejected.

## 14. Certification

14.1 When specified in the purchase order or contract, a manufacturer's or fabricator's certification, or both, shall be furnished to the purchaser stating that samples representing each lot have been tested and inspected in accordance with this specification and have been found to meet the requirements for the material described in the order. When specified in the order, a report of the test results shall be furnished.

## 15. Keywords

15.1 corrugated steel pipe; drainage pipe; metallic coated steel pipe; polymer precoated; sewer pipe

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# Standard Practice for Repair of Damaged and Uncoated Areas of Hot-Dip Galvanized Coatings<sup>1</sup>

This standard is issued under the fixed designation A 780; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reappraisal. A superscript epsilon ( $\epsilon$ ) indicates an editorial change since the last revision or reappraisal.

*This standard has been approved for use by agencies of the Department of Defense.*

## 1. Scope

1.1 This practice describes methods which may be used to repair damaged hot-dip galvanized coatings on hardware, structural shapes, and other products fabricated prior to hot-dip galvanizing, and uncoated areas remaining after initial hot-dip galvanizing. The damage may be the result of welding or cutting (flame), in which case the coating will be damaged predominantly by burning. This practice can also be used to repair hot-dip galvanized coatings damaged by excessively rough handling during shipping or erection. Requirements concerning the renovation of uncoated areas remaining after initial hot-dip galvanizing are contained within the applicable material specification.

1.2 This practice describes the use of low melting point zinc alloy repair rods or powders made specifically for this purpose, the use of paints containing zinc dust, and the use of sprayed zinc (metallizing).

1.3 The extent of repair shall be limited to an area mutually agreeable to the contracting parties. Similarly, contracting parties shall agree to the repair method to be used.

1.4 *This standard does not purport to address the safety problems, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

1.5 The values stated in inch-pound units are to be regarded as the standard. The values given in parentheses are for information only.

## 2. Referenced Documents

### 2.1 ASTM Standards:

A 902 Terminology Relating to Metallic Coated Steel Products<sup>2</sup>

D 520 Specification for Zinc Dust Pigment<sup>3</sup>

### 2.2 Society for Protective Coatings (SSPC) Documents:

SSPC-PA2 Measurement of Dry Paint Thickness with Magnetic Gages<sup>4</sup>

SSPC-SP2 Hand Tool Cleaning<sup>4</sup>

SSPC-SP5/NACE No.1 White Metal Blast Cleaning<sup>4</sup>

SSPC-SP10/NACE No.2 Near-White Blast Cleaning<sup>4</sup>

SSPC-SP11 Power Tool Cleaning to Bare Metal<sup>4</sup>

## 3. Terminology

3.1 *Definitions*—For definitions of terms used in this practice, refer to Terminology A 902.

## 4. Materials

4.1 *Properties*—The material used for repairs shall have the following characteristics:

4.1.1 One application of the material shall provide a coating thickness of at least 2.0 mils (50.8  $\mu\text{m}$ ).

4.1.2 The applied coating shall provide barrier protection and shall preferably be anodic to steel.

4.1.3 Application of the coating material shall be possible under shop or field conditions.

4.2 *Types*—There are three types of material that possess the required properties and may be used to repair damaged galvanized coatings, as follows:

4.2.1 *Zinc-Based Solders*—Zinc alloy solders are to be used for repairs. The most common types of solders are zinc-cadmium, zinc-tin-lead, and zinc-tin-copper alloys. Zinc-cadmium and zinc-tin-lead alloys have liquidus temperatures in the ranges from 518 to 527°F (270 to 275°C) and 446 to 500°F (230 to 260°C), respectively. (The liquidus temperature is that temperature above which an alloy is completely molten.) The zinc-tin-copper alloys have a liquidus temperature in the range from 660 to 670°F (349 to 354°C), but they are applied while in a semisolid state in the preferred application temperature range from 480 to 570°F (250 to 300°C). The solders can be used in rod form or as powders. Annex A1 describes the use of zinc-based solders.

4.2.2 *Paints Containing Zinc Dust*—These are usually based on organic binders, pre-mixed and formulated specifically for use on steel surfaces. Paints containing zinc dust, with concentrations of zinc dust in the range of 65 to 69 % or above

<sup>1</sup> This practice is under the jurisdiction of ASTM Committee A05 on Metallic Coated Iron and Steel Products and is the direct responsibility of Subcommittee A05.13 on Structural Shapes and Hardware Specifications.

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<sup>2</sup> *Annual Book of ASTM Standards*, Vol 01.06.

<sup>3</sup> *Annual Book of ASTM Standards*, Vol 06.03.

<sup>4</sup> Available from Steel Structures Painting Council, 4400 Fifth Ave., Pittsburgh, PA 15213.

92 % in the dried film, are considered equally effective for the repair of damaged galvanized coatings. The repair paint to be used shall be selected by the galvanizer, unless the purchaser specifies a particular concentration or paint system. Corrosion resistance and service performance are very dependent on the properties of the paint system, the extent of surface preparation, and skills of individual applicators. Annex A2 describes the use of paints containing zinc dust. Specification D 520 describes the zinc dust component of these paints.

4.2.3 *Sprayed Zinc*—This method involves the application of a zinc coating by spraying the surface to be repaired with

droplets of molten metal using wire or ribbon, or powder processes. Annex A3 describes the use of sprayed zinc.

4.3 For further information, reference may be made to the papers, procedures, and specifications in Refs. (1) through (4) (see list of references at the end of this practice).

## 5. Keywords

5.1 coatings—zinc; galvanized coating repair; galvanized coatings; touch-up; zinc coating repair; zinc coatings

## ANNEXES

### (Mandatory Information)

#### A1. REPAIR USING ZINC-BASED ALLOYS

A1.1 Clean the surface to be reconditioned using a wire brush, a light grinding action, or mild blasting. To ensure that a smooth reconditioned coating can be effected, surface preparation shall extend into the surrounding, undamaged galvanized coating.

A1.2 If the area to be reconditioned includes welds, first remove all weld flux residue and weld spatter (of a size that cannot be removed by wire brushing or blast cleaning) by mechanical means, such as chipping, grinding, or power scaling, etc.

A1.3 Preheat the cleaned area to be reconditioned to at least 600°F (315°C). Do not overheat the surface beyond 750°F (400°C), nor allow the surrounding galvanized coating to be

burned. Wire brush the surface to be reconditioned during preheating. Pre-flux, if necessary.

A1.4 Rub the cleaned, preheated area with the repair stick to deposit an evenly distributed layer of the zinc alloy. When powdered zinc alloys are used, sprinkle the powder on the cleaned, preheated surface and spread out with a spatula or similar tool. The thickness of the applied coating shall be as agreed upon between the contracting parties.

A1.5 When the repair has been effected, remove flux residue by rinsing with water or wiping with a damp cloth.

A1.6 Take thickness measurements with either a magnetic, electromagnetic, or eddy-current gage to ensure that the applied coating is as specified.

#### A2. REPAIR USING PAINTS CONTAINING ZINC DUST

A2.1 Preparation of the damaged surface will be influenced by the type of paint selected and the anticipated service conditions. Experience shows that in general, organic zinc-rich systems are tolerant of marginal surface preparation. Most organic paints containing zinc dust are not critical of climatic or atmospheric conditions for curing. The following general guidelines shall apply:

A2.1.1 Surfaces to be reconditioned with paints containing zinc dust shall be clean, dry, and free of oil, grease, preexisting paint, and corrosion by-products.

A2.1.2 Where anticipated, field service conditions include immersion, blast clean the surface in accordance with SSPC-SP10/NACE No. 2 near white metal. For less critical field exposure conditions, clean the surface to bare metal, in accordance with SSPC-SP11, as a minimum. Where circumstances do not allow blast or power tool cleaning, it is permissible to hand tool areas clean in accordance with SSPC-SP2. To ensure that a smooth reconditioned coating can be effected, surface preparation shall extend into the undam-

aged galvanized coating. The method and extent of surface preparation shall be mutually agreeable to the contracting parties.

A2.1.3 If the area to be reconditioned includes welds, first remove all weld flux residue and weld spatter (of a size that cannot be removed by wire brushing or blast cleaning) by mechanical means, such as chipping, grinding, or power scaling, etc.

A2.1.4 Spray or brush-apply the paints containing zinc dust to the prepared area. Apply the paint as in accordance with the manufacturer's printed instructions in a single application employing multiple passes to achieve a dry film thickness to be agreed upon between the contracting parties. Allow adequate curing time before subjecting repaired items to service conditions in accordance with the manufacturer's printed instructions.

A2.1.5 Take thickness measurements with either a magnetic, electromagnetic, or eddy-current gage to ensure that the applied coating is as specified in accordance with SSPC-PA2.

### **A3. REPAIR USING SPRAYED ZINC (METALLIZING)**

A3.1 Surfaces to be reconditioned by zinc metallizing shall be clean, dry and free of oil, grease, and corrosion products.

A3.2 If the area to be reconditioned includes welds, first remove all flux residue and weld spatter of a size or type that cannot be removed by blast cleaning by mechanical means, that is, chipping, etc.

A3.3 Blast clean the surface to be reconditioned in accordance with SSPC-SP5/NACE No. 1, white metal.

A3.4 To ensure that a smooth reconditioned coating can be effected, surface preparation shall be extended into the surrounding undamaged galvanized coating.

A3.5 Apply the coating to the clean and dry surface by means of metal-spraying pistols fed with either zinc wire or

zinc powder. Apply the sprayed coating as soon as possible after surface preparation and before visible deterioration of the surface has occurred.

A3.6 The surface of the sprayed coating shall be of uniform texture, free of lumps, coarse areas, and loosely adherent particles.

A3.7 The nominal thickness of the sprayed zinc coating shall be previously agreed upon between the contracting parties.

A3.8 Take thickness measurements with either a magnetic, electromagnetic, or eddy-current gage to ensure that the applied coating is as specified.

### **REFERENCES**

- (1) Van Eijnsbergen, J. F. H., et al, "Reconditioning Damaged Galvanized Surfaces," 6th International Conference on Hot Dip Galvanizing, Interlaken, June 1961, pp. 128-141.
- (2) SSPC-Paint-20, "Zinc Rich Coatings, Type I Inorganic, Type II Organic," Steel Structures Painting Council, 4400 Fifth Ave., Pittsburgh, PA 15213, 1979.
- (3) MIL-P-21035 (Ships), Military Specification, "Paint, High Zinc Dust Content, Galvanizing Repair," Amendment 1, U.S. Government Printing Office, Washington, DC, 1970.
- (4) "Recommended Practices for Fused Thermal Sprayed Deposits," American Welding Society, Inc., 550 N.W. LeJeune Rd., Miami, FL 33135, 1975.

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# Standard Specification for Steel Sheet, 55 % Aluminum-Zinc Alloy-Coated by the Hot-Dip Process<sup>1</sup>

This standard is issued under the fixed designation A 792/A 792M; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon ( $\epsilon$ ) indicates an editorial change since the last revision or reapproval.

*This standard has been approved for use by agencies of the Department of Defense.*

## 1. Scope\*

1.1 This specification covers 55 % aluminum-zinc alloy-coated steel sheet in coils and cut lengths.

1.2 This product is intended for applications requiring corrosion resistance or heat resistance, or both.

1.3 The product is produced in a number of designations, types, and grades which are designed to be compatible with differing application requirements.

1.4 Product furnished under this specification shall conform to the applicable requirements of the latest issue of Specification A 924 /A 924M, unless otherwise provided herein.

1.5 This specification is applicable to orders in either inch-pound units (as A 792) or SI units (as A 792M). Values in inch-pound and SI units are not necessarily equivalent. Within the text, SI units are shown in brackets. Each system shall be used independent of the other.

1.6 Unless the order specifies the “M” designation (SI units), the product shall be furnished to inch-pound units.

1.7 The text of this specification references notes and footnotes that provide explanatory material. These notes and footnotes, excluding those in tables and figures, shall not be considered as requirements of this specification.

1.8 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

## 2. Referenced Documents

### 2.1 ASTM Standards:<sup>2</sup>

A 90/A 90M Test Method for Weight [Mass] of Coating on Iron and Steel Articles with Zinc or Zinc-Alloy Coatings

A 568/A 568M Specification for Steel, Sheet, Carbon, and High-Strength, Low-Alloy, Hot-Rolled and Cold-Rolled, General Requirements for

A 902 Terminology Relating to Metallic Coated Steel Products

A 924/A 924M Specification for General Requirements for Steel Sheet, Metallic-Coated by the Hot-Dip Process

E 517 Test Method for Plastic Strain Ratio  $r$  for Sheet Metal

E 646 Test Method for Tensile Strain-Hardening Exponents

( $n$ -Values) of Metallic Sheet Materials

## 3. Terminology

3.1 *Definitions*—See Terminology A 902 for definitions of general terminology relating to metallic-coated hot-dip products.

### 3.2 Definitions of Terms Specific to This Standard:

3.2.1 *regular spangle*—the unaltered 55 % aluminum-zinc (Al-Zn) crystal structure that occurs during normal solidification of a hot-dip coated steel sheet.

3.2.2 *high temperature steel*—a product intended for use in elevated temperature applications.

## 4. Classification

4.1 The material is available in several designations, as follows:

4.1.1 *Commercial Steel*—CS Types A, B, and C,

4.1.2 *Forming Steel*—FS,

4.1.3 *Drawing Steel*—DS,

4.1.4 *High Temperature Steel*—HTS, and

4.1.5 *Structural Steel*—SS.

4.2 Structural steel is available in several grades based on mechanical properties. Structural Steel Grade 50 [340] is available in three classes based on tensile strength.

4.3 The product is available in several coating weights [masses] with the coating designation in accordance with Table 1.

<sup>1</sup> This specification is under the jurisdiction of ASTM Committee A05 on Metallic-Coated Iron and Steel Products and is the direct responsibility of Subcommittee A05.11 on Sheet Specifications.

Current edition approved October 1, 2003. Published December 2003. Originally approved in 1983. Last previous edition approved in 2002 as A 792/A 792M – 02.

<sup>2</sup> For referenced ASTM standards, visit the ASTM website, [www.astm.org](http://www.astm.org), or contact ASTM Customer Service at [service@astm.org](mailto:service@astm.org). For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

\*A Summary of Changes section appears at the end of this standard.

**TABLE 1 Weight [Mass] of Coating Requirements<sup>A</sup>**

NOTE 1—The coating thickness may be estimated from the coating weight [mass] by using Table X1.1.

Coating Designation	Minimum Requirements		
	Triple-Spot Test	Single-Spot Test	
	Inch-Pound Units		
Total Both Sides, oz/ft <sup>2</sup>	Total Both Sides, oz/ft <sup>2</sup>		
AZ50	0.50	0.43	
AZ55	0.55	0.50	
AZ60	0.60	0.52	

Coating Designation	Minimum Requirements		
	Triple-Spot Test	Single-Spot Test	
	SI Units		
Total Both Sides, g/m <sup>2</sup>	Total Both Sides, g/m <sup>2</sup>		
AZM150	150	130	
AZM165	165	150	
AZM180	180	155	

<sup>A</sup> The coating designation number is the term by which this product is specified. Because of the many variables and changing conditions that are characteristic of continuous hot-dip coating lines, the weight [mass] of the coating is not always evenly divided between the two surfaces of a sheet, nor is the coating evenly distributed from edge to edge. However, it can normally be expected that not less than 40 % of the single-spot test limit will be found on either surface.

## 5. Ordering Information

5.1 55 % aluminum-zinc alloy-coated steel sheet in coils and cut lengths is produced to thickness requirements expressed to 0.001 in. [0.01 mm]. The thickness of the sheet includes the base metal and the coating.

5.2 Orders for product to this specification shall include the following information, as necessary, to adequately describe the desired product.

5.2.1 Name of product (steel sheet, 55 % aluminum-zinc alloy coated),

5.2.2 Designation of sheet steel {CS (Type A, B, or C), FS, DS, HTS, or SS}.

5.2.2.1 When a CS type is not specified, Type B will be furnished.

5.2.3 Strength grade as required for Structural Steel,

5.2.4 ASTM designation number and year of issue, such as A 792 – \_\_\_\_ for inch-pound units or A 792M – \_\_\_\_ for SI units,

5.2.5 Coating designation,

5.2.6 Chemically treated or not chemically treated,

5.2.7 Oiled or not oiled,

5.2.8 Dimensions (show thickness, width, flatness requirements (if appropriate), and length (if cut length)). The purchaser shall specify the appropriate table of thickness tolerances in Specification A 924/A 924M that applies to the order, that is, the table of thickness tolerances for 3/8-in. [10-mm] edge distance, or the table of thickness tolerances for 1-in. [25-mm] edge distance.

5.2.9 Coil size requirements (specify maximum outside diameter (OD), acceptable inside diameter (ID), and maximum weight [mass]),

5.2.10 Packaging,

5.2.11 Certification, if required, and heat analysis and mechanical property report,

5.2.12 Application (show part identification and description), and

5.2.13 Special requirements (if any).

5.2.13.1 If required, the product may be ordered to a specified base metal thickness. See Supplementary Requirement S1.

NOTE 1—Typical ordering descriptions are as follows:

Steel sheet, 55 % aluminum-zinc alloy-coated, Forming Steel (FS), ASTM A 792 – \_\_\_\_, coating designation AZ55, chemical treatment, no oil, minimum 0.035 by 36 in. by coil, 48-in. maximum OD, 24-in. ID, 10 000-lb maximum, for muffler wrappers.

Steel sheet, 55 % aluminum-zinc alloy-coated, Commercial Steel (CS Type A), ASTM A 792M – \_\_\_\_, coating designation AZM150, chemical treatment, no oil, minimum 0.90 by 900 mm by coil, 1200-mm maximum OD, 600-mm ID, 4500-kg maximum, for building panels.

## 6. Chemical Composition

### 6.1 Base Metal:

6.1.1 The heat analysis of the base metal shall conform to the requirements of Table 2 for CS (Types A, B, and C), FS, DS, HTS, Table 3 for SS.

6.1.2 Include each of the elements listed in Tables 2 and 3 in the report of heat analysis. When the amount of copper, nickel, chromium, or molybdenum is less than 0.02 %, report the analysis either as <0.02 % or the actual determined value. When the amount of vanadium, titanium, or columbium is less than 0.008 %, report the analysis either as <0.008 % or the actual determined value.

6.2 *Coating Composition*—The 55 % aluminum-zinc alloy coating composition, by weight, is nominally 55 % aluminum, 1.6 % silicon, and the balance zinc.

**TABLE 2 Chemical Requirements<sup>A</sup>**

Designation	Composition, %—Heat Analysis Element, Maximum, Unless Otherwise Shown												
	C	Mn	P	S	Al	Cu	Ni	Cr	Mo	V	Cb	Ti <sup>B</sup>	N
CS Type A <sup>C,D,E</sup>	0.10	0.60	0.030	0.035	...	0.20	0.20	0.15	0.06	0.008	0.008	0.025	...
CS Type B <sup>C,F</sup>	0.02 to 0.15	0.60	0.030	0.035	...	0.20	0.20	0.15	0.06	0.008	0.008	0.025	...
CS Type C <sup>C,D,E</sup>	0.08	0.60	0.10	0.035	...	0.20	0.20	0.15	0.06	0.008	0.008	0.025	...
FS <sup>C,G</sup>	0.02 to 0.10	0.50	0.020	0.030	...	0.20	0.20	0.15	0.06	0.008	0.008	0.025	...
DS <sup>D,E</sup>	0.06	0.50	0.020	0.025	0.01, min	0.20	0.20	0.15	0.06	0.008	0.008	0.025	...
HTS <sup>C</sup>	0.02 to 0.15	0.60	0.040, min	0.035	...	0.20	0.20	0.15	0.06	0.008	0.008	0.025	...

<sup>A</sup>Where an ellipsis (. . .) appears in the table, there is no requirement, but the analysis result shall be reported.

<sup>B</sup>For steels containing more than 0.02% carbon, titanium is permitted to 0.025% provided the ratio of % titanium to % nitrogen does not exceed 3.4.

<sup>C</sup>When a deoxidized steel is required for the application, the purchaser has the option to order CS, FS, and HTS to a minimum of 0.01 % total aluminum.

<sup>D</sup>Steel is permitted to be furnished as a vacuum degassed or chemically stabilized steel, or both, at producer's option.

<sup>E</sup>For carbon levels less than or equal to 0.02%, vanadium, columbium, or titanium, or combinations thereof are permitted to be used as stabilizing elements at producer's option. In such cases, the applicable limit for vanadium and columbium shall be 0.10% max. and the limit for titanium shall be 0.15% max.

<sup>F</sup>For CS, specify Type B to avoid carbon levels below 0.02 %.

<sup>G</sup>Shall not be furnished as a stabilized steel.

**TABLE 3 Chemical Requirements**

Composition, %—Heat Analysis Element, maximum, Unless Otherwise Shown												
Designation	C	Mn	P	S	Cu	Ni	Cr	Mo	V	Cb	Ti <sup>A</sup>	N <sup>B</sup>
Structural Steel:												
Grade 33 [230]	0.20	1.15	0.04	0.040	0.20	0.20	0.15	0.06	0.008	0.008	0.025	...
Grade 37 [255]	0.20	1.15	0.10	0.040	0.20	0.20	0.15	0.06	0.008	0.008	0.025	...
Grade 40 [275]	0.25	1.15	0.10	0.040	0.20	0.20	0.15	0.06	0.008	0.008	0.025	...
Grade 50 Class 1, Class 2, and Class 4 [340 Class 1, Class 2, and Class 4]	0.25	1.15	0.20	0.040	0.20	0.20	0.15	0.06	0.008	0.008	0.025	...
Grade 80 [550]	0.20	1.15	0.04	0.040	0.20	0.20	0.15	0.06	0.008	0.015	0.025	...

<sup>A</sup>Titanium is permitted to 0.025 % provided the ratio of % titanium to % nitrogen does not exceed 3.4.

<sup>B</sup>Where an ellipsis ( . . . ) appears in the table, there is no requirement, but the analysis shall be reported.

## 7. Mechanical Properties

7.1 Structural Steel sheet shall conform to the mechanical property requirements of Table 4 for the grade specified.

7.2 The typical mechanical properties for CS (Types A, B, and C), FS, DS, and HTS are listed in Table 5. These typical mechanical properties are nonmandatory. They are intended solely to provide the purchaser with as much information as possible to make an informed decision on the steel to be specified. Values outside these ranges are to be expected.

7.3 All tests for mechanical properties shall be conducted in accordance with the methods described in Specification A 924/A 924M.

### 7.4 Bending Properties:

7.4.1 *Minimum Inside Radii for Cold Bending*—Structural Steel sheet is commonly fabricated by cold bending. There are many interrelated factors that affect the ability of a steel to cold form over a given radius under shop conditions. These factors include thickness, strength level, degree of restraint, relationship to rolling direction, chemistry, and base metal microstructure. Table lists the suggested minimum inside radii for 90°

**TABLE 4 Mechanical Property Requirements, Structural Steel Base Metal (Longitudinal)**

Inch-Pound Units			
Grade	Yield Strength, min, ksi	Tensile Strength, <sup>A</sup> min, ksi	Elongation in 2 in., min, %
33	33	45	20
37	37	52	18
40	40	55	16
50 Class 1	50	65	12
50 Class 2	50	...	12
50 Class 4	50	60	12
80 <sup>B</sup>	80 <sup>C</sup>	82	...
SI Units			
Grade	Yield Strength, min, MPa	Tensile Strength, min, MPa	Elongation in 50 mm, min, %
230	230	310	20
255	255	360	18
275	275	380	16
340 Class 1	340	450	12
340 Class 2	340	...	12
340 Class 4	340	410	12
550 <sup>B</sup>	550 <sup>C</sup>	570	...

<sup>A</sup> Where an ellipsis ( . . . ) appears in the table, there is no requirement.

<sup>B</sup> For sheet thicknesses of 0.028 in. and thinner, no tension test is required if the hardness result is Rockwell B 85 or higher.

<sup>C</sup> As there is no discontinuous yield curve, the yield strength should be taken as the stress at 0.5 % elongation under load or 0.2 % offset.

**TABLE 5 Typical Ranges of Mechanical Properties (Nonmandatory)<sup>A, B</sup>**

Designation	Longitudinal Direction				
	Yield Strength		Elongation 2 in. [50 mm] %	$r_m$ Value <sup>C</sup>	$n$ Value <sup>D</sup>
	ksi	MPa			
CS Type A	30/60	[205/410]	≥20	<i>E</i>	<i>E</i>
CS Type B	35/60	[245/410]	≥20	<i>E</i>	<i>E</i>
CS Type C	30/65	[205/450]	≥15	<i>E</i>	<i>E</i>
FS	25/40	[170/275]	≥24	1.0/1.4	0.16/0.20
DS	20/35	[140/240]	≥30	1.3/1.7	0.18/0.22
HTS	30/65	[205/450]	≥15	<i>E</i>	<i>E</i>

<sup>A</sup> The typical mechanical property values presented in this table are nonmandatory. They are intended solely to provide the purchaser with as much information as possible to make an informed decision on the steel to be specified. Values outside of these ranges are to be expected. The purchaser may negotiate with the supplier if a specific or restricted range is required for the application.

<sup>B</sup> These typical mechanical properties apply to the full range of steel sheet thicknesses. The yield strength tends to increase and some of the formability values tend to decrease as the sheet thickness decreases.

<sup>C</sup>  $r_m$  Value—Average plastic strain ratio as described in Test Method E 517.

<sup>D</sup>  $n$  Value—Strain hardening exponent as described in Test Method E 646.

<sup>E</sup> No typical properties have been established.

cold bending for Structural Steels. They presuppose “hard way” bending (bend axis parallel to the rolling direction) and reasonably good shop forming practices. Where possible, the use of larger radii or “easy way” bends are recommended for improved performance.

7.4.2 Fabricators should be aware that cracks may initiate upon bending a sheared or cold-worked edge. This is not considered to be a fault of the steel but is rather a function of the induced localized cold-work zone.

## 8. Coating Properties

8.1 *Coating Weight [Mass]*—Coating weight [mass] shall conform to the requirements as shown in Table 1 for the specific coating designation.

### 8.2 Coating Weight [Mass] Tests:

8.2.1 Coating weight [mass] tests shall be performed in accordance with the requirements stated in Specification A 924/A 924M.

8.2.2 The referee method to be used shall be the dilute hydrochloric acid method, in Test Method A 90/A 90M.

8.3 *Coating Bend Test*—The coating bend test specimens for all designations other than Structural Steel shall be capable of being bent through 180° flat on itself in any direction without flaking on the outside of the bend only. For Structural Steel, the coating bend test inside diameter shall have a relation



**TABLE 6 Coating Bend Test Requirements—Structural Steel**

Grade	Ratio of the Inside Bend Diameter to Thickness of the Specimen (Any Direction)
33 [230]	1½
37 [255]	2
40 [275]	2½
50 Class 1, Class 2, and Class 4 [340 Class 1, Class 2, and Class 4]	<sup>A</sup>
80 [350]	<sup>A</sup>

<sup>A</sup> Grades not subject to bend test requirements.

to the thickness of the specimen as shown in Table 6. Flaking of the coating within 0.25 in. [6 mm] of the edge of the bend specimen shall not be cause for rejection.

### 9. Dimensions and Permissible Variations

9.1 All dimensions and permissible variations shall comply with the requirements of Specification A 924/A 924M.

### 10. Keywords

10.1 coatings, metallic; 55 % aluminum-zinc alloy coating; steel sheet, metallic coated

## SUPPLEMENTARY REQUIREMENTS

The following standardized supplementary requirements are for use when desired by the purchaser. These additional requirements shall apply only when specified on the order.

### S1. Base Metal Thickness

S1.1 The specified minimum thickness shall apply to the base metal only.

S1.2 The coating designation shown on the order indicates the coating to be applied to the specified minimum base metal thickness.

S1.3 The applicable tolerances for base metal thickness are shown in Tables 16 and 17, Thickness Tolerance of Cold-Rolled Sheet (Carbon and High-Strength, Low-Alloy Steel), of Specification A 568/A 568M.

## APPENDIXES

### (Nonmandatory Information)

### X1. RELATIONSHIP BETWEEN COATING WEIGHT [MASS] AND THICKNESS

**TABLE X1.1 Conversion Factors Between Coating Weight [Mass] and Thickness<sup>A</sup>**

Coating Weight [Mass]		Coating Thickness	
oz/ft <sup>2</sup>	g/m <sup>2</sup>	mils	µm
1.0	305.15 <sup>B</sup>	3.2	81.28 <sup>B</sup>
0.00328 <sup>B</sup>	1.0	0.010487 <sup>B</sup>	0.26636 <sup>B</sup>
0.3125 <sup>B</sup>	95.360 <sup>B</sup>	1.0	25.4 <sup>B</sup>
0.012303 <sup>B</sup>	3.7543 <sup>B</sup>	0.03937 <sup>B</sup>	1.0

<sup>A</sup> One ounce of 55 % Al-Zn alloy coating per square foot of surface corresponds to an average coating thickness of 0.0032 in. [3.2 mils]. All other values in Table X1.1 are based on this relationship and on standard inch-pound to SI conversions.

<sup>B</sup> Weight [mass] to thickness conversions are reliable to only two significant figures. Inch-pound to SI conversions are reliable to five significant figures. A greater number of digits are shown in this table to reduce errors due to rounding when calculating equivalencies for coating weight [mass] or thickness greater than unity.

### X2. BENDING PROPERTIES

Note 1— $t$  = radius equivalent to the steel thickness.

Note 2—The suggested radii should be used as minimums for 90° bends in actual shop practice.

**TABLE X2.1 Suggested Minimum Inside Radii for Cold Bending**

Designation	Grade	Minimum Inside Radius for Cold Bending <sup>A</sup>
Structural Steel	33 [230]	1½ $t$
	37 [255]	2 $t$
	40 [275]	2 $t$

Note 1— $t$  = radius equivalent to the steel thickness.

Note 2—The suggested radii should be used as minimums for 90° bends in actual shop practice.

**TABLE X2.1 Suggested Minimum Inside Radii for Cold Bending**

Designation	Grade	Minimum Inside Radius for Cold Bending <sup>A</sup>
	50 Class 1, Class 2, and Class 4 [340 Class 1, Class 2, and Class 4]	not applicable

<sup>A</sup> Bending capability may be limited by the coating designation.

### X3. RATIONALE FOR CHANGES IN PRODUCT DESIGNATIONS

X3.1 Subcommittee A05.11 has revised the designations used to classify the various products available in each hot-dip coated specification. The previous “quality” designations have been replaced with designations and descriptions more closely related with product characteristics. Many of the former “quality” specifications described the steel only in terms of limited chemical composition, which in some cases was identical for two or more qualities. The former designations also did not reflect the availability of new steels which are the result of the use of new technologies such as vacuum degassing and steel ladle treatments.

X3.2 The former “quality” designators, defined in very broad qualitative terms, did not provide the user with all the information needed to select the appropriate steel for an application. The new designations are defined with technical information such as specific chemical composition limits and typical-nonmandatory mechanical properties. These steel characteristics are important to users concerned with the weldability and formability of the coated steel products. The typical mechanical properties included in the new designation system are those indicated by the tension test. These properties are more predictive of steel formability than other tests such as the hardness test which may not compensate adequately for product variables such as substrate thickness and coating weight.

X3.3 The new designations also provide the user with the flexibility to restrict the steels applied on any order. For example, a user can restrict the application of ultra low carbon steels on an application through the selection of an appropriate “type” designator.

X3.4 There is a limited relationship between the former and current systems of designation. Some of the reasons for this limited relationship are: addition of steels not previously described in ASTM specifications, restrictions placed on ranges of chemical composition, the addition of typical mechanical properties, and the enhanced capability of steel producers to combine chemical composition and processing methods to achieve properties tailored to specific applications.

X3.5 The changes in designation are significant which may create transition issues that will have to be resolved. Continued dialogue between users and producers will have to be maintained to assist the transition to the new system of designations. A user with concerns about the appropriate coated steel to order for a specific application should consult with a steel supplier or producer.

### SUMMARY OF CHANGES

Committee A05 has identified the location of selected changes to this standard since the last issue (A 792/A 792M – 02) that may impact the use of this standard.

A 792/A 792M - 03:

(1) Added a new SS Grade 50 Class 4 to paragraph 4.2, Tables 3, 4, and 6.

(2) Revised the metric yield strength from 345 to 340 in Table 4 and Appendix X2.

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*This standard is subject to revision at any time by the responsible technical committee and must be reviewed every five years and if not revised, either reapproved or withdrawn. Your comments are invited either for revision of this standard or for additional standards and should be addressed to ASTM International Headquarters. Your comments will receive careful consideration at a meeting of the responsible technical committee, which you may attend. If you feel that your comments have not received a fair hearing you should make your views known to the ASTM Committee on Standards, at the address shown below.*

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# Standard Practice for Structural Design of Corrugated Steel Pipe, Pipe-Arches, and Arches for Storm and Sanitary Sewers and Other Buried Applications<sup>1</sup>

This standard is issued under the fixed designation A 796/A 796M; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reappraisal. A superscript epsilon (ε) indicates an editorial change since the last revision or reappraisal.

## 1. Scope\*

1.1 This practice covers the structural design of corrugated steel pipe and pipe-arches, ribbed and composite ribbed steel pipe, closed rib steel pipe, and steel structural plate pipe, pipe-arches, and underpasses for use as storm sewers and sanitary sewers, and other buried applications. Ribbed and composite ribbed steel pipe, and closed rib steel pipe, shall be of helical fabrication having a continuous lockseam. This practice is for pipe installed in a trench or embankment and subjected to earth loads and live loads. It must be recognized that a buried corrugated steel pipe is a composite structure made up of the steel ring and the soil envelope, and both elements play a vital part in the structural design of this type of structure. This practice applies to structures installed in accordance with Practice A 798/A 798M or A 807/A 807M.

1.2 Corrugated steel pipe and pipe-arches shall be of annular fabrication using riveted or spot-welded seams, or of helical fabrication having a continuous lockseam or welded seam.

1.3 Structural plate pipe, pipe-arches, underpasses, and arches are fabricated in separate plates that, when assembled at the job site by bolting, form the required shape.

1.4 This specification is applicable to design in inch-pound units as A 796 or in SI units as A 796M. Inch-pound units and SI units are not necessarily equivalent. SI units are shown in brackets in the text for clarity, but they are the applicable values when the design is done per A 796M.

1.5 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

## 2. Referenced Documents

### 2.1 ASTM Standards:

A 760/A 760M Specification for Corrugated Steel Pipe, Metallic-Coated for Sewers and Drains<sup>2</sup>

A 761/A 761M Specification for Corrugated Steel Structural Plate, Zinc-Coated, for Field-Bolted Pipe, Pipe-Arches, and Arches<sup>2</sup>

A 762/A 762M Specification for Corrugated Steel Pipe, Polymer Precoated for Sewers and Drains<sup>2</sup>

A 798/A 798M Practice for Installing Factory-Made Corrugated Steel Pipe for Sewers and Other Applications<sup>2</sup>

A 807/A 807M Practice for Installing Corrugated Steel Structural Plate Pipe for Sewers and Other Applications<sup>2</sup>

A 902 Terminology Relating to Metallic-Coated Steel Products<sup>2</sup>

A 978/A 978M Specification for Composite Ribbed Steel Pipe, Precoated and Polyethylene-Lined for Gravity Flow Sanitary Sewers, Storm Sewers, and Other Special Applications<sup>2</sup>

A 1019/A 1019M Specification for Closed Rib Steel Pipe with a Diameter of 36 in. [900 mm] or Less, Polymer Precoated for Sewers and Drains<sup>2</sup>

D 698 Test Method for Laboratory Compaction Characteristics of Soil Using Standard Effort (12 400 ft-lbf/ft<sup>3</sup> [600 kN·m/m<sup>3</sup>])<sup>3</sup>

D 1556 Test Method for Density and Unit Weight of Soil in Place by the Sand-Cone Method<sup>3</sup>

D 2167 Test Method for Density and Unit Weight of Soil in Place by the Rubber Balloon Method<sup>3</sup>

D 2487 Classification of Soils for Engineering Purposes (Unified Soil Classification System)<sup>3</sup>

D 2922 Test Methods for Density of Soil and Soil-Aggregate in Place by Nuclear Methods (Shallow Depth)<sup>3</sup>

D 2937 Test Method for Density of Soil in Place by the Drive-Cylinder Method<sup>3</sup>

2.2 *AASHTO Standard:*  
Standard Specifications for Highway Bridges<sup>4</sup>

<sup>1</sup> This practice is under the jurisdiction of ASTM Committee A05 on Metallic-Coated Iron and Steel Products and is the direct responsibility of Subcommittee A05.17 on Corrugated Steel Pipe Specifications.

Current edition approved April 10, 2003. Published May 2003. Originally approved in 1982. Last previous edition approved in 1996 as A 796/A 796M – 01.

<sup>2</sup> *Annual Book of ASTM Standards*, Vol 01.06.

<sup>3</sup> *Annual Book of ASTM Standard*, Vol 04.08.

<sup>4</sup> Available from American Association of State Highway and Transportation Officials, 444 North Capitol St., N.W., Suite 225, Washington DC, 20001.

\*A Summary of Changes section appears at the end of this standard.

### 2.3 FAA Standard:

AC No. 150/5320-5B Advisory Circular, "Airport Drainage," Department of Transportation, Federal Aviation Administration, 1970<sup>5</sup>

## 3. Terminology

3.1 *General Definitions*—For definitions of general terms used in this practice, refer to Terminology A 902. For definitions of terms specific to this standard, refer to 3.2.

### 3.2 Definitions of Terms Specific to This Standard:

3.2.1 *bedding, n*—the earth or other material on which the pipe is laid, consisting of a thin layer of imported material on top of the in situ foundation.

3.2.2 *haunch, n*—the portion of the pipe cross section between the maximum horizontal dimension and the top of the bedding.

3.2.3 *invert, n*—the lowest portion of the pipe cross section; also, the bottom portion of the pipe.

3.2.4 *pipe, n*—a conduit having a full circular shape, or in a general context, all structure shapes covered by this practice.

3.2.5 *pipe-arch, n*—a pipe shape consisting of an approximate semi-circular top portion, small radius corners, and large radius invert.

3.2.6 *arch, n*—a pipe shape that is supported on footings and does not have a full metal invert.

## 4. Symbols

4.1 The symbols used in this practice have the following significance:

$A$	= required wall area, in. <sup>2</sup> /ft [mm <sup>2</sup> /mm]
$(AL)$	= maximum highway design axle load, lbf [N]
$C_l$	= longitudinal live load distribution factor for pipe arches
$d$	= depth of corrugation, in. [mm]
$E$	= modulus of elasticity = 29 by 10 <sup>6</sup> lbf/in. <sup>2</sup> [200 by 10 <sup>3</sup> MPa]
$(EL)$	= earth load, lbf/ft <sup>2</sup> [kPa]
$(FF)$	= flexibility factor, in./lbf [mm/N]
$f_y$	= specified minimum yield strength = 33 000 lbf/in. <sup>2</sup> [230 MPa], except = 44 000 lbf/in. <sup>2</sup> [300 MPa] for the 15 by 5½ -in. [380 by 140-mm] corrugation
$f_u$	= specified minimum tensile strength = 45 000 lbf/in. <sup>2</sup> [310 MPa], except = 55 000 lbf/in. <sup>2</sup> [380 MPa] for the 15 by 5½ -in. [380 by 140-mm] corrugation
$f_c$	= critical buckling stress, lbf/in. <sup>2</sup> [MPa]
$h$	= height of cover, in. [mm] determined as follows: (1) highways—from top of pipe to top of rigid pavement, or to top of subgrade for flexible pavement; (2) railways—top of pipe to bottom of tie
$H$	= depth of fill above top of pipe, ft [m]
$H_{min}$	= minimum depth of fill, ft [m]

$H_{max}$	= maximum depth of fill, ft [m]
$I$	= moment of inertia of corrugated shape, in. <sup>4</sup> /in. [mm <sup>4</sup> /mm] (see Tables 1-28)
$(IL)$	= pressure from impact load, lbf/ft <sup>2</sup> [kPa]
$k$	= soil stiffness factor = 0.22 for good side-fill material compacted to 90 % of standard density based on Test Method D 698
$L_1, L_2, L_3$	= loaded lengths, in. [mm] defined in 17.3
$(LL)$	= pressure from live load, lbf/ft <sup>2</sup> [kPa]
$P$	= total design load or pressure, lbf/ft <sup>2</sup> [kPa]
$P_c$	= corner pressure, lbf/ft <sup>2</sup> [kPa]
$P_f$	= factored crown pressure, lbf/ft <sup>2</sup> [kPa]
$r$	= radius of gyration of corrugation, in. [mm] (see Tables 1-28)
$r_c$	= corner radius of pipe-arch, in. [mm]
$R_n$	= nominal resistance for each limit state, lbf/ft [kN/m]
$R_f$	= factored resistance for each limit state, lbf/ft [kN/m]
$r_l$	= radius at crown, in. [mm]
$S$	= pipe diameter or span, ft [m]
$s$	= pipe diameter or span, in. [mm]
$(SF)$	= safety factor
$(SS)$	= required seam strength, lbf/ft [kN/m]
$T$	= thrust in pipe wall, lbf/ft [kN/m]
$T_f$	= factored thrust in pipe wall, lbf/ft [kN/m]
$w$	= unit force derived from 1 ft <sup>3</sup> [1 m <sup>3</sup> ] of fill material above the pipe, lbf/ft <sup>3</sup> [kN/m <sup>3</sup> ]. When actual fill material is not known, use 120 lbf/ft <sup>3</sup> [19 kN/m <sup>3</sup> ]
$\phi$	= resistance factor

## 5. Basis of Design

5.1 The safety factors and other specific quantitative recommendations herein represent generally accepted design practice. The design engineer should, however, determine that these recommendations meet particular project needs.

5.2 This practice is not applicable for long-span structural plate pipe or other multi-radius shapes not described herein. Such structures require additional design considerations for both the pipe and the soil envelope. In addition to meeting all other design requirements given herein, the maximum diameters or spans for structures designed by this practice are as follows:

Shape	Maximum Diameter or Span, ft [mm]
pipe, arch	26 [7920 mm]
pipe-arch, underpass	21 [6400 mm]

5.3 This practice is not applicable for pipe with a specified thickness less than 0.052 in. [1.32 mm] for installations under railways and airport runways.

## 6. Loads

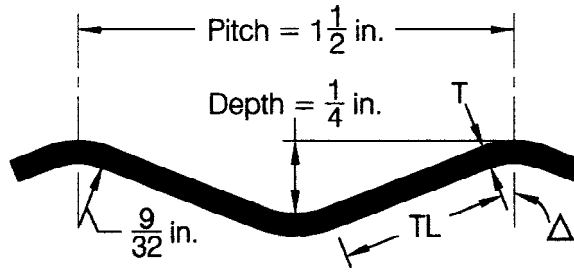
6.1 The design load or pressure on a pipe is comprised of earth load (EL), live load (LL), and impact load (IL). These loads are applied as a fluid pressure acting on the pipe periphery.

6.2 For steel pipe buried in a trench or in an embankment on a yielding foundation, loads are defined as follows:

<sup>5</sup> Available from Superintendent of Documents, U.S. Government Printing Office, Washington, DC 20402. Publication No. SN-050-007-00149-5.

**TABLE 1 Sectional Properties of Corrugated Steel Sheets for Corrugation: 1½ by ¼ in. (Helical)**

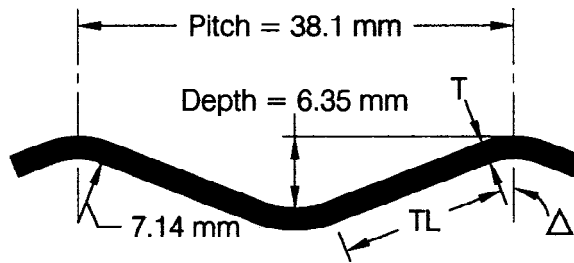
NOTE 1—Dimensions shown in the figure are exact values used in calculating the section properties. Nominal values, for some of these dimensions, are used in other places in this practice.



Specified Thickness, in.	Area of Section, A, in. <sup>2</sup> /ft	Tangent Length, TL, in.	Tangent Angle, Δ, °	Moment of Inertia, I × 10 <sup>-3</sup> , in. <sup>4</sup> /in.	Radius of Gyration, r, in.
0.040 <sup>A</sup>	0.456	0.571	21.44	0.253	0.0816
0.052	0.608	0.566	21.52	0.343	0.0824
0.064	0.761	0.560	21.61	0.439	0.0832
0.079	0.950	0.554	21.71	0.566	0.0846

<sup>A</sup>This thickness should only be used for the inner liner of double-wall type IA pipe, or for temporary pipe. When used for other than temporary pipe, it should be polymer coated.

**TABLE 2 Sectional Properties of Corrugated Steel Sheets for Corrugation: 38 by 6.5 mm (Helical) [SI Units]**



Specified Thickness, mm	Area of Section, A, mm <sup>2</sup> /mm	Tangent Length, TL, mm	Tangent Angle, Δ, °	Moment of Inertia, I, mm <sup>4</sup> /mm	Radius of Gyration, r, mm
1.02 <sup>A</sup>	0.965	14.5	21.44	4.15	2.07
1.32	1.287	14.4	21.52	5.62	2.08
1.63	1.611	14.2	21.61	7.19	2.11
2.01	2.011	14.1	21.71	9.28	2.15

<sup>A</sup>This thickness should only be used for the inner liner of double-wall type IA pipe, or for temporary pipe. When used for other than temporary pipe, it should be polymer coated.

6.2.1 The earth load (EL) is the weight of the column of soil directly above the pipe:

$$(EL) = H_w \quad (1)$$

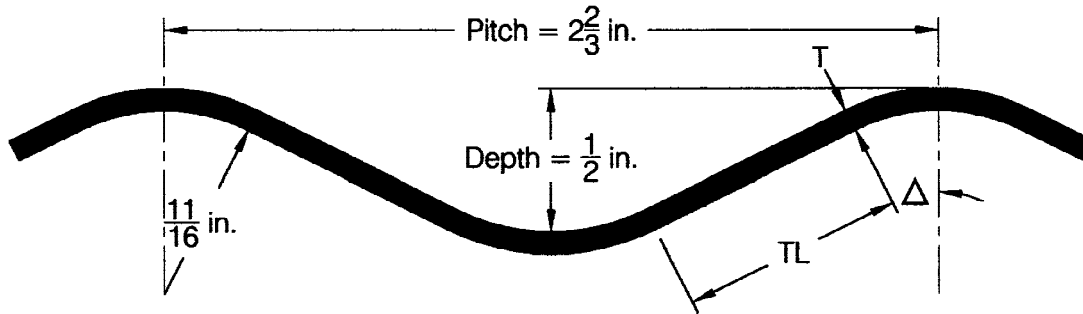
6.2.2 *Live Loads*—The live load (LL) is that portion of the weight of vehicle, train, or aircraft moving over the pipe that is distributed through the soil to the pipe.

6.2.2.1 *Live Loads Under Highway*—Live load pressures for H20 highway loadings, including impact effects, are:

Height of Cover, ft [m]	Live Load, lbf/ft <sup>2</sup> [kPa]
1 [0.30]	1800 [86.2]
2 [0.61]	800 [38.3]
3 [0.91]	600 [28.7]
4 [1.22]	400 [19.2]
5 [1.52]	250 [12.0]
6 [1.83]	200 [9.6]
7 [2.13]	175 [8.4]
8 [2.44]	100 [4.8]
over 8 [over 2.44]	neglect [–]

**TABLE 3 Sectional Properties of Corrugated Steel Sheets for Corrugation: 2<sup>2</sup>/<sub>3</sub> by 1/2 in. (Annular or Helical)**

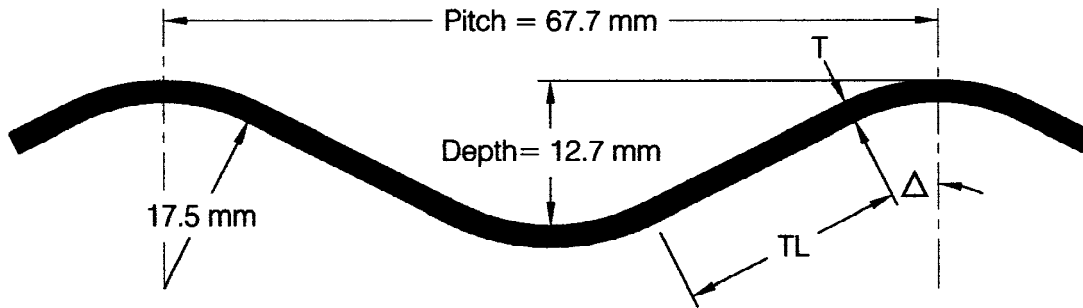
NOTE 1—Dimensions shown in the figure are exact values used in calculating the section properties. Nominal values, for some of these dimensions, are used in other places in this practice.



Specified Thickness, in.	Area of Section, A, in. <sup>2</sup> /ft	Tangent Length, TL, in.	Tangent Angle, Δ, °	Moment of Inertia, I × 10 <sup>-3</sup> , in. <sup>4</sup> /in.	Radius of Gyration, r, in.	Ultimate Longitudinal Seam Strength of Riveted or Spot Welded Corrugated Steel Pipe in Pounds per Foot of Seam			
						5/16-in. Rivets		3/8-in. Rivets	
						Single	Double	Single	Double
0.040 <sup>A</sup>	0.465	0.785	26.56	1.122	0.1702	...	...	...	...
0.052	0.619	0.778	26.65	1.500	0.1707	...	...	...	...
0.064	0.775	0.770	26.74	1.892	0.1712	16 700	21 600	...	...
0.079	0.968	0.760	26.86	2.392	0.1721	18 200	29 800	...	...
0.109	1.356	0.740	27.11	3.425	0.1741	...	...	23 400	46 800
0.138	1.744	0.720	27.37	4.533	0.1766	...	...	24 500	49 000
0.168	2.133	0.699	27.65	5.725	0.1795	...	...	25 600	51 300

<sup>A</sup>This thickness should only be used for the inner liner of double-wall type IA pipe, or for temporary pipe. When used for other than temporary pipe, it should be polymer coated.

**TABLE 4 Sectional Properties of Corrugated Steel Sheets for Corrugation: 68 by 13 mm (Annular or Helical) [SI Units]**

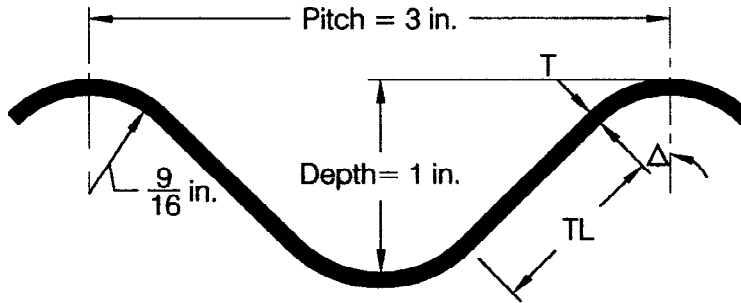


Specified Thickness, mm	Area of Section, A, mm <sup>2</sup> /mm	Tangent Length, TL, mm	Tangent Angle, Δ, °	Moment of Inertia, I, mm <sup>4</sup> /mm	Radius of Gyration, r, mm	Ultimate Longitudinal Seam Strength of Riveted or Spot Welded Corrugated Steel Pipe in kN per m of Seam			
						8-mm Rivets		10-mm Rivets	
						Single	Double	Single	Double
1.02 <sup>A</sup>	0.984	19.9	26.56	18.39	4.232	...	...	...	...
1.32	1.310	19.8	26.65	24.58	4.336	...	...	...	...
1.63	1.640	19.6	26.74	31.00	4.348	244	315	...	...
2.01	2.049	19.3	26.86	39.20	4.371	266	435	...	...
2.77	2.870	18.8	27.11	56.13	4.422	...	...	341	683
3.51	3.691	18.3	27.37	74.28	4.486	...	...	357	715
4.27	4.515	17.8	27.65	93.82	4.559	...	...	374	748

<sup>A</sup>This thickness should only be used for the inner liner of double-wall type IA pipe, or for temporary pipe. When used for other than temporary pipe, it should be polymer coated.

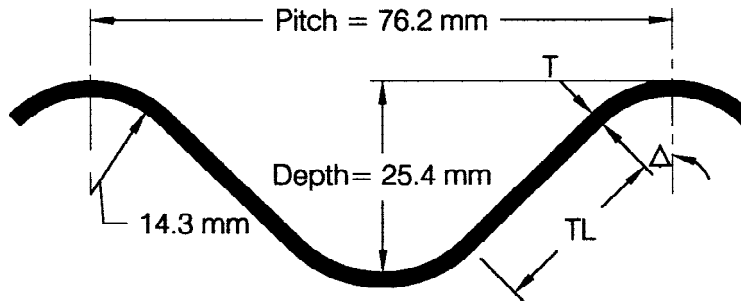
**TABLE 5 Sectional Properties of Corrugated Steel Sheets for Corrugation: 3 by 1 in. (Annular or Helical)**

NOTE 1—Dimensions shown in the figure are exact values used in calculating the section properties. Nominal values, for some of these dimensions, are used in other places in this practice.



Specified Thickness, in.	Area of Section, A, in. <sup>2</sup> /ft	Tangent Length, TL, in.	Tangent Angle, Δ, °	Moment of Inertia, I × 10 <sup>-3</sup> in. <sup>4</sup> /in.	Radius of Gyration, r, in.	Ultimate Longitudinal Seam Strength of Riveted or Spot Welded Corrugated Steel Pipe in Pounds per Foot of Seam	
						3/8 -in. Rivets	7/16 -in. Rivets
						Double	Double
0.052	0.711	0.951	44.39	6.892	0.3410	...	...
0.064	0.890	0.938	44.60	8.658	0.3417	28 700	...
0.079	1.113	0.922	44.87	10.883	0.3427	35 700	...
0.109	1.560	0.889	45.42	15.458	0.3448	...	53 000
0.138	2.008	0.855	46.02	20.175	0.3472	...	63 700
0.168	2.458	0.819	48.65	25.083	0.3499	...	70 700

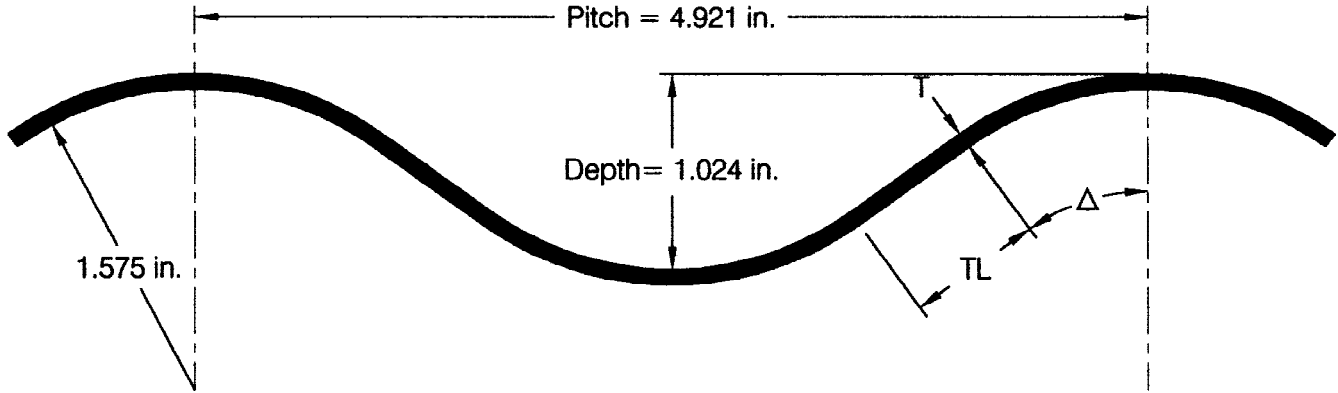
**TABLE 6 Sectional Properties of Corrugated Steel Sheets for Corrugation: 75 by 25 mm (Annular or Helical) [SI Units]**



Specified Thickness, mm	Area of Section, A, mm <sup>2</sup> /mm	Tangent Length, TL, mm	Tangent Angle, Δ, °	Moment of Inertia, I, mm <sup>4</sup> /m	Radius of Gyration, r, mm	Ultimate Longitudinal Seam Strength of Riveted or Spot Welded Corrugated Steel Pipe in kN per m of Seam	
						10-mm Rivets	11-mm Rivets
						Double	Double
1.32	1.505	24.2	44.39	112.94	8.661	...	...
1.63	1.884	23.8	44.60	141.88	8.679	419	...
2.01	2.356	23.4	44.87	178.34	8.705	521	...
2.77	3.302	22.6	45.42	253.31	8.758	...	773
3.51	4.250	21.7	46.02	330.61	8.819	...	929
4.27	5.203	20.8	46.65	411.04	8.887	...	1032

6.2.2.2 *Live Loads Under Railways*—Live load pressures for E80 railway loadings, including impact effects, are as follows:

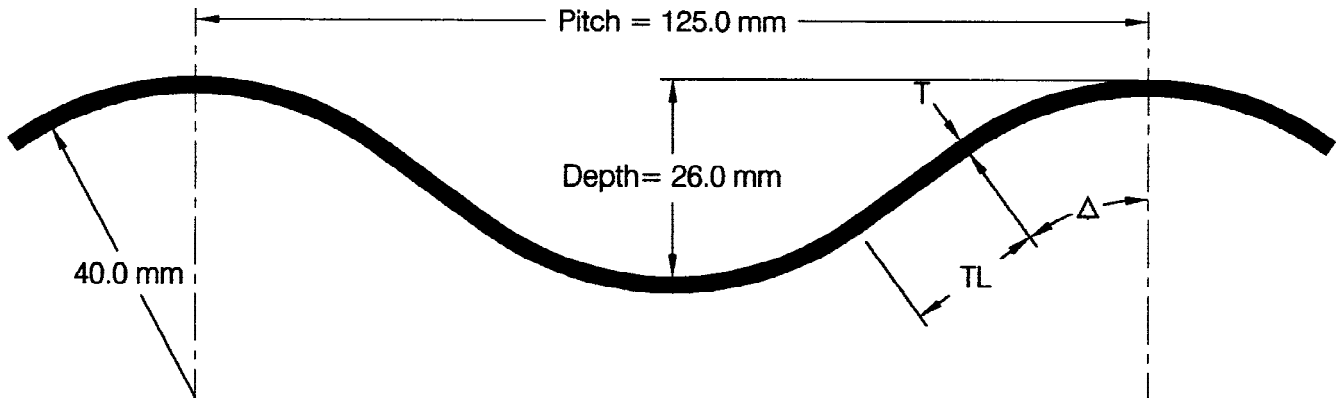
TABLE 7 Sectional Properties of Corrugated Steel Sheets for Corrugation: 5 by 1 in. (Helical)



Specified Thickness, in.	Area of Section, A, in. <sup>2</sup> /ft	Tangent Length, TL, in.	Tangent Angle, Δ, °	Moment of Inertia, I × 10 <sup>-3</sup> , in. <sup>4</sup> /in.	Radius of Gyration, r, in.
0.064	0.794	0.730	35.58	8.850	0.3657
0.079	0.992	0.708	35.80	11.092	0.3663
0.109	1.390	0.664	36.30	15.550	0.3677
0.138	1.788	0.610	36.81	20.317	0.3693
0.168	2.186	0.564	37.39	25.032	0.3711

TABLE 8 Sectional Properties of Corrugated Steel Sheets for Corrugation: 125 by 25 mm (Helical) [SI Units]

NOTE 1—Dimensions shown in the figure are exact values used in calculating the section properties. Nominal values, for some of these dimensions, are used in other places in this practice.



Specified Thickness, mm	Area of Section, A, mm <sup>2</sup> /mm	Tangent Length, TL, mm	Tangent Angle, Δ, °	Moment of Inertia, I, mm <sup>4</sup> /mm	Radius of Gyration, r, mm
1.63	1.681	18.5	35.58	145.03	9.289
2.01	2.100	18.0	35.80	181.77	9.304
2.77	2.942	16.9	36.30	256.46	9.340
3.51	3.785	15.6	36.81	332.94	9.380
4.27	4.627	14.3	37.39	411.18	9.426

Height of Cover, ft [m]	Live Load, lbf/ft <sup>2</sup> [kPa]
2 [0.61]	3800 [181.9]
5 [1.52]	2400 [114.9]
8 [2.44]	1600 [76.6]
10 [3.05]	1100 [52.7]
12 [3.66]	800 [38.3]
15 [4.57]	600 [28.7]
20 [6.10]	300 [14.4]
30 [9.14]	100 [4.8]
over 30 [over 9.14]	neglect [-]

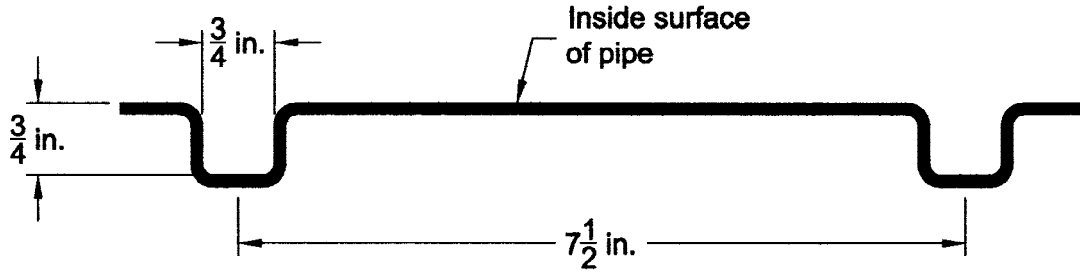
6.2.2.3 Values for intermediate covers shall be interpolated.

6.2.2.4 *Live Loads Under Aircraft Runways*—Because of the many different wheel configurations and weights, live load pressures for aircraft vary. Such pressures must be determined for the specific aircrafts for which the installation is designed; see FAA Standard AC No. 150/5320-5B.



**TABLE 9 Sectional Properties for Spiral Rib Pipe for 3/4 in. Wide by 3/4 in. Deep Rib with a Spacing of 7 1/2 in. Center to Center (Helical)**

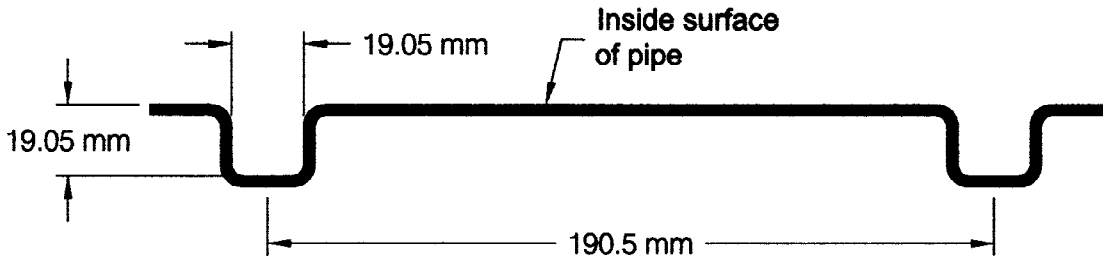
NOTE 1—Dimensions shown in the figure are exact values used in calculating the section properties. Nominal values, for some of these dimensions, are used in other places in this practice.



Effective Properties <sup>A</sup>			
Specified Thickness, in.	Area of Section, A, in. <sup>2</sup> /ft.	Moment of Inertia, I × 10 <sup>-3</sup> in. <sup>4</sup> /in.	Radius of Gyration, r, in.
0.064	0.509	2.821	0.258
0.079	0.712	3.701	0.250
0.109	1.184	5.537	0.237
0.138	1.717	7.433	0.228

<sup>A</sup>Net effective properties at full yield stress.

**TABLE 10 Sectional Properties of Spiral Rib Pipe for 19 mm Wide by 19 mm Deep Rib with a Spacing of 190 mm Center to Center (Helical) [SI Units]**



Effective Properties <sup>A</sup>			
Specified Thickness, mm	Area of Section, A, mm <sup>2</sup> /mm	Moment of Inertia, I, mm <sup>4</sup> /mm	Radius of Gyration, r, mm
1.63	1.077	46.23	6.55
2.01	1.507	60.65	6.34
2.77	2.506	90.74	6.02
3.51	3.634	121.81	5.79

<sup>A</sup>Net effective properties at full yield stress.

6.2.3 *Impact Loads*—Loads caused by the impact of moving traffic are important only at low heights of cover. Their effects have been included in the live load pressures in 6.2.2.

## 7. Design Method

7.1 Strength requirements for wall strength, buckling strength, and seam strength may be determined by either the allowable stress design (ASD) method presented in Section 8, or the load and resistance factor design (LRFD) method presented in Section 9. Additionally, the design considerations in other paragraphs shall be followed for either design method.

## 8. Design by ASD Method

8.1 The thrust in the pipe wall shall be checked by three criteria. Each considers the joint function of the steel pipe and the surrounding soil envelope.

### 8.1.1 Required Wall Area:

8.1.1.1 Determine the design pressure and the ring compression thrust in the steel pipe wall as follows:

$$P = EL + LL + IL \quad (2)$$

$$T = \frac{PS}{2} \quad (3)$$

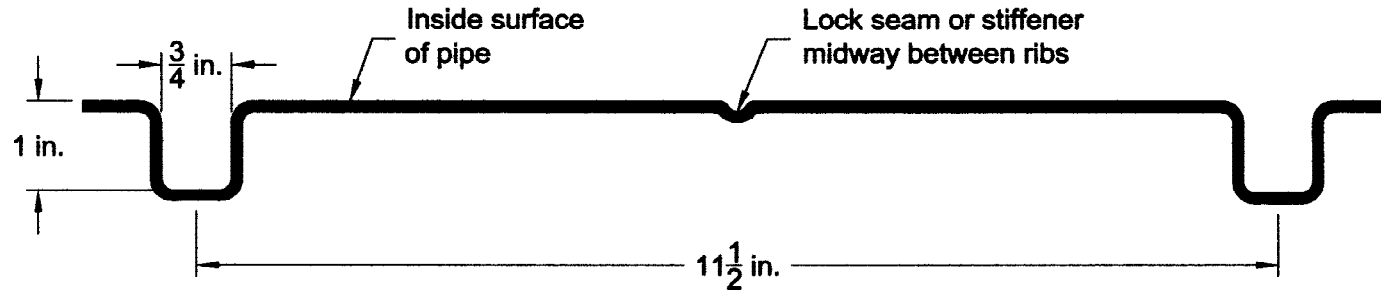
8.1.1.2 Determine the required wall cross-sectional area. The safety factor (SF) on wall area is 2.

$$A = \frac{T(SF)}{f_y} \quad (4)$$

Select from Table 1, Table 3, Table 5, Table 7, Table 9, Table 11, Table 13, Table 15, Table 17, Table 19, Table 21, Table 23, Table 25, or Table 27 [Table 2, Table 4, Table 6, Table 8, Table 10, Table 12, Table 14, Table 16, Table 18, Table 20, Table 22, Table 24, Table 26, or Table 28] a wall thickness equal to or greater than the required wall area (A).

**TABLE 11 Sectional Properties of Spiral Rib Pipe for 3/4 in. Wide by 1 in. Deep Rib with a Spacing of 11 1/2 in. Center to Center (Helical)**

NOTE 1—Dimensions shown in the figure are exact values used in calculating the section properties. Nominal values, for some of these dimensions, are used in other places in this practice.

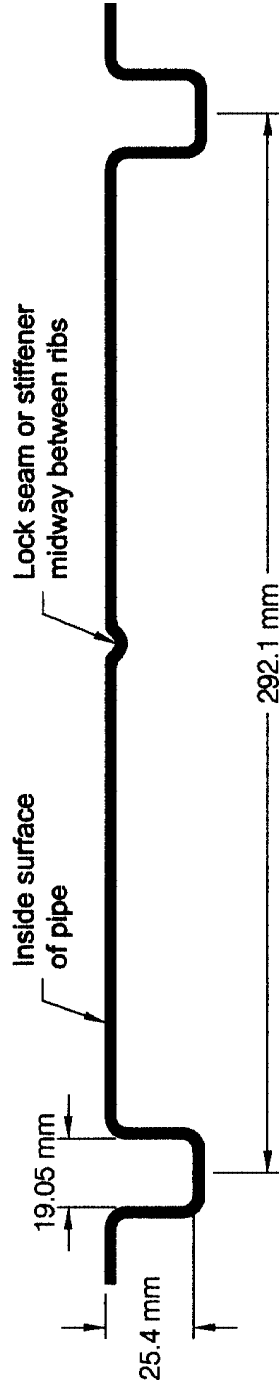


Effective Properties <sup>A</sup>			
Specified Thickness, in.	Area of Section, A, in. <sup>2</sup> /ft.	Moment of Inertia, I × 10 <sup>-3</sup> , in. <sup>4</sup> /in.	Radius of Gyration, r, in.
0.064	0.374	4.580	0.383
0.079	0.524	6.080	0.373
0.109	0.883	9.260	0.355

<sup>A</sup>Net effective properties at full yield stress.



TABLE 12 Sectional Properties of Spiral Rib Pipe for 19 mm Wide by 25 mm Deep Rib with a Spacing of 292 mm Center to Center (Helical) [SI Units]

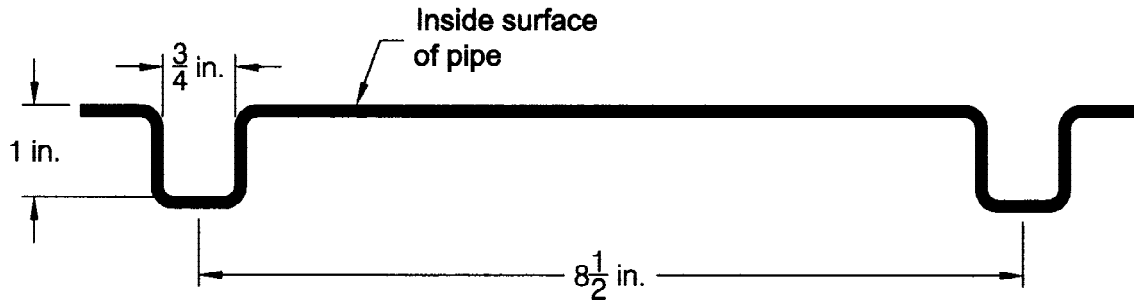


Specified Thickness, mm	Effective Properties <sup>a</sup>			Radius of Gyration, $r$ , mm
	Area of Section, $A$ , $\text{mm}^2/\text{mm}$	Moment of Inertia, $I$ , $\text{mm}^4/\text{mm}$		
1.63	0.792	75.05		9.73
2.01	1.109	99.63		9.47
2.77	1.869	151.74		9.02

<sup>a</sup>Net effective properties at full yield stress.

**TABLE 13 Sectional Properties of Spiral Rib Pipe for 3/4 in. Wide by 1 in. Deep Rib with a Spacing of 8 1/2 in. Center to Center (Helical)**

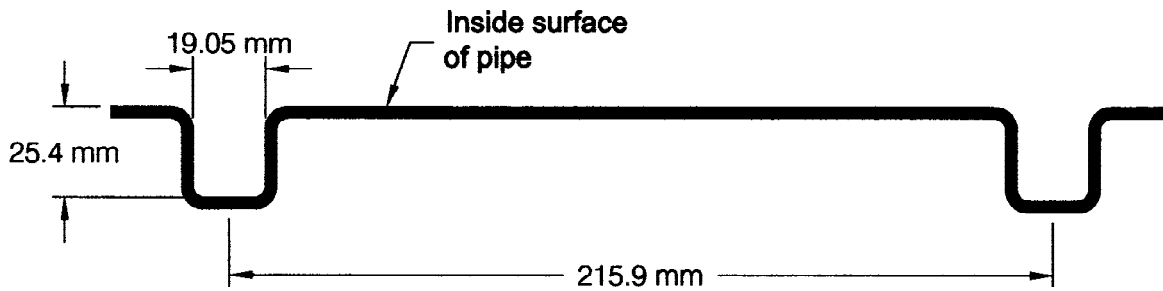
NOTE 1—Dimensions shown in the figure are exact values used in calculating the section properties. Nominal values, for some of these dimensions, are used in other places in this practice.



Effective Properties <sup>A</sup>			
Specified Thickness, in.	Area of Section, A, in. <sup>2</sup> /ft	Moment of Inertia, I × 10 <sup>-3</sup> in. <sup>4</sup> /in.	Radius of Gyration, r, in.
0.064	0.499	5.979	0.379
0.079	0.694	7.913	0.370
0.109	1.149	11.983	0.354

<sup>A</sup>Net effective properties at full yield stress.

**TABLE 14 Sectional Properties of Spiral Rib Pipe for 19 mm Wide by 25 mm Deep Rib with a Spacing of 216 mm Center to Center (Helical) [SI Units]**



Effective Properties <sup>A</sup>			
Specified Thickness, mm	Area of Section, A, mm <sup>2</sup> /mm	Moment of Inertia, I, mm <sup>4</sup> /mm	Radius of Gyration, r, mm
1.63	1.057	97.98	9.63
2.01	1.469	129.67	9.40
2.77	2.433	196.37	8.99

<sup>A</sup>Net effective properties at full yield stress.

8.1.2 *Critical Buckling Stress*—Check section profile with the required wall area for possible wall buckling. If the critical buckling stress  $f_c$  is less than the minimum yield stress  $f_y$ , recalculate the required wall area using  $f_c$  instead of  $f_y$ .

$$\text{If } s < \frac{r}{k} \sqrt{\frac{24E}{f_u}} \text{ then } f_c = f_u - \frac{f_u^2}{48E} \left(\frac{ks}{r}\right)^2 \quad (5)$$

$$\text{If } s > \frac{r}{k} \sqrt{\frac{24E}{f_u}} \text{ then } f_c = \frac{12E}{\left(\frac{ks}{r}\right)^2} \quad (6)$$

8.1.3 *Required Seam Strength*:

8.1.3.1 Since helical lockseam and welded-seam pipe have no longitudinal seams, this criterion is not valid for these types of pipe.

8.1.3.2 For pipe fabricated with longitudinal seams (riveted, spot-welded, or bolted) the seam strength shall be sufficient to develop the thrust in the pipe wall. The safety factor on seam strength (SS) is 3.

$$(SS) = T(SF) \quad (7)$$

8.1.3.3 Check the ultimate seam strengths shown in Table 3, Table 5, Table 25, or Table 27, [Table 4, Table 6, Table 26, or Table 28]. If the required seam strength exceeds that shown for the steel thickness already chosen, use a heavier pipe whose seam strength exceeds the required seam strength.

## 9. Design by LRFD Method

9.1 *Factored Loads*—The pipe shall be designed to resist the following combination of factored earth load (EL) and live load plus impact (LL + IL):

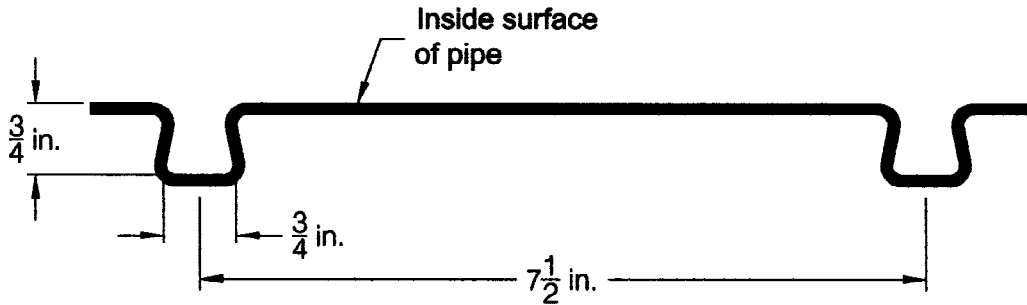
$$P_f = 1.95 EL + 1.75 (LL + IL) \quad (8)$$

9.2 *Factored Thrust*—The factored thrust,  $T_f$ , per unit length of wall shall be determined from the factored crown pressure  $P_f$  as follows:

$$T_f = P_f S/2 \quad (9)$$

**TABLE 15 Sectional Properties of Composite Ribbed Steel Pipe for 3/4 in. Wide by 3/4 in. Deep Rib With a Spacing of 7 1/2 in. Center to Center (Helical)**

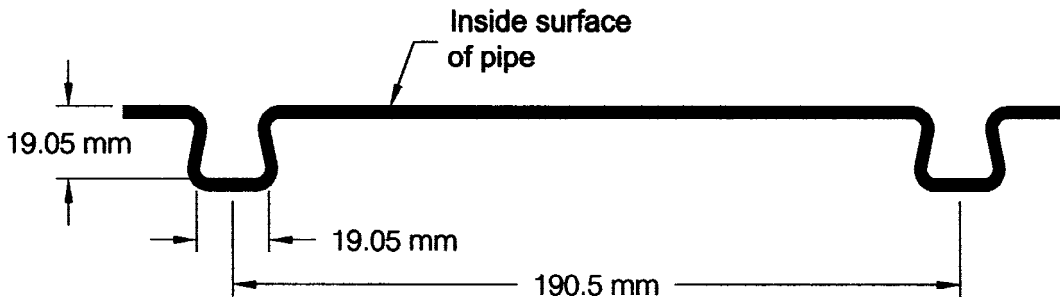
NOTE 1—Dimensions shown in the figure are exact values used in calculating the section properties. Nominal values, for some of these dimensions, are used in other places in this practice.



Effective Properties <sup>A</sup>				
Specified Thickness, in.	Area of Section, A, in. <sup>2</sup> /ft	Moment of Inertia, I × 10 <sup>-3</sup> , in. <sup>4</sup> /in.	Radius of Gyration, r, in.	
0.064	0.520	2.768	0.253	
0.079	0.728	3.628	0.245	
0.109	1.212	5.424	0.232	
0.138	1.758	7.280	0.223	

<sup>A</sup>Net effective properties at full yield stress.

**TABLE 16 Sectional Properties of Composite Ribbed Steel Pipe for 19 mm Wide by 19 mm Deep Rib With a Spacing of 190 mm Center to Center (Helical) [SI Units]**



Effective Properties <sup>A</sup>				
Specified Thickness, mm	Area of Section, A, mm <sup>2</sup> /mm	Moment of Inertia, I, mm <sup>4</sup> /mm	Radius of Gyration, r, mm	
1.63	1.101	45.36	6.43	
2.01	1.541	59.45	6.22	
2.77	2.565	88.88	5.89	
3.51	3.721	119.30	5.66	

<sup>A</sup>Net effective properties at full yield stress.

9.3 *Factored Resistance*—The factored resistance ( $R_f$ ) shall equal or exceed the factored thrust.  $R_f$  shall be calculated for the limit states of wall resistance, resistance to buckling, and seam resistance (where applicable) as follows:

$$R_f = \phi R_n \tag{10}$$

The resistance factor ( $\phi$ ) shall be as specified in Table 29. The nominal resistance ( $R_n$ ) shall be calculated as specified in 9.4, 9.5, and 9.6.

9.4 *Wall Resistance*—The nominal axial resistance per unit length of wall without consideration of buckling shall be taken as:

$$R_n = f_y A \tag{11}$$

9.5 *Resistance to Buckling*—The nominal resistance calculated using Eq 11 shall be investigated for buckling. If  $f_c < f_y$ ,  $R_n$  shall be recalculated using  $f_c$  instead of  $f_y$ . The value of  $f_c$  shall be determined from Eq 5 or Eq 6 as applicable.

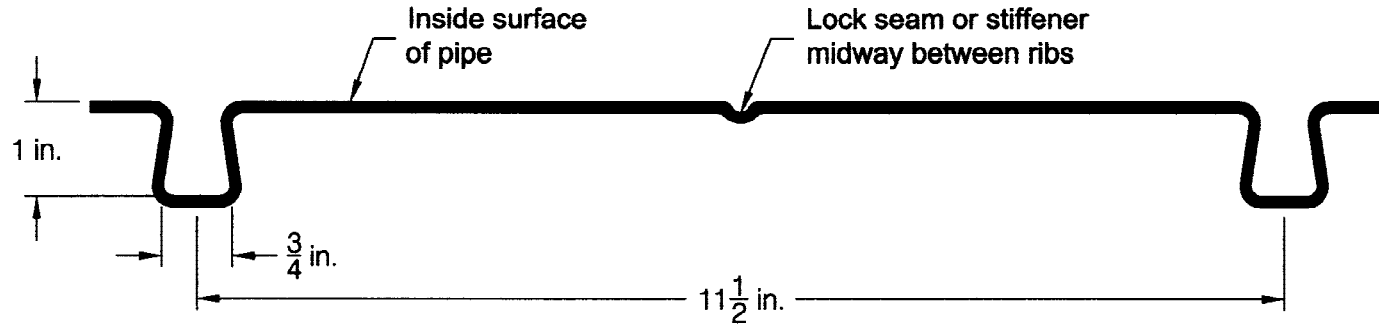
9.6 *Seam Resistance*—For pipe fabricated with longitudinal seams, the nominal resistance of the seam per unit length of wall shall be taken as the ultimate seam strength shown in Table 3, Table 5, Table 25, or Table 27 [Table 4, Table 6, Table 26, or Table 28].

## 10. Handling and Installation

10.1 The pipe shall have enough rigidity to withstand the forces that are normally applied during shipment, handling, and

**TABLE 17 Sectional Properties of Composite Ribbed Steel Pipe for 3/4 in. Wide by 1 in. Deep Rib With a Spacing of 11 1/2 in. Center to Center (Helical)**

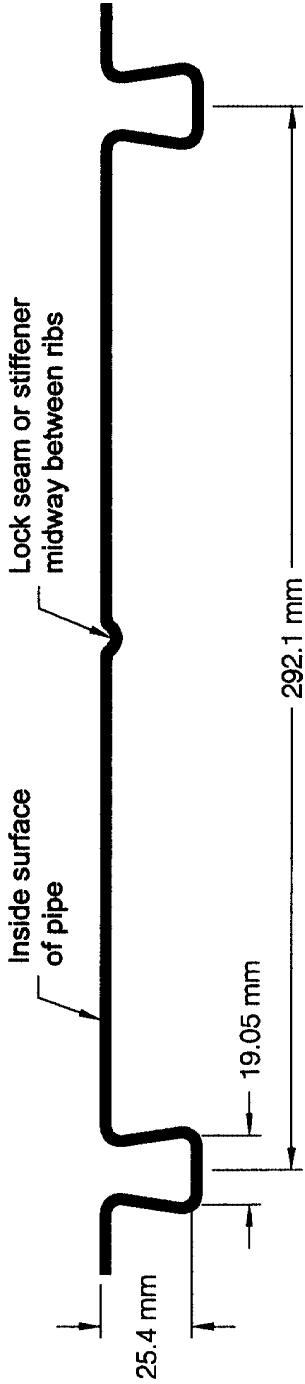
NOTE 1—Dimensions shown in the figure are exact values used in calculating the section properties. Nominal values, for some of these dimensions, are used in other places in this practice.



Effective Properties <sup>A</sup>				
Specified Thickness, in.	Area of Section, A, in. <sup>2</sup> /ft	Moment of Inertia, I × 10 <sup>-3</sup> in. <sup>4</sup> /in.	Radius of Gyration, r, in.	
0.064	0.371	3.753	0.348	
0.079	0.521	4.949	0.338	
0.109	0.878	7.472	0.320	

<sup>A</sup>Net effective properties at full yield stress.

TABLE 18 Sectional Properties of Composite Ribbed Steel Pipe for 19 mm Wide by 25 mm Deep Rib With a Spacing of 292 mm Center to Center (Helical) [SI Units]

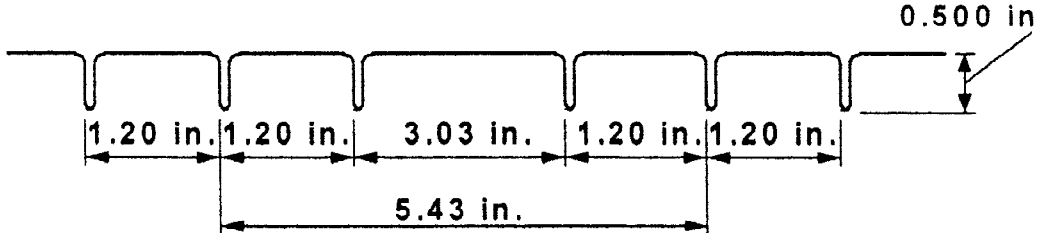


Specified Thickness, mm	Effective Properties <sup>A</sup>			Radius of Gyration, $r$ , mm
	Area of Section, $A$ , mm <sup>2</sup> /mm	Moment of Inertia, $I$ , mm <sup>4</sup> /mm		
1.63	0.785	61.50		8.84
2.01	1.103	81.10		8.59
2.77	1.858	122.44		8.13

<sup>A</sup>Net effective properties at full yield stress.

**TABLE 19 Sectional Properties for Closed Rib Pipe ½ in. Deep with Three Ribs Spaced Over 5<sup>7</sup>/<sub>16</sub> in. Center to Center (Helical)**

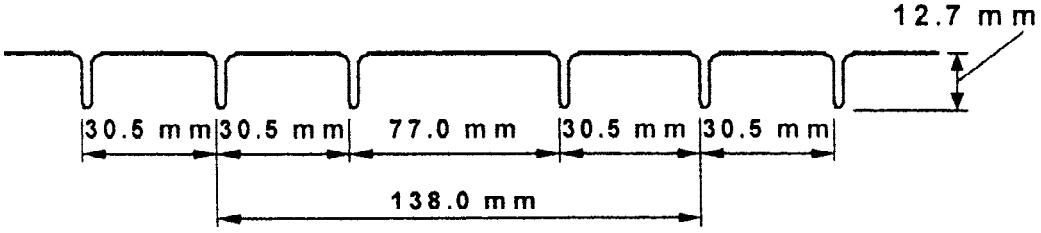
NOTE 1—Dimensions shown in the figure are exact values used in calculating the section properties. Nominal values, for some of these dimensions, are used in other places in the standard.



Effective Properties <sup>A</sup>			
Specified Thickness, in.	Area of Section, A, in. <sup>2</sup> /ft	Moment of Inertia, I × 10 <sup>-3</sup> , in. <sup>4</sup> /in.	Radius of Gyration, r, in.
0.022	0.230	0.550	0.169
0.028	0.341	0.778	0.166

<sup>A</sup>Net effective properties at full yield stress.

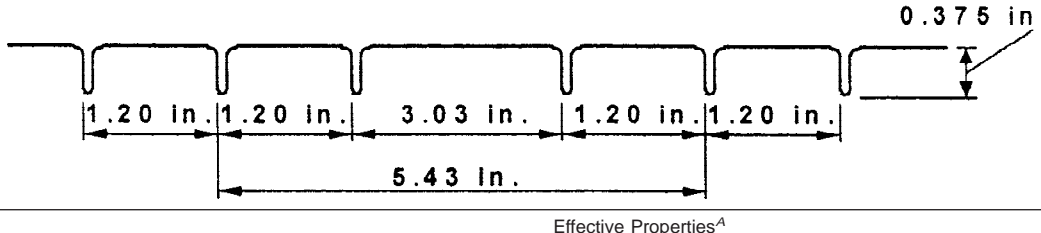
**TABLE 20 Sectional Properties for Closed Rib Pipe 13 mm Deep with Three Ribs Spaced Over 138 mm Center to Center (Helical)**



Effective Properties <sup>A</sup>			
Specified Thickness, mm	Area of Section, A, mm <sup>2</sup> /mm	Moment of Inertia, I, mm <sup>4</sup> /mm	Radius of Gyration, r, mm
0.56	0.487	9.01	4.29
0.71	0.722	12.75	4.22

<sup>A</sup>Net effective properties at full yield stress.

**TABLE 21 Sectional Properties for Closed Rib Pipe 3/8 in. Deep with Three Ribs Spaced Over 5<sup>7</sup>/<sub>16</sub> in. Center to Center (Helical)**



Effective Properties <sup>A</sup>			
Specified Thickness, in.	Area of Section, A, in. <sup>2</sup> /ft	Moment of Inertia, I × 10 <sup>-3</sup> , in. <sup>4</sup> /in.	Radius of Gyration, r, in.
0.022	0.200	0.261	0.125
0.028	0.301	0.366	0.121

<sup>A</sup>Net effective properties at full yield stress.

installation. Both shop- and field-assembled pipe shall have strength adequate to withstand compaction of the sidefill without interior bracing to maintain pipe shape. Handling and installation rigidity is measured by the following flexibility requirement.

$$(FF) = \frac{s^2}{EI} \quad (12)$$

10.2 For curve and tangent corrugated pipe installed in a trench cut in undisturbed soil, the flexibility factor shall not exceed the following:

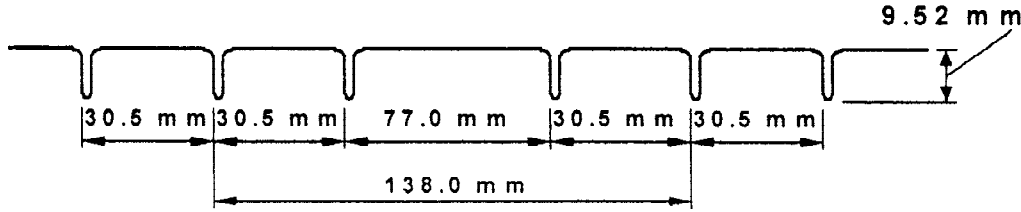
Depth of Corrugation, in. [mm]	FF, in./lbf [mm/N]
¼ [6.5]	0.043 [0.245]
½ [13]	0.060 [0.342]
1 [25]	0.060 [0.342]
2 [51]	0.020 [0.114]
5½ [140]	0.020 [0.114]

10.3 For curve and tangent corrugated pipe installed in an embankment or fill section and for all multiple lines of pipe, the flexibility factor shall not exceed the following:



**TABLE 22 Sectional Properties for Closed Rib Pipe 9.5 mm Deep with Three Ribs Spaced Over 138 mm Center to Center (Helical)**

NOTE 1—Dimensions shown in the figure are exact values used in calculating the section properties. Nominal values, for some of these dimensions, are used in other places in the standard.

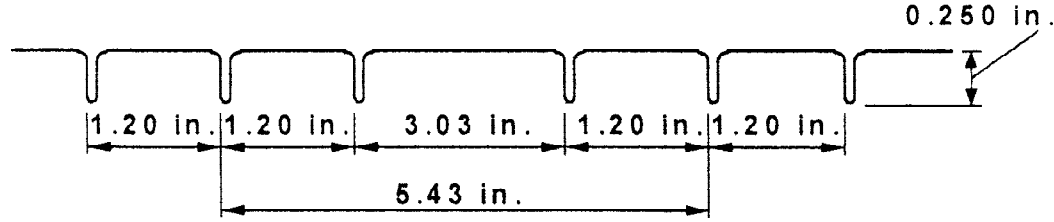


Effective Properties <sup>A</sup>			
Specified Thickness, mm	Area of Section, A, mm <sup>2</sup> /mm	Moment of Inertia, I, mm <sup>4</sup> /mm	Radius of Gyration, r, mm
0.56	0.423	4.28	3.18
0.71	0.637	6.00	3.07

<sup>A</sup>Net effective properties at full yield stress.

**TABLE 23 Sectional Properties for Closed Rib Pipe ¼ in. Deep with Three Ribs Spaced Over 5<sup>7</sup>/<sub>16</sub> in. Center to Center (Helical)**

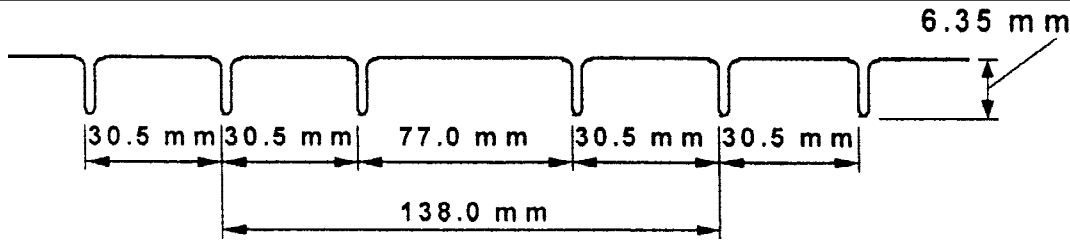
NOTE 1—Dimensions shown in the figure are exact values used in calculating the section properties. Nominal values, for some of these dimensions, are used in other places in the standard.



Effective Properties <sup>A</sup>			
Specified Thickness, in.	Area of Section, A, in. <sup>2</sup> /ft	Moment of Inertia, I × 10 <sup>-3</sup> in. <sup>4</sup> /in.	Radius of Gyration, r, in.
0.022	0.170	0.0912	0.0801
0.028	0.261	0.1266	0.0764

<sup>A</sup>Net effective properties at full yield stress.

**TABLE 24 Sectional Properties for Closed Rib Pipe 6 mm Deep with Three Ribs Spaced Over 138 mm Center to Center (Helical)**

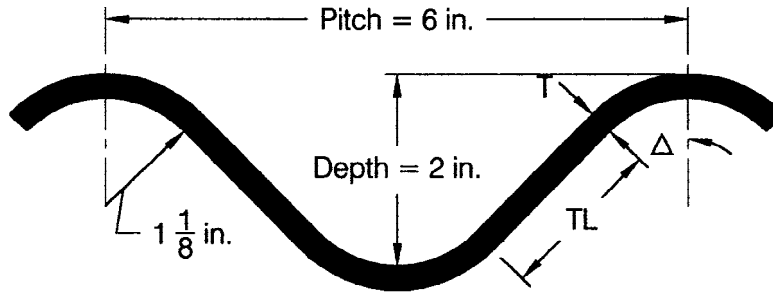


Effective Properties <sup>A</sup>			
Specified Thickness, mm	Area of Section, A, mm <sup>2</sup> /mm	Moment of Inertia, I, mm <sup>4</sup> /mm	Radius of Gyration, r, mm
0.56	0.360	1.49	2.03
0.71	0.552	2.07	1.94

<sup>A</sup>Net effective properties at full yield stress.

**TABLE 25 Sectional Properties of Corrugated Steel Plates for Corrugation: 6 by 2 in. (Annular)**

NOTE 1—Dimensions shown in the figure are exact values used in calculating the section properties. Nominal values, for some of these dimensions, are used in other places in this practice.

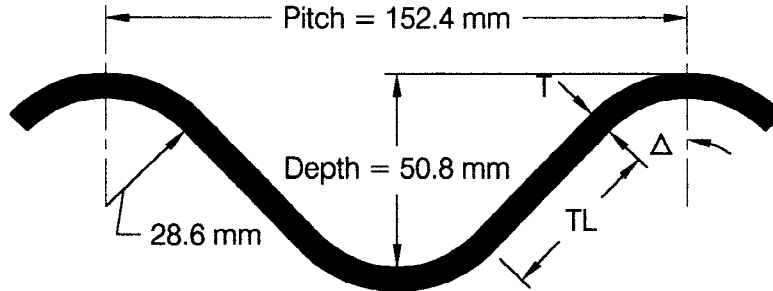


Specified Thickness, in.	Area of Section, A, in. <sup>2</sup> /ft	Tangent Length, TL, in.	Tangent Angle, Δ, °	Moment of Inertia, I × 10 <sup>-3</sup> in. <sup>4</sup> /in.	Radius of Gyration, r, in.	Ultimate Strength of Bolted Structural Plate Longitudinal Seams in Pounds per Foot of Seam		
						2 Bolts per Corrugation <sup>A,B</sup>	3 Bolts per Corrugation <sup>A,B</sup>	4 Bolts per Corrugation <sup>A,B</sup>
0.111	1.556	1.893	44.47	60.417	0.682	42 000	...	...
0.140	2.003	1.861	44.73	78.167	0.684	62 000	...	...
0.170	2.449	1.828	45.00	96.167	0.686	81 000	...	...
0.188	2.739	1.807	45.18	108.000	0.688	93 000	...	...
0.218	3.199	1.773	45.47	126.917	0.690	112 000	...	...
0.249	3.658	1.738	45.77	146.167	0.692	132 000	...	...
0.280	4.119	1.702	46.09	165.834	0.695	144 000	180 000	194 000
0.318	4.671	1.653	46.47	190.000	0.698	...	...	235 000
0.380	5.613	1.581	47.17	232.000	0.704	...	...	285 000

<sup>A</sup>Bolts are 3/4 -in. diameter for 0.280-in. or thinner materials. Thicker materials require 7/8 -in. bolts.

<sup>B</sup>The number of bolts per corrugation includes the bolts in the corrugation crest and in the corrugation valley; the number of bolts within one pitch.

**TABLE 26 Sectional Properties of Corrugated Steel Plates for Corrugation: 152 by 51 mm (Annular) [SI Units]**



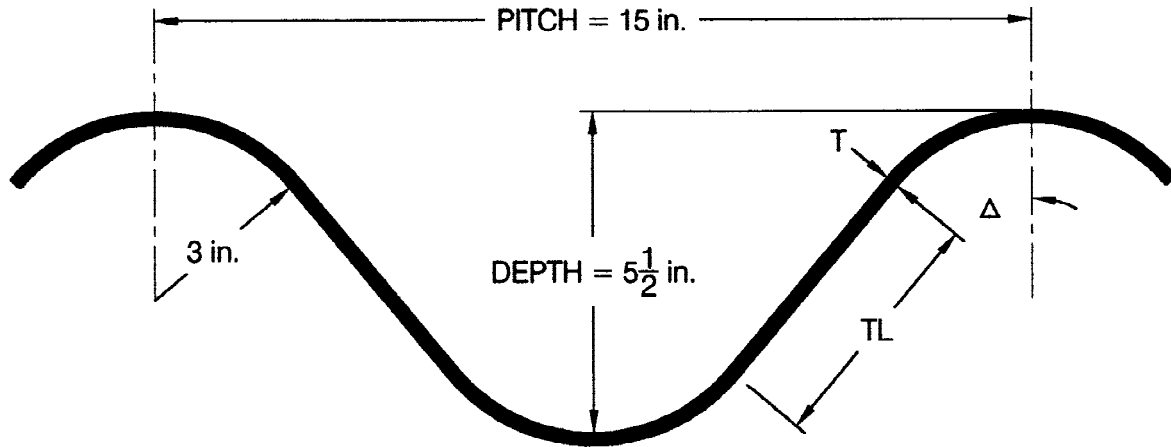
Specified Thickness, mm	Area of Section, A, mm <sup>2</sup> /mm	Tangent Length, TL, mm	Tangent Angle, Δ, °	Moment of Inertia, mm <sup>4</sup> /mm	Radius of Gyration, r, mm	Ultimate Strength of Bolted Structural Plate Longitudinal Seams in kN per m of Seam		
						2 Bolts per Corrugation <sup>A,B</sup>	3 Bolts per Corrugation <sup>A,B</sup>	4 Bolts per Corrugation <sup>A,B</sup>
2.82	3.294	48.08	44.47	990.06	17.3	613	...	...
3.56	4.240	47.27	44.73	1280.93	17.4	905	...	...
4.32	5.184	46.43	45.00	1575.89	17.4	1182	...	...
4.79	5.798	45.90	45.18	1769.80	17.5	1357	...	...
5.54	6.771	45.03	45.47	2079.80	17.5	1634	...	...
6.32	7.743	44.15	45.77	2395.25	17.6	1926	...	...
7.11	8.719	43.23	46.09	2717.53	17.7	2101	2626	2830
8.08	9.887	41.99	46.47	3113.54	17.7	...	...	3430
9.65	11.881	40.16	47.17	3801.80	17.9	...	...	4159

<sup>A</sup>Bolts are M20 for 7.11 mm or thinner materials. Thicker materials require M22 bolts.

<sup>B</sup>The number of bolts per corrugation includes the bolts in the corrugation crest and in the corrugation valley; the number of bolts within one pitch.

**TABLE 27 Sectional Properties of Corrugated Steel Plates for Corrugation: 15 by 5½ in. (Annular)**

NOTE 1—Dimensions shown in the figure are exact values used in calculating the section properties. Nominal values, for some of these dimensions, are used in other places in this practice.



Specified Thickness, in.	Area of Section, A, in. <sup>2</sup> /ft	Tangent Length, TL, in.	Tangent Angle, Δ, °	Moment of Inertia, I × 10 <sup>-3</sup> in. <sup>4</sup> /in.	Radius of Gyration, r, in.	Ultimate Strength of Bolted Structural Plate Longitudinal Seams in Pounds per Foot of Seam		Bolt Diameter, in.
						6 Bolts per Corrugation <sup>A</sup>		
0.140	2.260	4.361	49.75	714.63	1.948	66 000		¾
0.170	2.762	4.323	49.89	874.62	1.949	87 000		¾
0.188	3.088	4.299	49.99	978.64	1.950	102 000		¾
0.218	3.604	4.259	50.13	1143.59	1.952	127 000		¾
0.249	4.118	4.220	50.28	1308.42	1.943	144 000		¾
0.280	4.633	4.179	50.43	1472.17	1.954	144 000		¾
0.249	4.118	4.220	50.28	1308.42	1.943	159 000		7/8
0.280	4.633	4.179	50.43	1472.17	1.954	177 000		7/8

<sup>A</sup>The number of bolts per corrugation includes the bolts in the corrugation crest and in the corrugation valley; the number of bolts within one pitch.

Depth of Corrugation, in. [mm]	FF, in./lbf [mm/N]	Profile, in. [mm]	FF, in./lbf [mm/N]
¼ [6.5]	0.043 [0.245]	¾ by ¾ by 7½ [19 by 19 by 190]	0.217 <sup>1/3</sup> [0.0488]
½ [13]	0.043 [0.245]	¾ by 1 by 8½ [19 by 25 by 216]	0.140 <sup>1/3</sup> [0.0315]
1 [25]	0.033 [0.188]	¾ by 1 by 11½ [19 by 25 by 292]	0.140 <sup>1/3</sup> [0.0315]
2 (round pipe) [51]	0.020 [0.114]		
2 (pipe-arch, arch, underpass) [51]	0.030 [0.171]		
5½ (round pipe) [140]	0.020 [0.114]		
5½ (pipe-arch, arch, underpass) [140]	0.030 [0.171]		

10.4 For ribbed pipes installed in a trench cut in undisturbed soil and provided with a soil envelope meeting the requirements of 17.2.3 to minimize compactive effort, the flexibility factor shall not exceed the following:

Profile, in. [mm]	FF, in./lbf [mm/N]
¾ by ¾ by 7½ [19 by 19 by 190]	0.367 <sup>1/3</sup> [0.0825]
¾ by 1 by 8½ [19 by 25 by 216]	0.262 <sup>1/3</sup> [0.0589]
¾ by 1 by 11½ [19 by 25 by 292]	0.220 <sup>1/3</sup> [0.0495]

10.5 For ribbed pipes installed in a trench cut in undisturbed soil and where the soil envelope does not meet the requirements of 17.2.3, the flexibility factor shall not exceed the following:

Profile, in. [mm]	FF, in./lbf [mm/N]
¾ by ¾ by 7½ [19 by 19 by 190]	0.263 <sup>1/3</sup> [0.0591]
¾ by 1 by 8½ [19 by 25 by 216]	0.163 <sup>1/3</sup> [0.0366]
¾ by 1 by 11½ [19 by 25 by 292]	0.163 <sup>1/3</sup> [0.0366]

10.6 For ribbed pipes installed in an embankment or fill section, the flexibility factor shall not exceed the following:

10.7 For composite ribbed pipe, the flexibility factor limits for ribbed pipe in 10.4-10.6 shall be multiplied by 1.05.

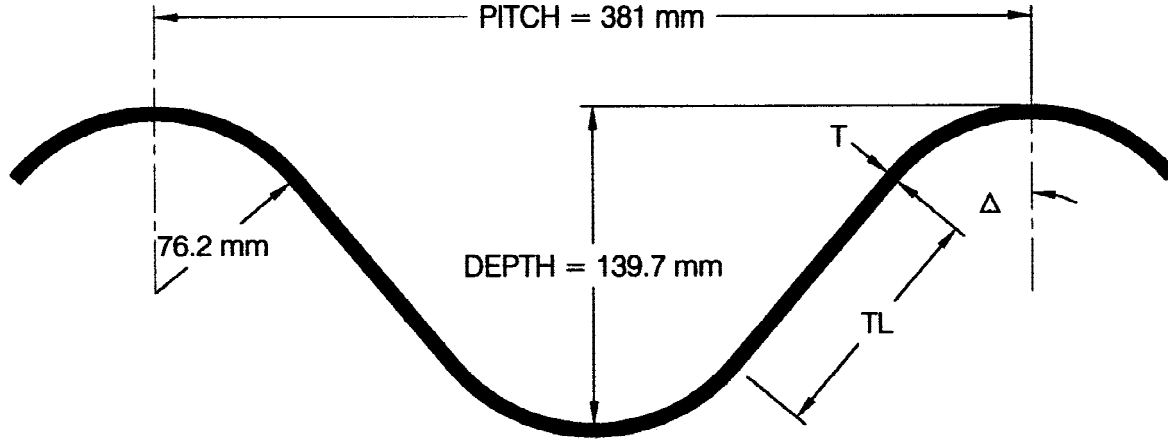
10.8 For closed rib pipe installed in a trench cut in undisturbed soil, or in an embankment or fill section, and for all multiple lines of such pipe, the flexibility factor shall not exceed the following:

Depth of Rib, in. [mm]	FF, in./lbf [mm/N]
½ [13]	0.0575 [0.328]
¾ [9.5]	0.0500 [0.286]
¼ [6]	0.0500 [0.286]

### 11. Minimum Cover Requirements

11.1 *Minimum Cover Design*—Where pipe is to be placed under roads, streets, or freeways, the minimum cover requirements shall be determined. Minimum cover ( $H_{min}$ ) is defined as the distance from the top of the pipe to the top of rigid pavement or to the top of subgrade for flexible pavement. Maximum axle loads in accordance with AASHTO “Standard Specification for Highway Bridges” are as follows:

TABLE 28 Sectional Properties of Corrugated Steel Plates for Corrugation: 381 by 140 mm (Annular) [SI Units]



Specified Thickness, mm	Area of Section, A, mm <sup>2</sup> /mm	Tangent Length, TL, mm	Tangent Angle, Δ, °	Moment of Inertia, I, mm <sup>4</sup> /mm	Radius of Gyration, r, mm	Ultimate Strength of Bolted Structural Plate Longitudinal Seams in kN per m of Seam		Bolt Diameter, mm
						6 Bolts per Corrugation <sup>A</sup>		
3.56	4.784	110.8	49.75	11710.7	49.48	963		19
4.32	5.846	109.8	49.89	14332.5	49.50	1270		19
4.79	6.536	109.2	49.99	16037.0	49.53	1489		19
5.54	7.628	108.2	50.13	18740.1	49.58	1853		19
6.32	8.716	107.2	50.28	21441.2	49.61	2101		19
7.11	9.807	106.1	50.43	24124.5	49.63	2101		19
6.32	8.716	107.2	50.28	21441.2	49.61	2320		22
7.11	9.807	106.1	50.43	24124.5	49.63	2583		22

<sup>A</sup>The number of bolts per corrugation includes the bolts in the corrugation crest and in the corrugation valley; the number of bolts within one pitch.

TABLE 29 Resistance Factors for LRFD Design

Type of Pipe	Limit State	Resistance Factor, φ
Helical pipe with lock seam or fully welded seam	Minimum wall area and buckling	1.00
Annular pipe with spot-welded, riveted, or bolted seam	Minimum wall area and buckling	1.00
	Minimum seam strength	0.67
Structural plate pipe	Minimum wall area and buckling	1.00
	Minimum seam strength	0.67

Class of Loading	Maximum Axle Load, lbf [N]
H20	32 000 [142 300]
HS 20	32 000 [142 300]
H15	24 000 [106 700]
HS 15	24 000 [106 700]

When:

$$\sqrt{\frac{(AL)d}{EI}} > 0.23 \text{ or } < 0.45, \quad (13)$$

the minimum cover requirement is:

$$H_{min} = 0.55S \sqrt{\frac{(AL)d}{EI}} \quad (14)$$

When:

$$\sqrt{\frac{(AL)d}{EI}} < 0.23 \text{ then } H_{min} = \frac{S}{8} \quad (15)$$

When:

$$\sqrt{\frac{(AL)d}{EI}} > 0.45 \text{ then } H_{min} = \frac{S}{4} \quad (16)$$

In all cases,  $H_{min}$  is never less than 1 ft [300 mm]. Additionally, for pipe with a specified thickness less than 0.052 in. [1.32 mm],  $H_{min}$  shall not be less than 2 ft [600 mm].

11.2 *Minimum Cover Under Railways*—Where pipe is to be placed under railways, the minimum cover (measured from the top of the pipe to the bottom of the cross-ties) shall not be less than 1/4 of the span for factory-made pipe, or 1/5 of the span for field-bolted pipe. In all cases, the minimum cover is never less than 1 ft [300 mm] for round pipe, or 2 ft [600 mm] for arches and pipe-arches.

11.3 *Minimum Cover Under Aircraft Runways*—Where pipe is to be placed under rigid-pavement runways, the minimum cover is 1.5 ft [450 mm] from the top of the pipe to the bottom of the slab, regardless of the type of pipe or the loading. For pipe under flexible-pavement runways, the minimum cover must be determined for the specific pipe and loadings that are to be considered; see FAA Standard AC No. 150/5320-5B.

11.4 *Construction Loads*—It is important to protect drainage structures during construction. Heavy construction equipment shall not be allowed close to or on buried pipe unless provisions are made to accommodate the loads imposed by such equipment. The minimum cover shall be 4 ft [1.2 m] unless field conditions and experience justify modification.

## 12. Deflection

12.1 The application of deflection design criteria is optional. Long-term field experience and test results have demonstrated that corrugated steel pipe, properly installed using suitable fill material, will experience no significant deflection. Some designers, however, continue to apply a deflection limit.

## 13. Smooth-Lined Pipe

13.1 Corrugated steel pipe composed of a smooth interior steel liner and a corrugated steel exterior shell that are attached integrally at the continuous helical lockseam shall be designed in accordance with this practice on the same basis as a standard corrugated steel pipe having the same corrugation as the shell and a weight per unit length equal to the sum of the weights of liner and shell. The corrugated shell shall be limited to corrugations having a maximum pitch of 3 in. [75 mm] nominal and a thickness of not less than 60 % of the total thickness of the equivalent standard pipe. The distance between parallel helical seams, when measured along the longitudinal axis of the pipe, shall be no greater than 30 in. [750 mm].

## 14. Smooth Pipe with Ribs

14.1 Pipe composed of a single thickness of smooth sheet, or smooth sheet and composite polyethylene liner, with helical rectangular or deltoid ribs projecting outwardly, shall be designed on the same basis as a standard corrugated steel pipe.

14.2 Pipe composed of a single thickness of smooth steel with helical closed ribs projecting outwardly shall be designed on the same basis as a standard corrugated pipe.

## 15. Pipe-Arch Design

15.1 Pipe-arch and underpass design shall be similar to round pipe using twice the top radius as the span ( $S$ ).

## 16. Materials

16.1 Acceptable pipe materials, methods of manufacture, and quality of finished pipe are given in Specifications A 760/A 760M, A 761/A 761M, A 762/A 762M, and A 978/A 978M.

## 17. Soil Design

17.1 The performance of a flexible corrugated steel pipe is dependent on soil-structure interaction and soil stiffness.

### 17.2 *Soil Parameters to be Considered:*

17.2.1 The type and anticipated behavior of the foundation soil under the design load must be considered.

17.2.2 The type compacted density and strength properties of the soil envelope immediately adjacent to the pipe shall be established. Good side-fill material is considered to be a granular material with little or no plasticity and free of organic material. Soils meeting the requirements of Groups GW, GP, GM, GC, SW, and SP as described in Classification D 2487 are

acceptable, when compacted to 90 % of maximum density as determined by Test Method D 698. Test Method D 1556, D 2167, D 2922, or D 2937 are alternate methods used to determine the in-place density of the soil. Soil types SM and SC are acceptable but require closer control to obtain the specified density; the recommendation of a qualified geotechnical or soils engineer is advisable, particularly on large structures.

17.2.3 Ribbed pipes and composite ribbed pipes covered by 10.4 shall have soil envelopes of clean, nonplastic materials meeting the requirements of Groups GP and SP in accordance with Classification D 2487, or well-graded granular materials meeting the requirements of Groups GW, SW, GM, SM, GC, or SC in accordance with Classification D 2487, with a maximum plasticity index (PI) of 10. All envelope materials shall be compacted to a minimum 90 % standard density in accordance with Test Method D 698. Maximum loose lift thickness shall be 8 in. [200 mm].

NOTE 1—Soil cement or cement slurries are acceptable alternatives to select granular materials

17.2.4 Closed rib pipes covered by 10.8 shall meet the requirements of 17.2.2 but, when the height of cover is over 15 ft [4.6 m], the structural soil envelope shall be compacted to 95 % of maximum density.

17.2.5 The size of the structural soil envelope shall be 2 ft [600 mm] minimum each side for trench installations and one diameter minimum each side for embankment installations. This structural soil envelope shall extend at least 1 ft [300 mm] above the top of the pipe.

17.3 *Pipe-Arch Soil Bearing Design*—The pipe-arch shape causes the soil pressure at the corner to be much higher than the soil pressure across the top of the pipe-arch. The maximum height of cover and the minimum cover requirement are often determined by the bearing capacity of the soil in the region of the pipe-arch corner. Accordingly, bedding and backfill material in the region of the pipe-arch corners shall be selected and placed such that the allowable soil bearing pressure is no less than the anticipated corner pressure calculated from the following equation:

$$P_c = (C_1LL + EL)r_1/r_c \quad (17)$$

LL shall be calculated as described in Section 6 for the design depths of fill (maximum and minimum), except that the following modifications shall be made to remove impact effects: (1) for H20 live loads (see 6.2.2.1) use 1600 psf [77 kPa] instead of 1800 psf [86 kPa]; and (2) for E80 live loads, divide the live load pressures listed in 6.2.2.2 by 1.5. The factor  $C_1$  may be conservatively taken as 1.0 or may be calculated as follows:

17.3.1 For H20 highway live loads:

$$C_1 = L_1/L_2 \text{ when } L_2 \leq 72 \text{ in. [1830 mm]} \quad (18)$$

$$C_1 = 2L_1/L_3 \text{ when } L_2 > 72 \text{ in. [1830 mm]}$$

where:

$$L_1 = 40 + (h - 12)1.75 \quad [L_1 = 1016 + (h - 305)1.75] \quad (19)$$

$$L_2 = L_1 + 1.37s \quad [L_2 = L_1 + 1.37s]$$

$$L_3 = L_2 + 72 \quad [L_3 = L_2 + 1829]$$

17.3.2 For E80 railway live loads:

$$C_1 = L_1/L_2 \quad (20)$$

where:

$$L_1 = 96 + 1.75h [L_1 = 2438 + 1.75h] \quad (21)$$

$$L_2 = L_1 + 1.37s [L_2 = L_1 + 1.37s]$$

## 18. Minimum Spacing

18.1 When multiple lines of pipes or pipe-arches greater than 48 in. [1200 mm] in diameter or span are used, they shall be spaced so that the sides of the pipe shall be no closer than one half of a diameter or 3 ft [900 mm], whichever is less, so that sufficient space for adequate compaction of the fill material is available. For diameters up to 48 in. [1200 mm], the minimum distance between the sides of the pipes shall be no less than 2 ft [600 mm].

18.2 Materials, such as cement slurry, soil cement, concrete, and various foamed mixes, that set-up without mechanical compaction are permitted to be placed between structures with as little as 6 in. [150 mm] of clearance.

## 19. End Treatment

19.1 Protection of end slopes shall require special consideration where backwater conditions occur or where erosion and uplift could be a problem.

19.2 End walls designed on a skewed alignment require special design.

## 20. Abrasive or Corrosive Conditions

20.1 Where additional resistance to corrosion is required, consider increasing the steel thickness or the use of coatings. Where additional resistance to abrasion is required, consider the use of invert paving as well.

## 21. Construction and Installation

21.1 The construction and installation of corrugated steel pipe and pipe-arches and steel structural plate pipe, pipe-arches, arches, and underpasses shall conform to Practice A 798/A 798M or A 807/A 807M.

## 22. Structural Plate Arches

22.1 The design of structural plate arches shall be based on a minimum ratio of rise to span of 0.3; otherwise, the structural design is the same as for structural plate pipe.

### 22.2 Footing Design:

22.2.1 The load transmitted to the footing is considered to act tangential to the steel plate at its point of connection to the footing. The load is equal to the thrust in the arch plate.

22.2.2 The footing shall be designed to provide settlement of an acceptable magnitude uniformly along the longitudinal axis. Providing for the arch to settle will protect it from possible overload forces induced by the settling adjacent embankment fill.

22.2.3 Where poor materials that do not provide adequate support are encountered, a sufficient quantity of the poor material shall be removed and replaced with acceptable material.

22.2.4 It is undesirable to make the arch relatively unyielding or fixed compared to the adjacent sidefill. The use of massive footings or piles to prevent settlement of the arch is generally not required.

22.2.5 Invert slabs or other appropriate methods should be provided when scour is anticipated.

## 23. Keywords

23.1 abrasive conditions; buried applications; composite structure; corrosive conditions; corrugated steel pipe; dead loads; embankment installation; handling and installation; live loads; minimum cover; sectional properties; sewers; steel pipe structural design; trench installation

## SUMMARY OF CHANGES

This section identifies the location of selected changes to this specification. For the convenience of the user, Committee A05 has highlighted those changes that may impact the use of this specification. This section may also include descriptions of the changes or reasons for the changes, or both.

### A 796/A 796M - 03:

Specification updated to reflect revised ultimate seam strength values for 15 by 5 1/5 -in [380 by 140-mm] corrugated plate.

(1) Paragraph 4.1, symbols definitions revised for yield and tensile strength of plate.

(2) Table 27 updated.

(3) Table 28 updated.

### A 796/A 796M - 00:

(1) The sectional properties for three new closed rib profiles for small diameter pipe have been added.

(2) Flexibility factors for the three new closed rib profiles have been added to limit the diameters over which the new profiles can be used.

(3) Restrictions have been added to exclude pipe with a specified thickness less than 0.052 in. [1.32 mm] for installations under railways and airport runways, and to require a minimum cover of at least 2 ft [600 mm] for other installations.

(4) For closed rib pipe, a requirement has been added for compaction of the structural soil envelope to 95 % of maximum density when the height of cover is over 15 ft [4.6 m].

 **A 796/A 796M – 03**

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# Standard Practice for Installing Factory-Made Corrugated Steel Pipe for Sewers and Other Applications<sup>1</sup>

This standard is issued under the fixed designation A 798/A 798M; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon ( $\epsilon$ ) indicates an editorial change since the last revision or reapproval.

*This standard has been approved for use by agencies of the Department of Defense.*

## 1. Scope

1.1 This practice covers procedures, soils, and soil placement for the proper installation of corrugated steel pipe and pipe-arches produced to Specification A 760/A 760M or A 762/A 762M, in either trench or embankment installations. A typical trench installation and a typical embankment (projection) installation are shown in Figs. 1 and 2, respectively. The pipes described in this practice are manufactured in a factory and furnished to the job in lengths ordinarily from 10 to 30 ft [3 to 9 m], with 20 ft [6 m] being common, for field joining. This practice applies to structures designed in accordance with Practice A 796/A 796M.

1.2 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

1.3 The values stated in either inch-pound units or SI units shall be regarded separately as standard. The values stated in each system may not be exact equivalents; therefore, each system must be used independently of the other, without combining values in any way. SI units are shown in brackets in the text for clarity, but they are the applicable values when the installation is to be performed using SI units.

## 2. Referenced Documents

### 2.1 ASTM Standards:

- A 760/A760M Specification for Corrugated Steel Pipe, Metallic-Coated for Sewers and Drains<sup>2</sup>
- A 762/A762M Specification for Corrugated Steel Pipe, Polymer Precoated for Sewers and Drains<sup>2</sup>
- A 796/A796M Practice for Structural Design of Corrugated Steel Pipe, Pipe-Arches, and Arches for Storm and Sanitary Sewers and Other Buried Applications<sup>2</sup>
- A 902 Terminology Relating to Metallic Coated Steel Products<sup>2</sup>

<sup>1</sup> This practice is under the jurisdiction of ASTM Committee A05 on Metallic Coated Iron and Steel Products and is the direct responsibility of Subcommittee A05.17 on Corrugated Steel Pipe Specifications.

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<sup>2</sup> *Annual Book of ASTM Standards*, Vol 01.06.

- D 698 Test Method for Laboratory Compaction Characteristics of Soil Using Standard Effort (12 400 ft-lbf/ft<sup>3</sup>[600 kN-m/m<sup>3</sup>])<sup>3</sup>
- D 1556 Test Method for Density of Soil in Place by the Sand-Cone Method<sup>3</sup>
- D 2167 Test Method for Density and Unit Weight of Soil in Place by the Rubber Balloon Method<sup>3</sup>
- D 2487 Classification of Soils for Engineering Purposes (Unified Soil Classification System)<sup>3</sup>
- D 2922 Test Methods for Density of Soil and Soil-Aggregate in Place by Nuclear Methods (Shallow Depth)<sup>3</sup>
- D 2937 Test Method for Density of Soil in Place by the Drive-Cylinder Method<sup>3</sup>

## 3. Terminology

3.1 *Definitions*—For definitions of general terms used in this practice, see Terminology A 902.

### 3.2 Definitions of Terms Specific to This Standard:

- 3.2.1 *bedding*—the earth or other material on which a pipe is supported.
- 3.2.2 *haunch*—the portion of the pipe cross section between the maximum horizontal dimension and the top of the bedding.
- 3.2.3 *invert*—the lowest point on the pipe cross section; also, the bottom portion of a pipe.
- 3.2.4 *pipe*—a conduit having full circular shape; also, in a general context, all structure shapes covered by this practice.
- 3.2.5 *pipe-arch*—an arch shape with an approximate semi-circular crown, small-radius corners, and large-radius invert.

## 4. Significance and Use

4.1 Corrugated steel pipe functions structurally as a flexible ring which is supported by and interacts with the compacted surrounding soil. The soil constructed around the pipe is thus an integral part of the structural “system.” It is therefore important to ensure that the soil structure or backfill is made up of acceptable material and well-constructed. Field verification of soil structure acceptability using Test Methods D 1556, D 2167, D 2922, or D 2937, as applicable, and comparing the results with Test Method D 698 in accordance with the specifications for each project is the most reliable basis for installation of an acceptable structure. The required density and

<sup>3</sup> *Annual Book of ASTM Standards*, Vol 04.08.



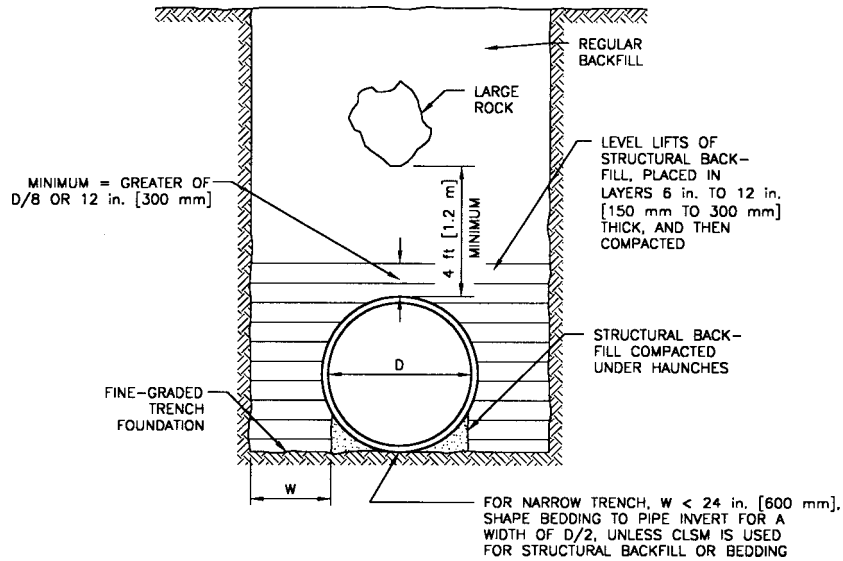


FIG. 1 Typical Trench Installation

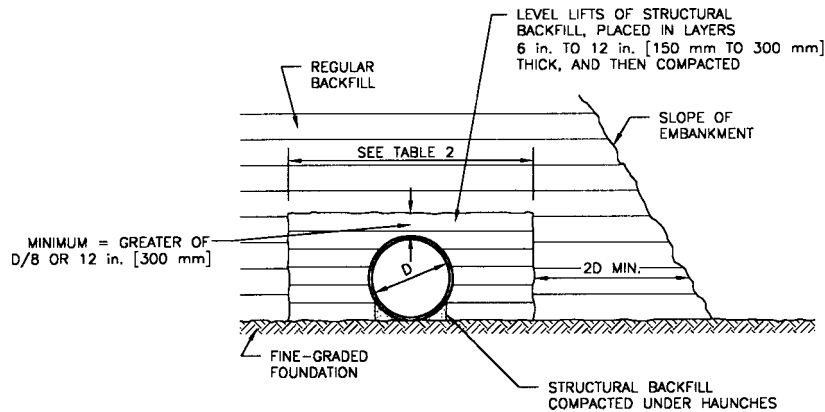


FIG. 2 Typical Embankment (Projection) Installation

method of measurement are not specified by this practice but must be established in the specifications for each project.

**5. Trench Excavation**

5.1 To obtain anticipated structural performance of corrugated steel pipe it is not necessary to control trench width beyond the minimum required for proper installation of pipe and backfill. However, the soil on each side beyond the excavated trench must be able to support anticipated loads. When a construction situation calls for a relatively wide trench, it may be made as wide as required, for its full depth if so desired. However, trench excavation must be in compliance with any local, state, and federal codes and safety regulations.

**6. Foundation**

6.1 The supporting soil beneath the pipe must provide a reasonably uniform resistance to the imposed load, both longitudinally and laterally. Sharp variations in the foundation must be avoided. When rock is encountered, it must be excavated and replaced with soil. If the pipe runs along a continuous rock foundation, it is necessary to provide a suitable soil bedding under the pipe. See Fig. 3.

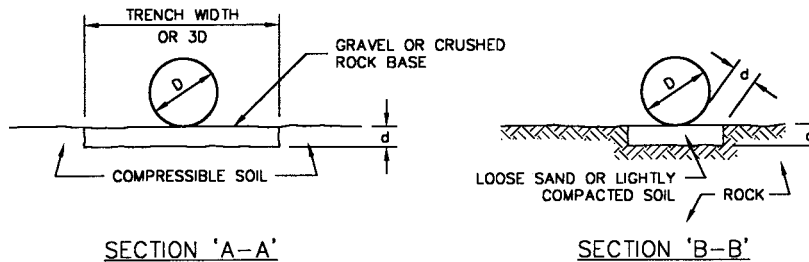
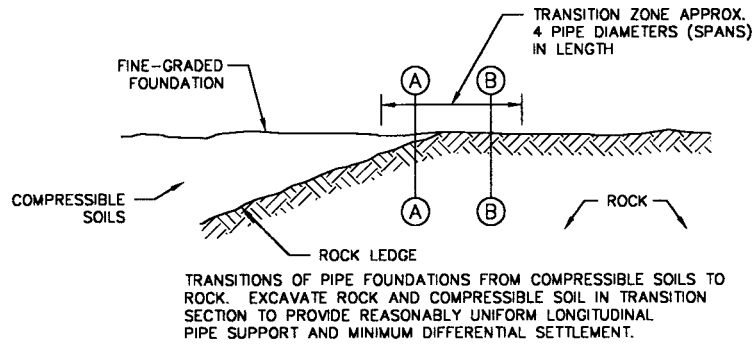
6.2 Lateral changes in foundation should never be such that

the pipe is firmly supported while the backfill alongside is not. When soft material is encountered and must be removed in order to maintain the pipe on grade during construction, it must be removed for at least three pipe widths. See Fig. 4. A smaller width of removal can sometimes be used if established by the engineer.

6.3 Performance of buried pipe is enhanced by allowing the pipe to settle slightly under load compared to the columns of soil alongside. Thus, for larger pipes it can be beneficial to purposely create a foundation under the pipe itself which will yield under load more than will the foundation under the columns of soil to each side. It can usually be obtained by placing beneath the structure a suitable-thickness layer of compressible soil, less densely compacted than the soil alongside. This creates “favorable” relative movement between pipe and the soil on each side. It is of particular importance on pipe-arches.

6.4 *Pipe-Arches*—All pipe-arch structures shall have excellent soil support at their corners by both the in-situ foundation and the structural backfill. See Figs. 4 and 5. They do not require the same degree of support under their large-radius inverts.

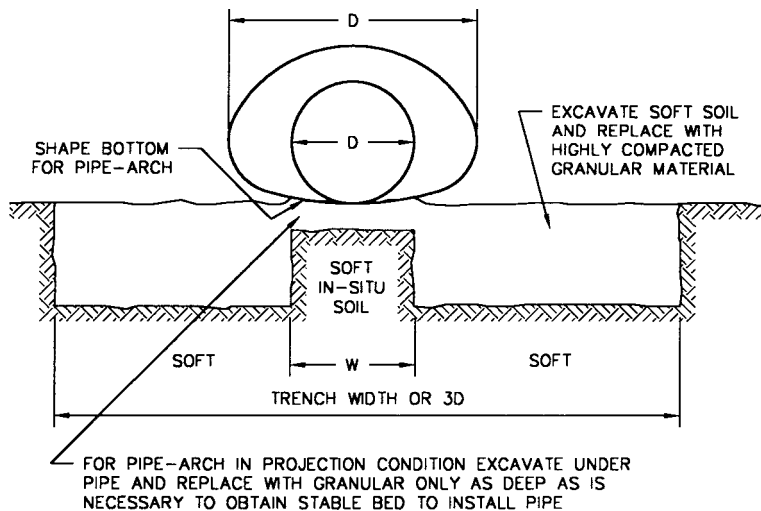
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NOTE 1— $d = \frac{1}{2}$  in./ft [40 mm/m] of fill over pipe, with a 24 in. [600 mm] maximum.

NOTE 2—Section B-B is applicable to all continuous rock foundations.

FIG. 3 Foundation Transition Zones and Rock Foundations



NOTE 1— $W = D$  for round pipe, and  $W =$  width of flat bottom arc for pipe-arch.

FIG. 4 Soft Foundation Treatment

6.5 The engineer is encouraged to develop details specific to the site based on the general principles for foundation conditions given in 6.1 through 6.4.

7. Bedding

7.1 Corrugated steel pipe may be placed directly on the fine-graded foundation for the pipe line. Material in contact with the pipe shall not contain rock retained on a 3-in. [75-mm] ring, frozen lumps, chunks of highly plastic clay, organic matter, corrosive material, or other deleterious material. It is not required to shape the bedding to the pipe geometry. However, for pipe-arches, it is recommended to either shape the bedding to the relatively flat bottom arc or fine-grade the

foundation to a slight v-shape. This avoids the problem of trying to backfill the difficult area beneath the invert of pipe-arches. See Fig. 5.

8. Pipe Installation

8.1 All pipe shall be unloaded and handled with reasonable care. Pipe shall not be rolled or dragged over gravel or rock and shall be prevented from striking rock or other hard objects during placement on bedding. Pipe with protective coatings shall be handled with special care to avoid damage. Paved inverts shall be placed and centered in the invert. Riveted pipe should be installed so that outside circumferential joints point upgrade.

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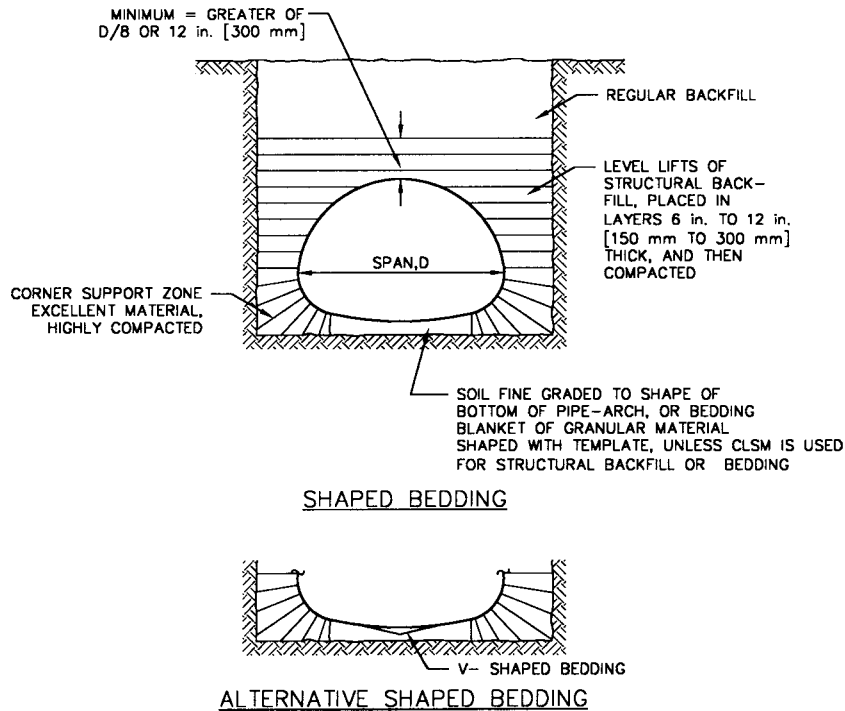


FIG. 5 Bedding and Corner Zone Treatment for Pipe Arch Structures

8.2 Joining Systems:

8.2.1 Purpose of Joining Systems—Joining systems for corrugated steel pipe serve several purposes: to maintain pipe alignment during installation; to join the ends of the pipe sections that will subsequently be buried; to create a continuous flow line; to limit the amount of infiltration of backfill material into the pipe and to limit exfiltration of the flow through the pipe line.

8.2.2 Joining System Components—The joining system has been specified by the project engineer. It shall conform to the requirements of Specification A 760/A 760M. The pipe fabricator shall provide the components specified for the project or as designated by the fabricator in accordance with Specification A 760/A 760M, 5.11.1. Conformance of the joining system components with the project requirements shall be verified upon delivery to the project site.

8.2.3 Joining System Installation—The performance of the pipe line and the joining system will be achieved only when all components of the pipe system are properly installed. As an integral portion of the pipe system, the joining system must be assembled in accordance with the details in the project drawings or the recommendations provided by the pipe fabricator.

8.2.3.1 Gaskets—If gaskets are a required component of the joining system, they shall be placed on the pipe ends, at the required location on the pipe, prior to installation of the coupler or bands or prior to stabbing a bell and spigot joint. For joining systems incorporating O-rings, one O-ring shall be placed on the end of each pipe placed and extended over the subsequent pipe as the joint is completed. For pipe supplied with a factory installed band or coupler, no gasket will be required on the pipe end with the factory installed device. When recommended by the pipe manufacturer, lubricant shall be applied to the designated surfaces. Once installed, the gasket shall be protected against damage until the joint is completely installed.

8.2.3.2 Coupling Bands—Coupling bands shall be placed on the end of the last pipe installed. When installing two part bands, the first portion of the band shall be placed to cover the bottom portion of the pipe. When the subsequent pipe is placed the installation of the joining system is completed to ensure proper alignment of the pipeline. The width of the opening between pipe ends shall be as recommended by the pipe fabricator. The band shall be tightened around the pipe ends to the extent necessary to achieve proper performance of the joining system. Follow the pipe fabricators' instructions and methods for tightening the bands.

8.2.3.3 Sleeve Coupler and Bell and Spigot Joining Systems—If a field installed sleeve coupler is utilized it shall be placed on the end of the pipe previously placed. With a bell and spigot system, the first pipe is to be oriented so the bell is open in the direction in which construction will proceed. The subsequent pipe is installed by inserting the spigot, or pipe end without the sleeve coupler, to the maximum depth permitted by the joining system. Follow the pipe fabricators instructions for the method of assembly and use of insertion force.

8.2.4 Joint Backfill—The joining system was selected based on the expected site conditions, specifically the type and gradation of backfill material. The structural backfill material used around the pipe shall be in accordance with the project specifications. Backfill material shall conform to Section 9, and shall be placed in accordance with Section 10. Care shall be exercised during backfill placement not to damage or dislodge the joining system.

9. Structural Backfill Material

9.1 Structural backfill is that material which surrounds the pipe, extending laterally to the walls of the trench, or to the fill material for embankment construction, and extending vertically from the invert to an elevation of 1 ft [300 mm], or 1/8th

diameter or span, whichever is greater, over the pipe. The necessary width of structural backfill depends on the quality of the trench wall or embankment material, the type of material and compaction equipment used for the structural backfill, and in embankment construction, the type of construction equipment used to compact the embankment fill. The width of structural backfill shall meet the requirements given in Table 1.

9.2 Structural backfill material shall be fine, readily compacted soil or granular fill material. Structural backfill material may be excavated native material, when suitable, or select material. Select materials such as bank run gravels or other processed granular materials less than 3 in. [75 mm] maximum with excellent structural characteristics are preferred. Desired end results can be obtained with this type of material with a minimum of compaction effort over a wide range of moisture content, lift depth, and compaction equipment characteristics. Excavated native soils used as structural backfill shall not contain stones retained on a 3-in. [75-mm] ring, frozen lumps, highly plastic clay, organic material, corrosive material, or other deleterious foreign materials. Soils meeting the requirements of Groups GW, GP, GM, GC, SW, and SP as described in Test Method D 2487 are generally acceptable, when compacted to the specified percent of maximum density as determined by Test Method D 698. Test Methods D 1556, D 2167, D 2922, and D 2937 may be used to determine the in-place density of the soil. Soil Types SM and SC are acceptable, but may require closer control to obtain the specified density. Soil Types ML and CL are not preferred materials, while Soil Types OL, MH, CH, OH, and PT are not acceptable.

9.3 Special materials other than soil may be used as described in 10.1.

## 10. Structural Backfill Placement

10.1 Structural backfill shall be placed in layers from 6 to 12 in. [150 to 300 mm] in depth depending on the type of material and compaction equipment or method. Each layer or “lift” shall be compacted before adding the next lift. On flat bedding, care must be taken to place material under the pipe haunches and compact it firmly. Structural backfill on each side of the pipe shall be kept in balance. Generally, no more than one lift

difference should be permitted. Construction equipment shall not be used over or alongside the pipe without sufficient compacted soil between it and the pipe to prevent distortion, damage, or overstressing. Mechanical soil compaction of layers is preferred. However, when acceptable end results can be achieved with water consolidation, it may be used. When water methods are used, care must be taken to prevent flotation. It shall be used only on free-draining structural backfill material. If cohesive soils are used as structural backfill, good compaction can only be obtained at proper moisture content. Shallower lifts are generally required for acceptable end results with cohesive soils than with granular or mixed soils. In general, much closer inspection and testing must be exercised to ensure good results with cohesive structural backfill material. Water compaction is not acceptable with cohesive material. Unusual field conditions may make relatively costly special backfill material practical. Materials that set up without compaction, such as cement slurry, controlled low-strength material (CLSM), and various foamed mixtures, provide excellent structural backfill provided they are designed to yield the compressive strength required. As with water compaction, care must be taken to avoid flotation.

10.2 The compaction of structural backfill shall provide a soil structure around the pipe to uniformly apply overburden pressures on the crown of the pipe and provide uniform bearing for the pipe side walls and lower haunches. The required degree of compaction will vary with the job and structural backfill material. The structural backfill is an integral part of the design process. Therefore, required end results regarding in-place density of structural backfill shall be in accordance with job specifications. Most structural design tables for corrugated steel pipe establish maximum overfill depths based on a specified field density of 90 % in accordance with Test Method D 698 with good structural backfill material. However, the majority of sewer pipe installations do not require deep overfills. For relatively shallow buried pipes not subject to live load, an acceptable structural backfill material and its degree of compaction may be determined by the character of the adjacent ground. A “balanced design” making the conduit homogeneous with the ground on either side is often desirable. For this reason, it is not practical to establish arbitrary minimums for soil characteristics of structural backfill for all installations.

10.3 *Pipe-Arches*—Special attention must be given to the material used and compaction obtained around the corners of pipe-arches. Vertical load over the pipe is transmitted into the soil principally at the corners. Therefore, the quality of structural backfill is particularly important adjacent to pipe-arch corners. In the case of higher fills or deep trenches, special designs may be required for corner backfill zones.

10.4 Generally, construction experience and a site appraisal will establish the most economical combination of material, method, and equipment to yield acceptable end results. Test Method D 698 is the preferred means of determining maximum (standard) density and optimum moisture content. A construction procedure must then be established that will result in the specified percent of maximum density. Once that is established, primary inspection effort should be directed at ensuring that the established procedure is followed. Such a procedure may

**TABLE 1 Structural Backfill Width Requirements<sup>AB</sup>**

Adjacent Material	Required Structural Backfill Width
Normal highway embankment compacted to minimum of 90 % Test Method D 698 density or equivalent trench wall.	As needed to establish pipe bedding and to fill and compact the backfill in the haunch area and beside the pipe. Where backfill materials that do not require compaction are used, such as cement slurry or controlled low-strength material (CLSM), a minimum of 3 in. [75 mm] on each side of the pipe is required.
Embankment or trench wall of lesser quality.	Increase backfill width as necessary to reduce horizontal pressure from pipe to a level compatible with bearing capacity of adjacent materials.

<sup>A</sup>For pipe-arches and other multiple-radius structures, as well as for all structures carrying off-road construction equipment, the structural backfill width, including any necessary foundation improvement materials, must be sufficient to reduce the horizontal pressure from the structure so that it does not exceed the bearing capacity of the adjacent material.

<sup>B</sup>In embankment construction, the structural backfill width must be adequate to resist forces caused by the embankment construction equipment. Generally, the width on each side of the pipe should be no less than 1 diameter or span, or 2 ft [600 mm], whichever is less.

involve material, depth of lift, moisture content, and compactive effort. Only occasional checks may then be required, as long as the material and procedures are unchanged. In situ density may be determined by Test Methods D 1556, D 2167, D 2922, or D 2937 as applicable, for field verification. Testing should be conducted on both sides of the structure. Any construction methods and equipment that achieve required end results without damage to or distortion of the pipe shall be acceptable.

10.5 *Shape Control*—Excessive compaction, unbalanced loadings, loads from construction equipment, as well as inadequate compaction or poor backfill materials, can cause excessive pipe distortion. For larger pipe, the construction contractor may set up a shape monitoring system, prior to placement of structural backfill, to aid in establishing and maintaining proper installation procedures. Direct measurement of span and rise, offset measurements from plumb bobs hanging over reference points, and similar types of measurements are effective means for monitoring shape change during backfill placement and compaction. In general, it is desirable for the crown of the pipe to rise slightly, in a balanced concentric manner, during placement and compaction of soil beside the pipe. Under the load of the completed fill and the service load, vertical deflections will be a small percentage of the pipe rise dimension if backfill compaction is adequate.

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*This standard is subject to revision at any time by the responsible technical committee and must be reviewed every five years and if not revised, either reapproved or withdrawn. Your comments are invited either for revision of this standard or for additional standards and should be addressed to ASTM Headquarters. Your comments will receive careful consideration at a meeting of the responsible technical committee, which you may attend. If you feel that your comments have not received a fair hearing you should make your views known to the ASTM Committee on Standards, at the address shown below.*

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## **11. Regular Backfill**

11.1 Regular backfill in trench installation is that material replaced in the trench above the structural backfill. In projection conditions, it is also the embankment fill adjacent to the structural backfill.

11.2 Regular backfill shall consist of native materials and shall be placed and compacted as required by job specifications. Large rocks or boulders shall not be placed within 4 ft [1.2 m] of the pipe. Large boulders should not be permitted in regular backfill in trenches that are under surface structures, including pavements. Construction equipment shall not be used over or alongside the pipe without sufficient compacted soil in between it and the pipe to prevent distortion, damage, or overstressing.

## **12. Multiple Structures**

12.1 When two or more structures are installed in adjacent lines, the minimum spacing requirements given in Practice A 796/A 796M must be provided.

## **13. Keywords**

13.1 corrugated steel pipe; installation; sewers; steel pipe



# Standard Practice for Installing Corrugated Steel Structural Plate Pipe for Sewers and Other Applications<sup>1</sup>

This standard is issued under the fixed designation A 807/A 807M; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon ( $\epsilon$ ) indicates an editorial change since the last revision or reapproval.

<sup>ε1</sup> NOTE—Editorially corrected the term specification to practice in 3.2.4 in September 2002.

## 1. Scope

1.1 This practice covers procedures, soils, and soil placement for the proper installation of corrugated steel structural plate pipe, pipe-arches, arches, and underpasses produced to Specification A 761/A 761M, in either trench or embankment installations. A typical trench installation and a typical embankment (projection) installation are shown in Figs. 1 and 2, respectively. Structural plate structures as described herein are those structures factory fabricated in plate form and bolted together on site to provide the required shape, size, and length of structure. This practice applies to structures designed in accordance with Practice A 796/A 796M.

1.2 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

1.3 The values stated in either inch-pound units or SI units shall be regarded separately as standard. The values stated in each system may not be exact equivalents; therefore, each system must be used independently of the other, without combining values in any way. SI units are shown in brackets in the text for clarity, but they are the applicable values when the installation is to be performed using SI units.

## 2. Referenced Documents

### 2.1 ASTM Standards:

A 761/A 761M Specification for Corrugated Steel Structural Plates, Zinc Coated, for Field-Bolted Pipe, Pipe Arches, and Arches<sup>2</sup>

A 796/A 796M Practice for the Structural Design of Corrugated Steel Pipe, Pipe-Arches, and Arches for Storm and Sanitary Sewers and Other Buried Applications<sup>2</sup>

A 902 Terminology Relating to Metallic Coated Steel Products<sup>2</sup>

D 698 Test Method for Laboratory Compaction Characteristics of Soil Using Standard Effort (12 400 ft-lbf/ft<sup>3</sup> [600 kN-m/m<sup>3</sup>])<sup>3</sup>

D 1556 Test Method for Density and Unit Weight of Soil in Place by the Sand-Cone Method<sup>3</sup>

D 1557 Test Method for Laboratory Compaction Characteristics of Soil Using Modified Effort (56 000 ft-lbf/ft<sup>3</sup> [2700 kN-m/m<sup>3</sup>])<sup>3</sup>

D 2167 Test Method for Density and Unit Weight of Soil in Place by the Rubber Balloon Method<sup>3</sup>

D 2487 Classification of Soils for Engineering Purposes (Unified Soil Classification System)<sup>3</sup>

D 2922 Test Methods for Density of Soil and Soil-Aggregate in Place by Nuclear Methods (Shallow Depth)<sup>3</sup>

D 2937 Test Method for Density of Soil in Place by the Drive-Cylinder Method<sup>3</sup>

## 3. Terminology

3.1 *Definitions*—For definitions of general terms used in this practice, refer to Terminology A 902.

3.2 *Definitions of Terms Specific to This Standard:*

3.2.1 *arch*—a part circle shape spanning an open invert between the footings on which it rests.

3.2.2 *bedding*—the earth or other material on which a pipe is supported.

3.2.3 *haunch*—the portion of the pipe cross section between the maximum horizontal dimension and the top of the bedding.

3.2.4 *invert*—the lowest point on the pipe cross section; also, the bottom portion of a pipe.

3.2.5 *pipe*—a conduit having full circular shape; also, in a general context, all structure shapes covered by this practice.

3.2.6 *pipe-arch*—an arch shape with an approximate semi-circular crown, small-radius corners, and large-radius invert.

<sup>1</sup> This practice is under the jurisdiction of ASTM Committee A05 on Metallic Coated Iron and Steel Products and is the direct responsibility of Subcommittee A05.17 on Corrugated Steel Pipe Specifications.

Current edition approved April 10, 2002. Published June 2002. Originally published as A 807 – 82. Last previous edition A 807 – 97.

<sup>2</sup> *Annual Book of ASTM Standards*, Vol 01.06.

<sup>3</sup> *Annual Book of ASTM Standards*, Vol 04.08.

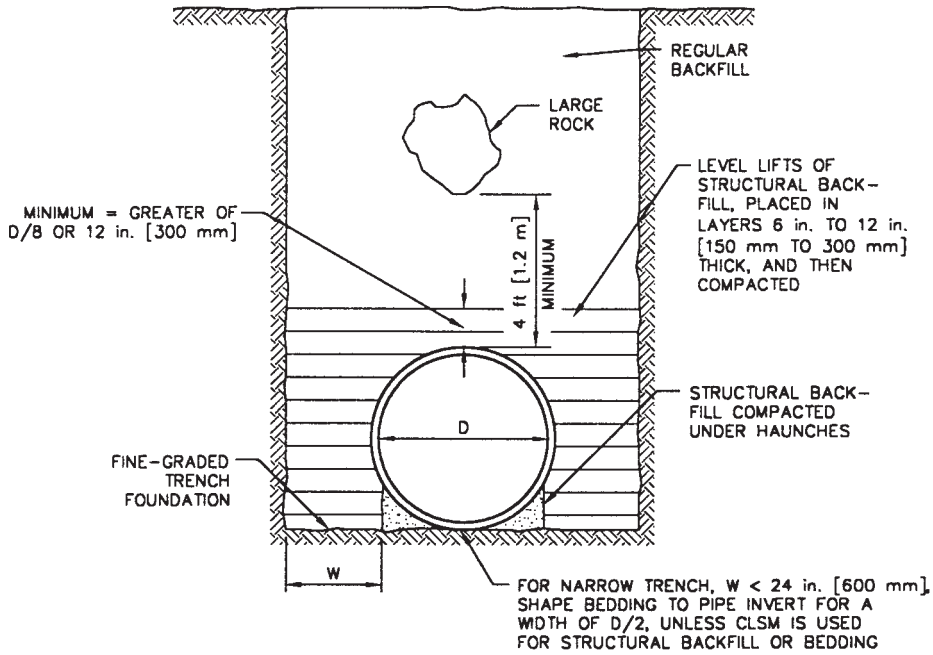


FIG. 1 Typical Trench Installation

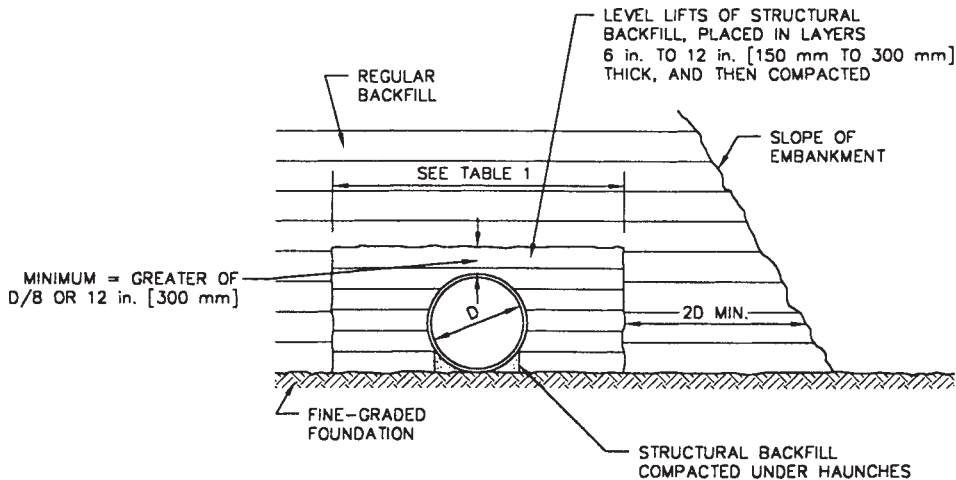


FIG. 2 Typical Embankment (Projection) Installation

3.2.7 *underpass*—a high arch shape with an approximate semicircular crown, large-radius sides, small-radius corners between sides and invert, and large-radius invert.

#### 4. Significance and Use

4.1 Structural plate structures function structurally as a flexible ring that is supported by and interacts with the compacted surrounding soil. The soil placed around the structure is thus an integral part of the structural system. It is therefore important to ensure that the soil structure is made up of acceptable material and is well constructed. Field verification of soil structure acceptability using Test Methods D 1556, D 2167, D 2922, or D 2937, as applicable, and comparing the results with either Test Methods D 698 or D 1557, in accordance with the specifications for each project, is the most

reliable basis for installation of an acceptable structure. The required density and method of measurement are not specified by this practice, but must be established in the specifications for each project.

#### 5. Trench Excavation

5.1 To obtain the anticipated structural performance of structural plate structures, it is not necessary to control trench width beyond the minimum necessary for proper assembly of the structure and placement of the structural backfill. However, the soil on each side beyond the excavated trench must be able to support anticipated loads. Any sloughed material shall be removed from the trench or compacted to provide the necessary support. When a construction situation calls for a relatively wide trench, it may be made as wide as required, for its

full depth if so desired. However, trench excavation must be in compliance with any local, state, and federal codes and safety regulations.

**6. Foundation**

6.1 The supporting soil beneath the structure must provide a reasonably uniform resistance to the imposed load, both longitudinally and laterally. Sharp variations in the foundation must be avoided. When rock is encountered, it must be excavated and replaced with soil. If the structure is to be placed on a continuous rock foundation, it will be necessary to provide a bedding of soil between rock and structure. See Fig. 3.

6.2 Lateral changes in foundation should never be such that the structure is firmly supported while the backfill on either side is not. When soft material is encountered in the structure excavation and must be removed to maintain the grade (limit settlement) of the structure, then it must be removed, usually for a minimum of three structure widths (see Fig. 4). A smaller width of removal can sometimes be used if established by the engineer.

6.3 Performance of buried structures is enhanced by allowing the structure to settle slightly relative to the columns of earth alongside. Therefore, when significant settlement of the overall foundation is expected, it is beneficial to provide a yielding foundation under structural plate structures. A yielding foundation is one that allows the structure to settle vertically by a greater amount than the vertical settlement of the columns of earth alongside. It can usually be obtained by placing a layer of compressible soil of suitable thickness beneath the structure

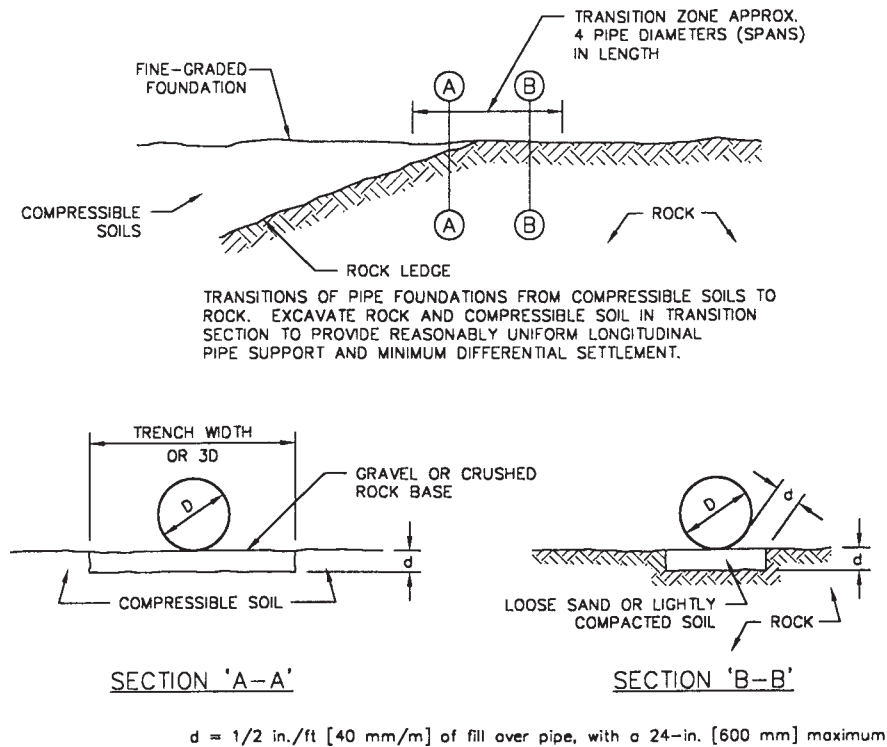
that is less densely compacted than the soil alongside. This is particularly important on structures with relatively large-radius invert plates.

6.4 For all structures with relatively small-radius corner plates adjacent to large-radius invert plates (such as pipe-arches or underpass structures), excellent soil support must be provided adjacent to the small-radius corner plates by both the in situ foundation and the structural backfill. See Figs. 4 and 5. A yielding foundation must be provided beneath the invert plates for such structures when soft foundation conditions are encountered.

6.5 The engineer is encouraged to develop details specific to the site based on the general principles for foundation conditions given in 6.1 through 6.4.

**7. Bedding**

7.1 In most cases, structural plate structures may be assembled directly on in-situ material fine-graded to proper alignment and grade. Take care to compact the material beneath the haunches before placing structural backfill. Material in contact with the pipe must not contain rock retained on a 3 in. [75 mm] diameter ring, frozen lumps, chunks of highly plastic clay, organic matter, corrosive material, or other deleterious material. For structures with relatively small-radius corner plates adjacent to large-radius invert plates, it is recommended to either shape the bedding to the invert plate radius or fine-grade the foundation to a slight V-shape. The soil adjacent to the corners shall be of an excellent quality and highly compacted to accommodate the high reaction pressures that can develop at that location. See Fig. 5.



NOTE 1—Section B-B is applicable to all continuous rock foundations.

**FIG. 3 Foundation Transition Zones and Rock Foundations**



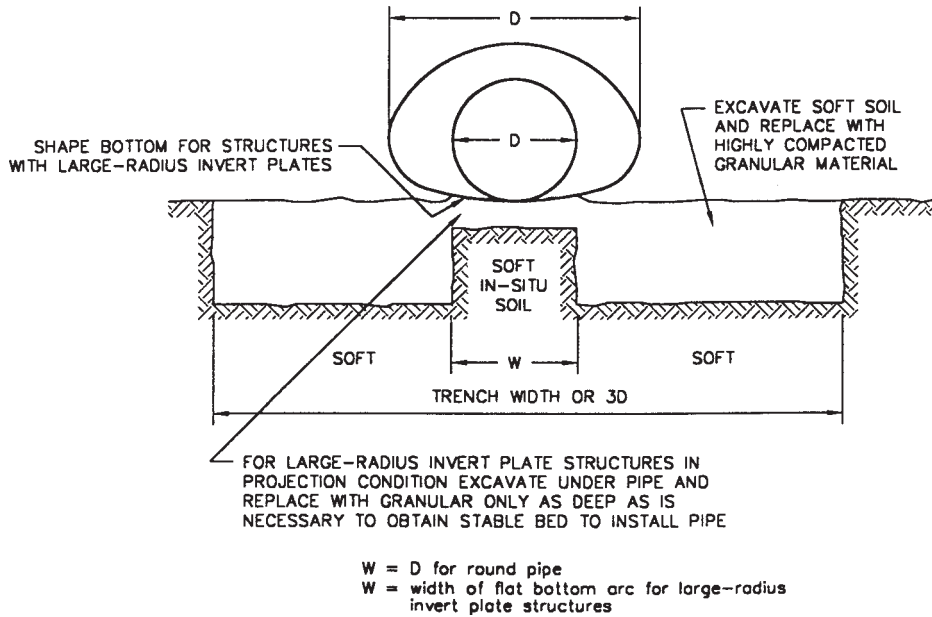
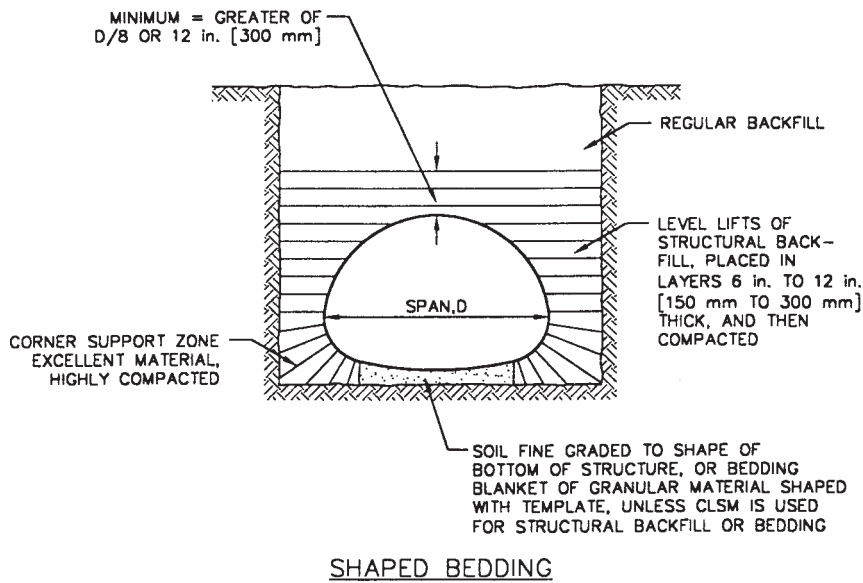


FIG. 4 Soft Foundation Treatment



ALTERNATIVE SHAPED BEDDING

FIG. 5 Bedding and Corner Zone Treatment for Large-Radius Invert Plate Structures

7.2 Structures having a span greater than 15 ft [4.5 m] or a depth of cover greater than 20 ft [6 m] should be provided with a shaped bedding on a yielding foundation. The bedding should be shaped to facilitate the required compaction of the structural backfill under the haunches. A shaped bedding on a yielding foundation is always required under structures with small-radius corner plates adjacent to large-radius invert plates.

## 8. Assembly

8.1 Structural plate structures are furnished in components of plates and fasteners for field assembly. These components are furnished in accordance with Specification A 761/A 761M. Plates are furnished in various widths and multiple lengths, preformed and punched for assembling into the required

structure shape, size, and length. The plate widths form the periphery of the structure. The various widths and the multiple lengths can be arranged to allow for staggered seams (longitudinal or transverse, or both) to avoid four-plate laps. The fabricator of the structural plate shall furnish an assembly drawing showing the location of each plate by width, length, thickness, and curvature. The plates must be assembled in accordance with the fabricator’s drawing.

8.2 For structures with inverts, assembly shall begin with the invert plates at the downstream end. As assembly proceeds upstream, plates that fall fully or partly below the maximum width of the structure are lapped over the preceding plates to construct the transverse seams.

8.3 Arches have no integral invert and usually rest in special channels cast into, or connected to, footings. Channels must be accurately set to span, line, and grade as shown on the fabricator’s drawing. When the arch is other than a half circle, the channel must be rotated in the footing to allow for entrance of the plates. For arches with ends cut on a skew, the base channels will also be skewed, but properly aligned across the structure. All pertinent dimensions must be shown on the fabricator’s drawing. For arch structures, assembly begins at the upstream end and proceeds downstream, with each succeeding plate lapping on the outside of the previous plate. Plates attached to the footing channel are not self-supporting and will require temporary support. Assemble as few plates as practical, from the channels toward the top center of the structure, and complete the periphery to maintain the structure shape.

8.4 Generally, structural plate should be assembled with as few bolts as practical. These bolts should be placed loose and remain loose until the periphery has been completed for several plate lengths. However, on large structures, it is practical to align bolt holes during assembly and tighten the bolts to maintain structure shape. After the periphery of the structure is completed for several plate lengths, all bolts may be placed and tightened. Correct any significant deviation in structure shape before tightening bolts (see Section 10). It is advisable not to tighten bolts on the loosely assembled structure within a distance of 30 ft [9 m] of where plate assembly is ongoing. All bolts shall be tightened using an applied torque of between 100 and 300 ft-lbf [135 and 405 N·m]. It is important not to overtorque the bolts.

8.5 Standard structural plate structures, because of the bolted construction, are not intended to be watertight. On occasions in which a degree of watertightness is required, it is practical to introduce a seam sealant tape within the bolted seams. The tape shall be wide enough to effectively cover all rows of holes in plate laps, and of the proper thickness and consistency to effectively fill all voids in plate laps. General procedures for installing sealant tape are as follows: On longitudinal seams, before placing the lapping plate, roll the tape over the seam and work into the corrugations. Do not stretch the tape. Remove any paper backing before making up the joint. Seal transverse seams in a like manner with tape. At all points where three plates intersect, place an additional thickness of tape for a short distance to fill the void caused by the transverse seam overlap. It is most practical to punch the

tape for bolts with a hot spud wrench or sharp tool. Several hours after the bolts are initially tightened, a second tightening will usually be necessary to maintain a minimal torque level and properly seat the plates. Since the seam sealant tape will creep (flow) from the joint under higher torque levels, additional tightening is not recommended.

## 9. Structural Backfill Material

9.1 Structural backfill is that material which surrounds the pipe, extending laterally to the walls of the trench, or to the fill material for embankment construction, and extending vertically from the invert to an elevation of 1 ft [300 mm], or 1/8 the span, whichever is greater, over the pipe. The necessary width of structural backfill depends on the quality of the trench wall or embankment material, the type of material and compaction equipment used for the structural backfill, and in embankment construction, the type of construction equipment used to compact the embankment fill. The width of structural backfill shall meet the requirements given in Table 1.

9.2 Structural backfill material shall be readily compacted soil or granular fill material. Structural backfill may be excavated native material, when suitable, or select material. Select material such as bank-run gravel, or other processed granular materials (not retained on a 3 in. [75 mm] diameter ring) with excellent structural characteristics, is preferred. Desired end results can be obtained with such material with a minimum of effort over a wide range of moisture content, lift depths, and compaction equipment. Soil used as structural backfill must not contain rock retained on a 3 in. [75 mm] diameter ring, frozen lumps, highly plastic clays, organic matter, corrosive material, or other deleterious foreign matter. Soils meeting the requirements of Groups GW, GP, GM, GC, SW, and SP as described in Classification D 2487, are generally acceptable, when compacted to the specified percent of maximum density as determined by Test Method D 698. Test Methods D 1556, D 2167, D 2922, and D 2937 may be used to determine the in-place density of the soil. Soil Types SM and SC are acceptable but may require closer control to obtain the specified density. Soil Types ML and CL are not preferred materials, while soil Types OL, MH, CH, OH, and PT are not acceptable.

**TABLE 1 Structural Backfill Width Requirements<sup>A,B</sup>**

Adjacent Material	Required Structural Backfill Width
Normal highway embankment compacted to minimum of 90 % Test Method D 698 density, or equivalent trench wall.	As needed to establish pipe bedding and to place and compact the backfill in the haunch area and beside the pipe. Where backfill materials that do not require compaction are used, such as cement slurry or controlled low-strength material (CLSM), a minimum of 3 in. [75 mm] on each side of the pipe is required.
Embankment or trench wall of lesser quality.	Increase backfill width as necessary to reduce horizontal pressure from pipe to a level compatible with bearing capacity of adjacent materials.

<sup>A</sup>For pipe-arches and other multiple-radius structures, as well as for all structures carrying off-road construction equipment, the structural backfill width, including any necessary foundation improvement materials, must be sufficient to reduce the horizontal pressure from the structure so that it does not exceed the bearing capacity of the adjacent material.

<sup>B</sup>In embankment construction, the structural backfill width must be adequate to resist forces caused by the embankment construction equipment. Generally, the width on each side of the pipe should be no less than 2 ft [600 mm] for spans that do not exceed 12 ft [3.6 m], or 3 ft [900 mm] for greater spans.

## 10. Shape Control

10.1 Excessive compaction, unbalanced loadings, loads from construction equipment, as well as inadequate compaction or poor structural backfill materials, can cause excessive pipe distortion. For larger pipe, it is helpful for the construction contractor to set up a shape monitoring system, before placement of structural backfill, to aid in establishing and maintaining proper installation procedures. Such a system is particularly desirable for structures having a span greater than 20 ft [6 m]. Direct measurement of span and rise, offset measurements from plumb bobs hanging over reference points, and use of surveying instruments are effective means for monitoring shape change during structural backfill placement and compaction. The final installed shape must be within the design criteria, exhibit smooth uniform radii, and provide acceptable clearances for its intended use. In general, it is desirable for the crown of the pipe to rise slightly, in a balanced concentric manner, during placement and compaction of structural backfill beside the pipe. Under the load of the completed fill and the service load, vertical deflections will be a small percentage of the pipe rise dimension if structural backfill compaction is adequate. Structures having a span greater than 20 ft [6 m] should be within 2 % of the calculated dimensions as given in Specification A 761/A 761M before structural backfill placement.

## 11. General Placement of Structural Backfill

11.1 Structural backfill should be placed by moving equipment longitudinally, parallel to the structure centerline, rather than at right angles to the structure. Material must not be dumped directly on or against the structure. In embankment installations, heavy compaction equipment should stay at least 4 ft [1.2 m] away from the structure. In trench installations, the width of trench will dictate the type of compaction equipment. Heavy construction equipment must not be operated over the structure without adequate protective cover. Adequate cover depends on structure size and structural backfill placement, and must be determined by the engineer. *Depending on the type of material and compaction equipment or method used*, the structural backfill should be placed in 6 to 12 in. [150 to 300 mm] “lifts” or layers before compaction. Each lift must be compacted before the next lift is placed. The difference in the depth of structural backfill on opposite sides of the structure should not be greater than 2 ft [600 mm]. The compacted structural backfill should usually be placed to 0.75 the height of structure before covering the crown. However, structural backfill may be placed on the crown whenever required to control the structure shape. A layer of structural backfill (depth of 1 ft [300 mm] or  $\frac{1}{8}$  the span, whichever is greater) should be placed over the crown before introduction of regular backfill.

11.2 The compaction of structural backfill shall provide a soil structure around the pipe to uniformly apply overburden on the crown of the structure and provide adequate uniform bearing for the structure side walls and haunches. For relatively shallow buried structures, under no live loads, acceptable structural backfill and the degree of compaction may be determined by the character of the total installation. The structural backfill is, however, an integral part of the structural

system. Therefore, required end results regarding material type and in-place density of the structural backfill must be in accordance with project specifications.

11.3 When cohesive soils are used for structural backfill, good compaction can be obtained only at proper moisture content. Shallower lifts are usually necessary with cohesive soils than with granular materials to arrive at acceptable in-place density. Mechanical compaction effort shall be used with all cohesive soils. Mechanical soil compaction in layers is generally preferred. However, when acceptable end results can be achieved with water consolidation, it may be used. When water methods are used, care must be taken to prevent flotation. Water methods can be used only on free-draining structural backfill material. The structural backfill and adjacent soil must be sufficiently permeable to dispose of the excess water. Water consolidation is not acceptable with cohesive soils.

11.4 *Pipe-Arches*—Special attention must be given to materials used and compaction obtained around the corners of pipe-arches. At the corners of all structures with short-radius haunch plates, the structural backfill must be well compacted, particularly for those structures under significant loads. For structures with large spans or heavy loads, special design of the structural backfill may be required for the corner plate zone. See Figs. 4 and 5.

11.5 *Arches*—Placement procedures for structural backfill for arches deviates from that for other structures. The desired procedure is to place fill material in lifts evenly on both sides of the structure to construct a narrow envelope over the crown. Begin backfilling near the center of the arch unless cast-in-place headwalls are used and already in place. If headwalls are in place, begin at one head wall. Compact each lift as the envelope is constructed. Take care not to distort the arch. Continue to build structural backfill away from the original envelope maintaining sufficient load on the crown to limit “peaking” as the side fill is compacted.

11.6 Generally, construction experience and a site appraisal will establish the most economical combination of material, method, and equipment to yield acceptable end results. Test Methods D 698 or D 1557 are usually the preferred means of determining maximum (standard) density and optimum moisture content. A construction procedure must then be established that will result in the specified percent of maximum density. Once a procedure is established, the primary inspection effort should be directed at ensuring that the established procedure is followed. Such a procedure may involve material, depth of lift, moisture content, and compaction effort. Only occasional checks of soil density may then be required, as long as the material and procedures are unchanged. In situ density may be determined by Test Methods D 1556, D 2167, D 2922, or D 2937, as applicable, for field verification. Testing should be conducted on both sides of the structure. Any construction methods and materials that achieve required end results in the completed structural backfill, without damage to or distortion of the structure, are acceptable. Unless project specifications provide other limits, the soil should be compacted to a minimum of 90 % density in accordance with Test Method D 698.



## 12. Regular Backfill

12.1 Regular backfill in trench installations is that material placed in the trench above the structural backfill. In embankment installations, regular backfill is that material, outside the limits of the structural backfill. Regular backfill usually consists of native materials placed in accordance with project specifications. Large boulders must not be permitted in regular backfill in trenches that are under surface loads and never within 4 ft [1.2 m] of the structure (Fig. 1).

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## 13. Multiple Structures

13.1 When two or more structures are installed in adjacent lines, the minimum spacing requirements given in Practice A 796/A 796M must be provided.

## 14. Keywords

14.1 installation; sewers; steel pipe; structural plate pipe



# Standard Specification for Aluminum-Coated (Aluminized) Carbon Steel Wire<sup>1</sup>

This standard is issued under the fixed designation A 809; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon ( $\epsilon$ ) indicates an editorial change since the last revision or reapproval.

*This standard has been approved for use by agencies of the Department of Defense.*

## 1. Scope\*

1.1 This specification covers soft, medium, and hard temper carbon steel wire coated with aluminum by a hot-dip process, supplied in coils for general use.

1.2 The values stated in inch-pound units are to be regarded as the standard. The values given in brackets are provided for information purposes only.

## 2. Referenced Documents

### 2.1 ASTM Standards:<sup>2</sup>

A 370 Test Methods and Definitions for Mechanical Testing of Steel Products

A 428 Test Method for Weight [Mass] of Coating on Aluminum-Coated Iron or Steel Articles

A 700 Practices for Packaging, Marking, and Loading Methods for Steel Products for Domestic Shipment

E 29 Practice for Using Significant Digits in Test Data to Determine Conformance with Specification

### 2.2 U.S. Military Standards:<sup>3</sup>

MIL-STD-129 Marking for Shipment and Storage

MIL-STD-163 Steel Mill Products, Preparation for Shipment and Storage

MIL-STD-1188 Commercial Packaging of Supplies and Equipment

### 2.3 U.S. Federal Standard:

Fed. Std. No. 123 Marking for Shipment (Civil Agencies)<sup>3</sup>

## 3. Terminology

### 3.1 Definitions of Terms Specific to This Standard:

3.1.1 *carbon steel*—steel is considered to be carbon steel (1) when no minimum content is specified or required for aluminum, chromium, cobalt, columbium, molybdenum, nickel,

titanium, tungsten, vanadium, or zirconium or any other element is added to obtain a desired alloying effect; (2) when the specified minimum copper content does not exceed 0.40 %; or (3) when the maximum specified content for any of the following elements does not exceed these percentages: manganese 1.65, silicon 0.60, or copper 0.60.

3.1.2 *aluminum-coated (aluminized) wire*—aluminum-coated (aluminized) wire is produced by passing individual wires through a bath of molten aluminum, after first being properly preheated, cleaned, and pickled.

3.1.3 *temper—as applied to aluminum-coated (aluminized) wire*, pertains to stiffness or resistance to bending. It has customarily been expressed by tensile strength as shown in the three ranges given in Table 1. The temper of a given chemical composition can be controlled by the use of a different thermal treatment for each temper. Different properties can also be obtained by varying the chemical composition for a given thermal treatment. A thorough understanding of the end use of the wire, which involves both tensile strength and ductility, should be reached between the user and the manufacturer of the aluminum-coated (aluminized) wire. Requirements for both chemical composition and mechanical properties may be technologically impracticable.

## 4. Ordering Information

4.1 Orders for material under this specification should include the following information:

4.1.1 Quantity (weight in pounds [kilograms]),

4.1.2 Coated wire diameter, expressed to 0.001 in. [0.025 mm],

4.1.3 Name of material (aluminum-coated carbon steel wire),

4.1.4 Temper (soft, medium, or hard) (Table 1),

4.1.5 Packaging requirements, and

4.1.6 ASTM designation and year of issue.

NOTE 1—A typical ordering description is as follows: 40 000 lb, 0.148-in. aluminum-coated carbon steel wire, medium temper, in 500- to 600-lb catch-weight coils on tubular carriers to ASTM A 809–88.

<sup>1</sup> This specification is under the jurisdiction of ASTM Committee A05 on Metallic-Coated Iron and Steel Products and is the direct responsibility of Subcommittee A05.12 on Wire Specifications.

Current edition approved October 1, 2003. Published December 2003. Originally approved in 1983. Last previous edition approved in 1998 as A 809 – 98.

<sup>2</sup> For referenced ASTM standards, visit the ASTM website, [www.astm.org](http://www.astm.org), or contact ASTM Customer Service at [service@astm.org](mailto:service@astm.org). For Annual Book of ASTM Standards volume information, refer to the standard's Document Summary page on the ASTM website.

<sup>3</sup> Available from Standardization Documents Order Desk, Bldg. 4, Section D, 700 Robbins Ave., Philadelphia, PA 19111-5094, Attn: NPODS.

\*A Summary of Changes section appears at the end of this standard.

**TABLE 1 Tensile Strength for Temper Designation**

Wire Diameter, in. [mm]	Tensile Strength, ksi [MPa] <sup>A</sup>		
	Soft Temper	Medium Temper	Hard Temper
0.080 to under 0.106 [2.03 to 2.69]	75 max [515 max]	70 to 95 [485 to 655]	85 to 115 [585 to 795]
0.106 to 0.176, incl [2.69 to 4.47]	70 max [485 max]	65 to 90 [450 to 620]	80 to 110 [550 to 760]
Over 0.176 [over 4.47]	70 max [485 max]	60 to 85 [415 to 585]	75 to 105 [515 to 725]

<sup>A</sup>For the purpose of determining conformance with this specification, an observed value shall be rounded to the nearest 1 ksi in accordance with the rounding method of Practice E 29.

## 5. Materials and Manufacture

5.1 The steel rod from which the wire is produced shall be manufactured by any commercially accepted steel making practice.

5.2 The ingot or pig aluminum used for coating shall conform to the following impurity limits:

	max, %
Copper	0.10
Iron	0.50

## 6. Mechanical Properties

6.1 The aluminum-coated wire shall meet the tensile strength in accordance with Table 1 when tested in accordance with Test Methods and Definitions A 370.

6.2 Test specimens containing a weld or an obvious defect shall be discarded and another test specimen obtained to verify conformance to the tensile strength requirements.

## 7. Dimensions and Tolerances

7.1 The permissible variation in diameter of the aluminum-coated wire as represented by the test specimens shall be in accordance with Table 2.

## 8. Weight of Coating

8.1 The aluminum-coated wire as represented by the test specimens tested in accordance with Test Method A 428, shall have a minimum weight of aluminum coating in accordance with Table 2.

**TABLE 2 Dimensions, Tolerances, and Minimum Weight of Aluminum Coating per Unit Area of Uncoated Wire Surface**

Specified Wire Diameter, in. [mm] <sup>A</sup>	Tolerance, ±in. [mm] <sup>B</sup>	Minimum
		Weight of Aluminum Coating, oz/ft <sup>2</sup> [g/m <sup>2</sup> ]
0.080 to under 0.092 [2.03 to under 2.34]	0.004 [0.10]	0.30 [92]
0.092 to under 0.106 [2.34 to under 2.69]		0.32 [98]
0.106 to under 0.148 [2.69 to under 3.76]	0.004 [0.10]	0.35 [107]
0.148 to under 0.244 [3.76 to under 6.20]		0.40 [122]
0.244 [6.20]	0.005 [0.13]	0.40 [122]

<sup>A</sup>For the purpose of determining conformance with this specification, an observed value shall be rounded to the nearest 0.001 in., in accordance with the rounding method of Practice E 29.

<sup>B</sup>It is recognized that the surfaces of heavy aluminum coatings, particularly those produced by the hot dip process, are not perfectly smooth. If the tolerances shown in this table are rigidly applied to such irregularities that are inherent to the product, unjustified rejections of wire that would actually be satisfactory for use could occur. Therefore, it is intended that these tolerances be used in gaging the uniform areas of the aluminized wire.

## 9. Adherence of Coating

9.1 The aluminum-coated wire as represented by the test specimens shall be capable of being wrapped in a close helix at a rate not exceeding 15 turns/min around a cylindrical steel mandrel having a diameter equal to three times the nominal diameter of the coated wire under test, without cracking or flaking the aluminum coating to such an extent that any aluminum can be removed by rubbing with the bare fingers.

9.2 Loosening or detachment during the adhesion test of superficial, small particles of aluminum formed by mechanical polishing of the surface of the aluminum-coated wire shall not be considered cause for rejection.

## 10. Workmanship

10.1 The aluminum-coated wire shall be free of slivers, scale, and other imperfections not consistent with good commercial practice. The coating shall be continuous and reasonably uniform. To ensure large continuous length coils, welds may be present in the finished wire.

## 11. Number of Tests and Retests

11.1 A lot shall consist of all of the coils of wire of the same size, type and class, and shall be offered for inspection at one time. A wire sample of sufficient length, approximately 4 ft. [1.2 m], shall be cut from either end of each coil selected for tests described in Sections 6, 8, and 9.

11.2 The number of test specimens taken from the ends of coils during production to assure compliance with Sections 6 and 7 varies with the quality control procedures and the manufacturing facilities of each manufacturer, but is generally not less than 10 % of the coils produced. For the purpose of final product testing, one specimen from every ten coils or fraction thereof in a lot shall be selected at random, or a total of seven specimens, whichever is less.

11.3 Should one or more of the wire specimens fail any requirement, the lot shall be subjected to retest. For retest purposes the original lot shall be regrouped into 50 coil lots or fractions thereof. Each lot shall be tested for the property in which the original sample failed to comply at a frequency of 10 % or more so that the total number of tests is at least double the original. Any lot that exhibits a failure shall be rejected. If during retesting an additional quality parameter is observed to be defective, the lot of 50 is subject to rejection for that cause. The manufacturer may test each coil in the failed lot for the property in which failure occurred and reject only the nonconforming coils.

## 12. Inspection

12.1 Unless otherwise specified in the contract or purchase order, the manufacturer is responsible for the performance of all inspection and test requirements specified in this specification. Except as otherwise specified in the contract or purchase order, the manufacturer may use his own or any other suitable facilities for the performance of the inspection and test requirements, unless disapproved by the purchaser at the time the order is placed. The purchaser shall have the right to perform any of the inspections and tests set forth in this

specification when such inspections and tests are deemed necessary to assure that the material conforms to prescribed requirements.

### **13. Rejection and Rehearing**

13.1 Material that fails to conform to the requirements of this specification may be rejected. Rejections should be reported to the producer or supplier promptly and in writing. In case of dissatisfaction with the results of the test, the producer or supplier may make claim for a rehearing.

13.2 The material must be adequately protected and correctly identified in order that the producer or supplier may make a proper investigation.

### **14. Packaging, Marking, and Loading**

14.1 Marking shall be by a tag securely attached to each coil of wire and shall show the identity of the producer, name of product, temper, and ASTM designation.

14.2 Packaging of the coils of wire shall be by agreement between the producer and the purchaser. This agreement shall include coil dimensions and mass.

14.3 Unless otherwise specified, the packaging, marking, and loading shall be in accordance with Practices A 700.

14.4 For procurement by or direct shipment to the U.S. Government, marking for shipment, in addition to the requirements specified in the contract or order, shall be in accordance with MIL-STD-129 for military agencies and with Fed. Std. No. 123 for civil agencies.

14.5 When specified in the contract or order, and for direct procurement by or direct shipment to the U.S. Government, when Level A is specified preservation, packaging, and packing shall be in accordance with Level A requirements of MIL-STD-163. Commercial packaging shall be in accordance with MIL-STD-1188.

### **15. Keywords**

15.1 aluminized wire; aluminum-coated carbon steel wire; steel wire; wire

## **SUMMARY OF CHANGES**

Committee A05 has identified the location of selected changes to this standard since the last issue (A 809 - 03) that may impact the use of this standard.

A 809 - 03:

(I) Revised paragraph 5.1 to keep wording of steel making

practices uniform between standards.

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# Standard Specification for Zinc-Coated (Galvanized) Steel Pipe Winding Mesh<sup>1</sup>

This standard is issued under the fixed designation A 810; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon ( $\epsilon$ ) indicates an editorial change since the last revision or reapproval.

## 1. Scope

1.1 This specification covers various designs of welded wire mesh or twisted (woven) hexagonal wire mesh, zinc coated before fabrication, to be used as reinforcement for the concrete applied in the manufacture of negative buoyancy pipe needed for laying pipe in marshes or in water. The mesh is also used as reinforcement for concrete applied to pipe as a bendable or nonbendable mechanical protective coating when laying pipe in a harsh environment.

1.2 The values stated in inch-pound units are to be regarded as the standard. The values given in parentheses are for information only.

1.3 The text of this standard references notes and footnotes that provide explanatory material. These notes and footnotes (excluding those in tables and figures) shall not be considered as requirements of the standard.

## 2. Referenced Documents

### 2.1 ASTM Standards:

A 90/A 90M Test Method for Weight (Mass) of Coating on Iron and Steel Articles with Zinc or Zinc-Alloy Coatings<sup>2</sup>

A 370 Test Methods and Definitions for Mechanical Testing of Steel Products<sup>3</sup>

A 641/A 641M Specification for Zinc-Coated (Galvanized) Carbon Steel Wire<sup>2</sup>

A 902 Terminology Relating to Metallic Coated Steel Products<sup>2</sup>

B 6 Specification for Zinc<sup>4</sup>

## 3. Terminology

3.1 *Definitions*—For definitions of terms used in this specification, see Terminology A 902.

## 4. Classification

4.1 The steel pipe winding mesh is classified by type, based on method of manufacture, and by design number, related to width, number of longitudinal wires, and wire sizes.

### 4.2 Types of Fabric:

4.2.1 *Type TW*—Fabric manufactured by twisting wires to form a mesh with a series of hexagonal openings, as shown in Fig. 1. One of the edges of the fabric includes a straight selvage wire. Additional longitudinal reinforcing wires are included when specified.

4.2.2 *Type WW*—Fabric manufactured by welding a series of longitudinal wires to transverse wires to form a mesh with rectangular openings.

4.2.2.1 *Type WW-C*—Type WW fabric having uniform spacing of longitudinal wires, with the longitudinal wires crimped as indicated in Fig. 2.

4.2.2.2 *Type WW-N*—Type WW fabric having nonuniform spacing of longitudinal wires, by having the space between the edge wire and adjacent longitudinal wire double the spacing of the intermediate longitudinal wires. All longitudinal wires are crimped as indicated in Fig. 3.

4.2.2.3 *Type WW-S*—Type WW fabric having straight longitudinal wires (without crimping), with uniform spacing as indicated in Fig. 4.

4.3 *Design Numbers*—The design number is in the form of  $A \times B \times C \times D$ .

4.3.1 For Type TW fabric, where

$A$  = nominal width of wire mesh fabric, in inches (millimetres),

$B$  = number of straight reinforcing wires, not including the straight selvage wire,

$C$  = nominal diameter of wire in hexagonal mesh and straight selvage wire, in inches (millimetres), and

$D$  = nominal diameter of straight reinforcing wires, not including straight selvage wire, in inches (millimetres). (Example:  $7.5 \times 1 \times 0.054 \times 0.048$ .)

4.3.2 For Type WW fabric, where

$A$  = nominal overall width of wire mesh fabric, in inches (millimetres),

$B$  = number of longitudinal wires,

$C$  = nominal diameter of longitudinal wires, in inches (millimetres), and

$D$  = nominal diameter of transverse wires, in inches (millimetres). (Example:  $7.5 \times 8 \times 0.063 \times 0.063$ .)

## 5. Ordering Information

5.1 Orders for zinc-coated steel pipe winding mesh under this specification shall include the following information, as

<sup>1</sup> This specification is under the jurisdiction of ASTM Committee A05 on Metallic-Coated Iron and Steel Products and is the direct responsibility of Subcommittee A05.12 on Wire Specifications.

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<sup>2</sup> *Annual Book of ASTM Standards*, Vol 01.06.

<sup>3</sup> *Annual Book of ASTM Standards*, Vol 01.03.

<sup>4</sup> *Annual Book of ASTM Standards*, Vol 02.04.



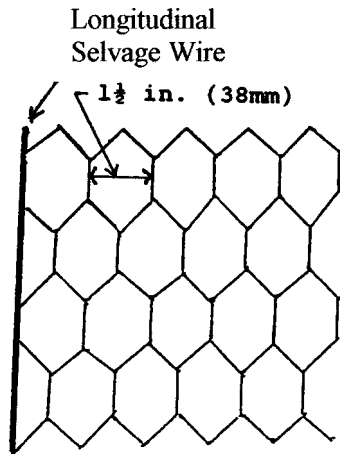


FIG. 1 Type TW—Twisted Hexagonal Mesh (Design Number 7.5 × 0 × 0.054 × 0)

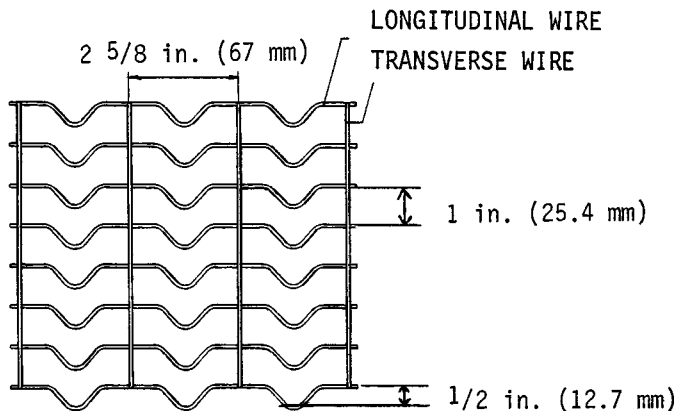


FIG. 2 Type WW-C—Crimped Welded Mesh with Uniform Longitudinal Wire Spacing

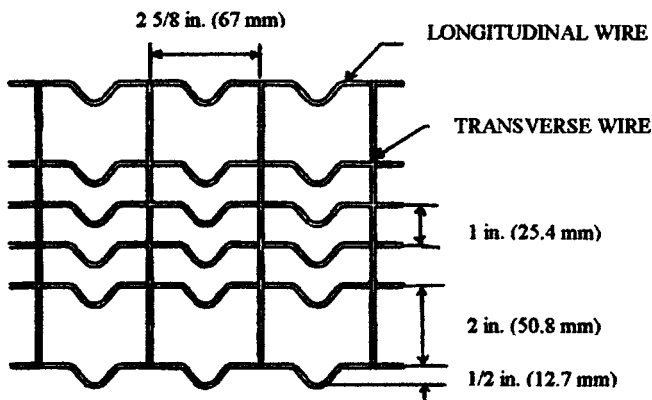


FIG. 3 Type WW-N—Crimped Welded Mesh with Non-Uniform Longitudinal Wire Spacing

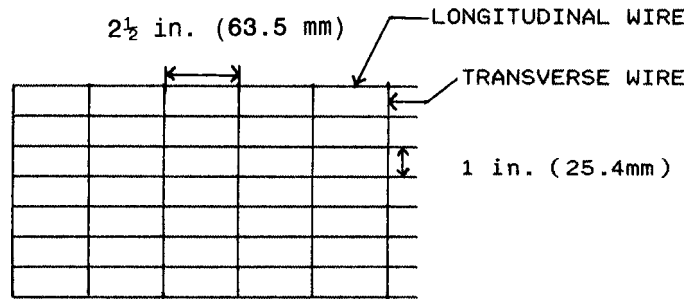


FIG. 4 Type WW-S—Welded Mesh with Straight Longitudinal Wires

- 5.1.6 Quantity (number of rolls),
- 5.1.7 Width of fabric and length of rolls, and
- 5.1.8 Packaging (see Section 14).

## 6. Materials

6.1 The steel from which the wire is produced shall be made by any commercially accepted steelmaking process.

6.1.1 The base metal shall be a steel having composition to permit drawing to a finished size and also to ensure freedom from zinc flaking during weaving or welding into mesh.

6.1.2 *Wire for Welded Mesh*—Before welding the galvanized wire shall have a minimum tensile strength of 70 000 psi (483 MPa),

6.1.3 *Wire for Hexagonal Woven Mesh*—Before weaving the galvanized wire shall have a maximum tensile strength of 75 000 psi (515 MPa),

6.2 Slab zinc used for the coating shall be any grade of zinc conforming to Specification B 6.

## 7. Manufacture

7.1 *Hexagonal Woven Mesh*—This fabric is manufactured by twisting wires to form a series of openings, hexagonal in shape, as specified in Table 1 and Fig. 1. One of the edges of the fabric shall be constructed to include a selvage wire. In addition to those specified in Table 1 and Fig. 1, other designs (width and other reinforcing wire configurations) are subject to agreement between the purchaser and manufacturer.

7.2 *Welded Mesh*—This fabric is manufactured by welding a series of parallel longitudinal wires to transverse wires to form rectangular openings. The longitudinal wires shall be crimped or not crimped as indicated for the type specified. Crimping shall be as indicated in Fig. 2. In addition to those specified in Table 2, and Figs. 2-4, other designs (width and longitudinal wire configurations) are subject to agreement between the purchaser and manufacturer.

## 8. Coating Requirements

8.1 The zinc coating shall be Class 1 coating, or shall be “regular coating”, whichever is specified in the purchase order.

8.1.1 Class 1 zinc coating shall be as specified in Specification A 641/A 641M.

8.1.2 Zinc-coated wire produced as “regular coating” shall have the full surface covered with zinc, but there is no specified minimum weight of coating.

8.2 Slight burning of the zinc coating at welded intersections of welded mesh shall not be cause for rejection.

necessary to adequately describe the desired product:

- 5.1.1 Name of material (steel pipe winding mesh),
- 5.1.2 ASTM designation and year of issue,
- 5.1.3 Type of fabric (see 4.2),
- 5.1.4 Design number (see 4.3 and Tables 1 and 2),
- 5.1.4.1 Mesh dimensions for welded mesh (see 9.3 and Table 3),
- 5.1.5 Zinc coating class (see 8.1),

TABLE 1 Standard Sizes and Constructions for Type TW Woven Hexagonal Mesh

Design Numbers	Previous Design Numbers	Nominal Width, in. (mm)	Nominal Diameter of Zinc-Coated Wire, in. (mm)	Nominal Cross Sectional Area Per Nominal Width, in. <sup>2</sup> (mm <sup>2</sup> ) <sup>A</sup>	Nominal Cross Sectional Area Per Foot (Meter) of Width, in. <sup>2</sup> (mm <sup>2</sup> ) <sup>AB</sup>
7.5 × 0 × 0.054 × 0	107½ × 1½ × 17	7½ (190)	0.054 (1.37)	0.0252 (16.26)	0.0430 (91.02)
7.5 × 1 × 0.054 × 0.048 <sup>C</sup>	207½ × 1½ × 1718 <sup>C</sup>	7½ (190)	0.054 (1.37)/0.048 (1.22)	0.0270 (17.42)	0.0489 (103.51)
7.5 × 2 × 0.054 × 0.048 <sup>D</sup>	307½ × 1½ × 1718 <sup>D</sup>	7½ (190)	0.054 (1.37)/0.048 (1.22)	0.0287 (18.52)	0.0519 (109.86)
7.5 × 4 × 0.054 × 0.048 <sup>E</sup>	507½ × 1½ × 1718 <sup>E</sup>	7½ (190)	0.054 (1.37)/0.048 (1.22)	0.0323 (20.84)	0.0580 (122.77)
14.25 × 4 × 0.054 × 0.048 <sup>F</sup>	514¼ × 1½ × 1718 <sup>F</sup>	14¼(362)	0.054 (1.37)/0.048 (1.22)	0.0529 (34.13)	0.0475 (100.55)

<sup>A</sup>Based on nominal diameter.

<sup>B</sup>Includes minimum ½-in. (12.70-mm) lap of mesh as applied.

<sup>C</sup>Plus 0.048 in. (1.22 mm) line wire placed 4½ in. (114.30 mm) from selvage.

<sup>D</sup>Plus 0.048 in. (1.22 mm) line wires placed 3 in. (76.20 mm) and 6 in. (152.40 mm) from selvage.

<sup>E</sup>Plus 0.048 in. (1.22 mm) line wires placed 1½ in. (38.10 mm), 3 in. (76.20 mm), 4½ in. (114.30 mm), and 6 in. (152.40 mm) from selvage.

<sup>F</sup>Plus 0.048 in. (1.22 mm) line wires placed 3 in. (76.20 mm), 6 in. (152.40 mm), 9 in. (228.60 mm), and 12 in. (304.80 mm) from selvage.

TABLE 2 Standard Sizes and Constructions For Type WW Welded Wire Mesh

Design Numbers	Previous Design Numbers	Nominal Diameter of Zinc-Coated Wire, in. (mm)	Nominal Cross Sectional Area Per Nominal Width, in. <sup>2</sup> (mm <sup>2</sup> ) <sup>A</sup>	Nominal Cross Sectional Area per Foot (Metre) of Width, in. <sup>2</sup> (mm <sup>2</sup> ) <sup>AB</sup>
<i>Type WW-C—Uniform Spacing—Crimped</i>				
7.5 × 8 × 0.059 × 0.059	1.50 × 1.50	0.059 (1.50)/0.059 (1.50)	0.0219 (14.13)	0.0373 (78.96)
7.5 × 8 × 0.063 × 0.063	1.60 × 1.60	0.063 (1.60)/0.063 (1.60)	0.0249 (16.06)	0.0426 (90.17)
7.5 × 8 × 0.079 × 0.063	2.00 × 1.60	0.079 (2.00)/0.063 (1.60)	0.0392 (25.29)	0.0669 (141.61)
7.5 × 8 × 0.079 × 0.079	2.00 × 2.00	0.079 (2.00)/0.079 (2.00)	0.0392 (25.29)	0.0669 (141.61)
7.5 × 8 × 0.098 × 0.079	2.50 × 2.00	0.098 (2.50)/0.079 (2.00)	0.0603 (38.90)	0.1030 (218.03)
7.5 × 8 × 0.118 × 0.079	3.00 × 2.00	0.118 (3.00)/0.079 (2.00)	0.0875 (56.45)	0.1493 (316.03)
<i>Type WW-N—Non-uniform Spacing—Crimped</i>				
7.5 × 6 × 0.063 × 0.063	...	0.063 (1.60)/0.063 (1.60)	0.0187 (12.06)	0.0374 (79.16)
7.5 × 6 × 0.079 × 0.063	...	0.079 (2.00)/0.063 (1.60)	0.0294 (18.97)	0.0588 (124.46)
7.5 × 6 × 0.098 × 0.079	...	0.098 (2.50)/0.079 (2.00)	0.0453 (29.23)	0.0905 (191.56)
7.5 × 6 × 0.118 × 0.079	...	0.118 (3.00)/0.079 (2.00)	0.0656 (42.32)	0.1312 (277.71)
<i>Type WW-S—Uniform Spacing—Not Crimped</i>				
8 × 9 × 0.079 × 0.079	14 × 14	0.079 (2.00)/0.079 (2.00)	0.0446 (28.80)	0.0685 (145.06)

<sup>A</sup>Based on nominal diameter.

<sup>B</sup>Includes minimum ½-in. (12.70-mm) lap of mesh for Types WW-C and WW-S, and 1-in. (25.4-mm) lap of mesh for Type WW-N, as applied.

TABLE 3 Welded Mesh Sizes and Tolerances

NOTE 1—Mesh sizes are measured from center to center and always indicated by two figures,  $L \times S$ , where  $L$  = the distance between the longitudinal wires, in. (mm).

NOTE 2—Crimp depth ½ in. (12.7 mm), tolerance  $\pm \frac{1}{8}$  in. (3.2 mm).

Nominal Mesh Size, $L \times S$ , in. (mm)	Tolerance, $L \times S$ , in. (mm)
Crimped mesh, where $L$ = the distance between the transverse wires after crimping; with $L$ = 1 in. (25.4 mm) for Type WW-C mesh, and 1 in. (25.4 mm) or 2 in. (50.8 mm) for Type WW-N mesh (as indicated in Fig. 3).	
$L \times 2\frac{5}{8}$ (67)	$\pm \frac{5}{64}$ (2) $\times \pm \frac{13}{64}$ (5)
$L \times 3\frac{5}{8}$ (92)	$\pm \frac{5}{64}$ (2) $\times \pm \frac{13}{64}$ (5)
Noncrimped Style, where $S$ = the distance between the transverse wires, in. (mm)	
1 (25.4) $\times$ 2½ (63)	$\pm \frac{5}{64}$ (2) $\times \pm \frac{13}{64}$ (5)

9. Dimensions and Permissible Variations

9.1 *Width of Fabric*—Hexagonal mesh fabric is usually available in 7½-in. (190-mm) width. Welded mesh fabric, crimped, is usually available in 7-in. (178-mm) width having a maximum width of 7½ in. (190 mm) including crimp. Non-crimped welded mesh fabric is usually available in 8-in. (203-mm) width. Other widths of woven and welded fabrics are available. Nominal width of fabric shall be as agreed upon between the purchaser and manufacturer.

9.2 *Length of Roll*—Nominal length of rolls shall be as agreed upon between the purchaser and manufacturer.

9.3 Standard openings in Type TW mesh, between adjacent wires parallel to the selvage wire, is shown in Fig. 1. Standard spacing for longitudinal wires in Type WW-C, Type WW-N, and Type WW-S mesh is shown in Figs. 2-4, respectively. Standard spacing for transverse wires in Type WW fabrics is shown in Table 3. All measurements are center to center of wires. Spacing other than indicated are subject to agreement between the purchaser and manufacturer.

9.4 Tolerances:

9.4.1 *Width:*

9.4.1.1 *Hexagonal Mesh*—Actual width between outer wires shall not be more than ½ in. (13 mm) under the specified width.

9.4.1.2 *Welded Mesh*—Actual width between outer wires shall not be more than 1¾ in. (5 mm) under the specified width.

9.4.2 *Length*—Actual length shall be ordered length -0, +3 %.

9.4.3 *Mesh Size:*

9.4.3.1 For hexagonal mesh, the tolerance shall be  $\pm \frac{1}{8}$  in. ( $\pm 3.2$  mm).

9.4.3.2 Welded mesh size tolerances shall be in accordance with Table 3.

9.4.4 *Wire Size:*

9.4.4.1 Permissible variation of the nominal diameter of wire shall be as follows:

0.035 in. (0.89 mm) to under 0.076 in. (1.93 mm)  $\pm$  0.002 in. (0.05 mm)  
0.076 in. (1.93 mm) and over  $\pm$  0.003 in. (0.08 mm)

## 10. Sampling and Testing

10.1 For test purposes, one sample shall be taken from one roll selected at random from each 200 rolls or fraction thereof.

10.1.1 Development of cross-sectional area data shall come from these samples.

10.1.2 Because of the distortion inherent in the manufacturing of the mesh, it is normal to test for coating weight and tensile compliance on samples of wire before fabrication. The number of test specimens will vary with the quality control procedures and facilities of each manufacturer.

10.2 Determine the weight of zinc coatings for wire specified to have a Class 1 coating, by the stripping test in accordance with Test Method A 90/A 90M. Inspect wire specified to have a “regular coating” to verify that the wire is completely coated (except for slight burning at welded intersections for wire inspected after fabrication).

10.2.1 For wire tested before fabrication, the minimum test specimen length shall be 24 in. (600 mm).

10.2.2 For wire tested after fabrication, cut short lengths of wire from between twists or welds, such that the total length equals at least 24 in. (600 mm).

10.3 Tensile testing shall be as described in Test Methods and Definitions A 370.

## 11. Retests and Rejection

11.1 If one or more of the samples fail to show compliance with any of the requirements of this specification, the lot shall be subjected to retest.

11.2 Retesting of the lot shall be on the basis of a sampling frequency of one sample for each 50 rolls. If any sample fails

to show compliance with the requirements of this specification, the entire lot shall be rejected.

## 12. Inspection

12.1 The manufacturer shall afford the inspector representing the purchaser all reasonable facilities to satisfy the inspector that the material is being furnished in accordance with this specification. All tests and inspections shall be made at the place of manufacture before shipment, unless otherwise specified, and be conducted so as not to interfere unnecessarily with the operation of the works.

## 13. Certification

13.1 When specified in the purchase order or contract, the purchaser shall be furnished certification that the samples representing each lot have been either tested or inspected as directed in this specification and that the requirements have been met. When specified in the purchase order or contract, a report of the test results shall be furnished.

## 14. Packaging, Marking, and Loading

14.1 Packaging will be based on negotiations between the purchaser and the manufacturer. Banding or strapping with or without pallets represents a common form of package.

14.2 A tag shall be securely attached to each bundle and shall be marked with the type, design number, wire sizes, ASTM designation, and name or mark of the manufacturer.

## 15. Keywords

15.1 concrete reinforcement; mesh (for steel pipe/tube); steel wire; zinc-coated steel wire

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# Standard Specification for Metallic-Coated Steel Wire for Chain-Link Fence Fabric and Marcelled Tension Wire<sup>1</sup>

This standard is issued under the fixed designation A 817; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon ( $\epsilon$ ) indicates an editorial change since the last revision or reapproval.

## 1. Scope\*

1.1 This specification covers metallic-coated carbon steel wire used in the manufacture of chain-link fence fabric and marcelled tension wire. Three types of coatings are covered:

- 1.1.1 *Type I*—Aluminum-coated (aluminized),
- 1.1.2 *Type II*—Zinc-coated (galvanized), and
- 1.1.3 *Type III*—Zinc-5 % Aluminum-Mischmetal (Zn-5Al-MM) alloy-coated.

1.2 The chain-link fabric woven from wire in this specification is covered separately by Specifications A 491 for Type I, A 392 for Type II, and F 1345 for Type III.

1.3 The marcelled tension wire manufactured from wire in this specification is covered separately in Specifications A 824 and F 1664.

1.4 This specification does not cover the wire used for Specification A 392 when the chain-link fence producer applies the coating after the weaving process.

1.5 The values stated in inch-pound units are to be regarded as the standard. The values given in brackets are provided for information only.

## 2. Referenced Documents

### 2.1 *ASTM Standards:*

- A 90/A 90M Test Method for Weight [Mass] of Coating on Iron or Steel Articles with Zinc and Zinc-Alloy Coatings<sup>2</sup>
- A 370 Test Methods and Definitions for Mechanical Testing of Steel Products<sup>3</sup>
- A 392 Specification for Zinc-Coated Steel Chain-Link Fence Fabric<sup>2</sup>
- A 428/A 428M Test Method for Weight of Coating on Aluminum-Coated Iron or Steel Articles<sup>2</sup>
- A 491 Specification for Aluminum-Coated Steel Chain-Link Fence Fabric<sup>2</sup>
- A 700 Practices for Packaging, Marking, and Loading

<sup>1</sup> This specification is under the jurisdiction of ASTM Committee A05 on Metallic-Coated Iron and Steel Products and is the direct responsibility of Subcommittee A05.12 on Wire Specifications.

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<sup>2</sup> *Annual Book of ASTM Standards*, Vol 01.06.

<sup>3</sup> *Annual Book of ASTM Standards*, Vol 01.03.

- Methods for Steel Products for Domestic Shipment<sup>4</sup>
- A 824 Specification for Metallic-Coated Steel Marcelled Tension Wire for Use With Chain Link Fence<sup>2</sup>
- A 902 Terminology Relating to Metallic Coated Steel Products<sup>2</sup>
- B 6 Specification for Zinc<sup>5</sup>
- B 750 Specification for Zinc-5 % Aluminum-Mischmetal Alloy (UNS Z38510) in Ingot Form for Hot-Dip Coatings<sup>5</sup>
- E 29 Practice for Using Significant Digits in Test Data to Determine Conformance with Specifications<sup>6</sup>
- E 47 Test Methods for Chemical Analysis of Zinc Die-Casting Alloys<sup>7</sup>
- E 536 Test Method for Chemical Analysis of Zinc and Zinc Alloys<sup>8</sup>
- F 1345 Specification for Zinc-5 % Aluminum-Mischmetal Alloy-Coated Steel Chain-Link Fence Fabric<sup>2</sup>
- F 1664 Specification for Poly (Vinyl Chloride) (PVC)-Coated Steel Tension Wire Used With Chain-Link Fence<sup>2</sup>
- 2.2 *International Lead Zinc Research Organization:*
  - GF-1 Standard Practice for Determination of Cerium and Lanthanum Compositions in Galfan Alloy (5 % Al-0.04 % La-0.04 % Ce Bal SHG Zn)<sup>9</sup>

## 3. Terminology

3.1 *Definitions*—For definitions of terms used in this specification, see Terminology A 902.

## 4. Ordering Information

4.1 Orders for metallic-coated steel wire for chain link fence fabric or marcelled tension wire shall include the following information:

- 4.1.1 Quantity.
- 4.1.2 Name of product.
- 4.1.3 Coated wire diameter.
- 4.1.4 Type of coating (see 5.3).

<sup>4</sup> *Annual Book of ASTM Standards*, Vol 01.05.

<sup>5</sup> *Annual Book of ASTM Standards*, Vol 02.04.

<sup>6</sup> *Annual Book of ASTM Standards*, Vol 14.02.

<sup>7</sup> Discontinued; see 1996 *Annual Book of ASTM Standards*, Vol 03.05.

<sup>8</sup> *Annual Book of ASTM Standards*, Vol 03.06.

<sup>9</sup> Available from International Lead Zinc Research Organization, P.O. Box 12036, Research Triangle Park, NC 27709.

\*A Summary of Changes section appears at the end of this standard.

- 4.1.5 Class of coating, if applicable (see Table 1 or Table 2).
- 4.1.6 Packaging requirements (see Section 14).
- 4.1.7 Certification or test report, or both, if specified (see Section 13).
- 4.1.8 ASTM designation and year of issue.

NOTE 1—A typical ordering description is as follows: 80 000-lb steelwire for chain-link fence fabric, 0.148-in. diameter, Type II, Class 2, in 500 to 600-lb catchweight coils on tubular carriers to ASTM A 817 – \_\_\_\_\_.

## 5. Materials and Manufacture

5.1 The steel rod from which the wire is drawn shall be manufactured by the open-hearth, electric-furnace, or basic-oxygen process.

5.2 The wire shall be cold-drawn, then metallic-coated at finished size to produce the specified mechanical properties.

5.3 The wire shall be furnished with one of three types of coating, as specified:

5.3.1 *Type I—Aluminum-Coated (Aluminized)*, in one class of coating weight as specified in Table 1.

5.3.2 *Type II—Zinc-Coated (Galvanized)*, with coating weights as specified in Table 1.

5.3.3 *Type III—Zn-5Al-MM Alloy Coated*, with coating weights as specified in Table 1.

5.4 Type I coating shall be produced by a hot-dip process. Type II coating shall be produced by either a hot-dip or an electrolytic process at the option of the producer. Type III coating shall be produced by a hot-dip process.

5.5 The ingot or pig aluminum used for Type I coating shall conform to the following impurity limits: copper, 0.10 % max, iron, 0.50 % max.

5.6 Slab zinc if used for Type II coating shall be one of the appropriate grades that are described in Specification B 6.

5.7 The ingot used for Type III coating shall conform to Specification B 750.

5.7.1 *Method of Analysis*—The determination of chemical composition shall be made in accordance with suitable chemical methods (Test Methods E 47 or E 536), or other methods. In case of dispute, the results secured by Test Methods E 47 shall be the basis of acceptance.

5.7.2 A standard practice for X-ray fluorescence spectrometry for determination of cerium and lanthanum in a Zn-5Al-MM alloy has been established by the International Lead Zinc Research Organization (as Standard Practice GF-1).<sup>9</sup>

**TABLE 2 Breaking Strength**

Specified Diameter of Coated Wire, in. [mm]	Breaking Strength, min, lbf [N]
0.192 [4.88]	2170 [9650]
0.148 [3.76]	1290 [5740]
0.135 [3.43]	1290 [5740]
0.120 [3.05]	850 [3780]
0.113 [2.87]	750 [3340]

## 6. Mechanical Properties

6.1 The metallic-coated wire for chain-link fence fabric shall meet the minimum breaking strength shown in Table 2 when tested in accordance with Test Methods and Definitions A 370.

6.2 The metallic coated wire for marcelled tension wire shall have a breaking strength of 1 950 lbf [8 670 N] minimum and 3 200 lbf [14 230 N] maximum when tested in accordance with Test Methods and Definitions A 370.

## 7. Size and Tolerance

7.1 The diameter of the coated wire shall be determined as the average of two readings taken at right angles to each other, and in accordance with Practice E 29.

7.2 The permissible variation from the specified diameter of the coated wire shall be  $\pm 0.005$  in. [0.13 mm].

NOTE 2—It is recognized that the surfaces of heavy metallic coatings, particularly those produced by the hot-dip process, are not perfectly smooth. If the tolerance specified is rigidly applied to such irregularities that are inherent to the product, unjustified rejections of wire that would actually be satisfactory for use would occur. Therefore, it is intended that this tolerance be used in gaging the uniform areas of the coated wire.

## 8. Weight of Coating

8.1 Coating weights for Types I, II, or III shall conform to the requirements of Table 1.

### 8.2 Coating Weight Determination:

8.2.1 The coating weight for Type I shall be determined in accordance with Test Method A 428/A 428M.

8.2.2 The coating weight for Types II or III shall be determined in accordance with Test Method A 90/A 90M.

## 9. Adherence of Coating

9.1 The undeformed length of coated wire as represented by the test specimens shall be capable of being wrapped in a close helix at a rate not exceeding 15 turns/min around a cylindrical steel mandrel having a diameter equal to three times the test specimen without cracking or flaking the coating to such an

**TABLE 1 Minimum Weight of Metallic Coating**

Specified Diameter of Coated Wire, in. [mm]	Minimum Weight of Coating, oz/ft <sup>2</sup> [g/m <sup>2</sup> ] of Uncoated Wire Surface					
	Type I	Type II, Class 3	Type II, Class 4	Type II, Class 5	Type III, Class 60	Type III, Class 100
0.192 [4.88]	0.40 [122]	1.00 [305]	1.20 [366]	2.00 [610]	0.60 [183]	1.00 [305]
0.177 [4.50] <sup>A</sup>	0.40 [122]	0.90 [275]	1.20 [366]	2.00 [610]	0.60 [183]	1.00 [305]
0.148 [3.76]	0.40 [122]	0.90 [275]	1.20 [366]	2.00 [610]	0.60 [183]	1.00 [305]
0.135 [3.43]	0.40 [122]					
0.120 [3.05]	0.35 [107]	0.85 [259]	1.20 [366]	2.00 [610]	0.60 [183]	1.00 [305]
0.113 [2.87]	0.30 [92]	0.80 [244]	1.20 [366]	2.00 [610]	0.60 [183]	1.00 [305]

<sup>A</sup>Size 177 in. is only used for tension wire, not chain-link fabric.

extent that any coating metal can be removed by rubbing with the bare fingers. Loosening or detachment during the adhesion test of superficial, small particles of coating metal formed by mechanical polishing of the surface of the coated wire shall not be considered cause for rejection.

### 10. Number of Tests and Retests

10.1 A lot shall consist of all of the coils of wire of the same size, type, and class, and shall be offered for inspection at one time. A wire sample of sufficient length, approximately 4 ft [1.2 m], shall be cut from either end of each coil selected for tests described in Sections 6, 8, and 9.

10.2 The number of test specimens taken from the ends of coils during production to ensure compliance with Sections 6 and 7 varies with the quality-control procedures and the manufacturing facilities of each manufacturer, but is generally not less than 10 % of the coils produced. For the purpose of final product testing, one specimen from every ten coils or fraction thereof in a lot shall be selected at random, or a total of seven specimens, whichever is less.

10.3 If one or more of the wire specimens fail any requirement, the lot shall be retested. For retest purposes the original lot shall be regrouped into 50 coil lots or fraction thereof. Each lot shall be tested for the property in which the original sample failed to comply at a frequency of 10 % or more so that the total number of tests is at least double the original. Any lot that exhibits a failure shall be rejected. If during retesting an additional quality parameter is observed to be defective, the lot of 50 is subject to rejection for that cause. The manufacturer is permitted to test each coil in the failed lot for the property in which failure occurred and reject only the nonconforming coils.

### 11. Inspection

11.1 Unless otherwise specified in the contract or purchase order, the producer is responsible for the performance of all inspection and test requirements of this specification. Except as otherwise specified in the contract or purchase order, the producer shall use his own or any other suitable facilities for the performance of the inspection and test requirements unless

disapproved by the purchaser at the time the order is placed. The purchaser shall have the right to perform any of the inspections and tests set forth in this specification when such inspections and tests are deemed necessary to ensure that the material conforms to prescribed requirements.

### 12. Rejection and Rehearing

12.1 Material that fails to conform to the requirements of this specification shall be rejected. Rejections shall be reported to the producer or supplier promptly and in writing. In case of dissatisfaction with the results of the test, the producer or supplier may make claim for a rehearing.

12.2 The material must be adequately protected and correctly identified in order that the producer may make a proper investigation.

### 13. Certification

13.1 When specified in the purchase order or contract, a producer's or supplier's certification shall be furnished to the purchaser that the material was manufactured, sampled, tested, and inspected in accordance with this specification and has been found to meet the requirements. When specified in the contract or purchase order, a report of the test results shall be furnished.

### 14. Packaging, Marking, and Loading

14.1 Marking shall be by a tag securely attached to each coil of wire and shall show the identity of the producer, size of wire, type of coating, class of coating (if applicable), and ASTM designation.

14.2 Packaging of the coils of wire shall be by agreement between the producer and the purchaser. This agreement may include coil dimensions and weight.

14.3 Unless otherwise specified, the packaging, marking, and loading shall be in accordance with Practices A 700.

### 15. Keywords

15.1 chain-link fencing materials; fence fabric; fencing material; metallic-coated steel wire; steel wire; tension wire; wire

## SUMMARY OF CHANGES

This section identifies the location of selected changes to this specification. For the convenience of the user, Committee A05 has highlighted those changes that may impact the use of this specification. This section may also include descriptions of the changes or reasons for the changes, or both.

*A 817/A 817M - 03:*

(1) Added .135" wire to Table 1.

(2) Added .135" wire to Table 2.

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## Standard Specification for Coppered Carbon Steel Wire<sup>1</sup>

This standard is issued under the fixed designation A 818; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon ( $\epsilon$ ) indicates an editorial change since the last revision or reapproval.

*This standard has been approved for use by agencies of the Department of Defense.*

### 1. Scope

1.1 This specification covers coppered carbon steel wire supplied in coils for general use. It may be produced hard drawn, annealed in process, or annealed at finish size. The coating is very thin and is not designed for protection against corrosion.

1.2 The values stated in inch-pound units are to be regarded as the standard. The values given in parentheses are provided for information only.

### 2. Referenced Documents

#### 2.1 ASTM Standards:

A 370 Test Methods and Definitions for Mechanical Testing of Steel Products<sup>2</sup>

A 510 Specification for General Requirements for Wire Rods and Coarse Round Wire, Carbon Steel<sup>2</sup>

A 700 Practices for Packaging, Marking, and Loading Methods for Steel Products for Domestic Shipment<sup>3</sup>

E 29 Practice for Using Significant Digits in Test Data to Determine Conformance with Specification<sup>4</sup>

#### 2.2 U.S. Federal Standard:

Fed. Std. No. 123 Marking for Shipments (Civil Agencies)<sup>5</sup>

#### 2.3 U.S. Military Standards:

MIL-STD-129 Marking for Shipment and Storage<sup>5</sup>

MIL-STD-163 Steel Mill Products, Preparation for Shipment and Storage<sup>5</sup>

### 3. Terminology

#### 3.1 Definitions of Terms Specific to This Standard:

3.1.1 *annealed coppered wire*—wire that may be either

3.1.2 *annealed-in-process wire*—at some stage before application of the copper, the steel wire is thermally treated and subsequently coated with copper and redrawn. coated with

copper, drawn, and annealed at finish size, or drawn, annealed at finish size and then coppered.

3.1.3 *carbon steel*—steel that has no minimum content specified or required for aluminum, chromium, cobalt, columbium, molybdenum, nickel, titanium, tungsten, vanadium, or zirconium or any other element added to obtain a desired alloying effect; steel that has the specified minimum copper content that does not exceed 0.40 %; or the maximum content for any of the following elements that does not exceed these percentages: manganese 1.65, silicon 0.60, or copper 0.60.

3.1.4 *coppered steel wire*—produced by cold drawing rod or wire that has been immersed in a copper sulfate solution.

3.1.5 *hard drawn wire*—wire that is coppered and drawn without the use of thermal treatment.

### 4. Ordering Information

4.1 Orders for material under this specification should include the following information:

4.1.1 Quantity (weight in pounds),

4.1.2 Coated wire diameter, in inches, to the third decimal point,

4.1.3 Name of material (coppered carbon steel wire),

4.1.4 Grade of steel,

4.1.5 Condition (hard drawn, annealed in process, or annealed at finished size),

4.1.6 Finish (lustrous or matte),

4.1.7 Packaging requirements, and

4.1.8 ASTM designation and year of issue.

NOTE 1—A typical ordering description is as follows: 40 000 lb, 0.148-in. coppered carbon steel wire, Grade 1008, hard drawn, lustrous finish in 600-lb catch-weight coils on tubular carriers to ASTM A818 – .

### 5. Materials and Manufacture

5.1 The steel rod from which the wire is drawn shall be manufactured by the open-hearth, electric-furnace, or basic-oxygen process.

5.2 Coppered wire may be supplied in any of the following conditions: hard-drawn, annealed-in-process, or annealed.

<sup>1</sup> This specification is under the jurisdiction of ASTM Committee A05 on Metallic-Coated Iron and Steel Products and is the direct responsibility of Subcommittee A05.12 on Wire Specifications.

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<sup>2</sup> Annual Book of ASTM Standards, Vol 01.03.

<sup>3</sup> Annual Book of ASTM Standards, Vol 01.05.

<sup>4</sup> Annual Book of ASTM Standards, Vol 14.02.

<sup>5</sup> Available from Standardization Documents Order Desk, Bldg. 4 Section D, 700 Robbins Ave., Philadelphia, PA 19111-5094, Attn: NPODS.



## 6. Mechanical Properties

6.1 The coppered steel wire shall meet the tensile strength requirements shown in Table 1 when tested in accordance with Methods A 370.

6.2 Test specimens found to contain a weld or an obvious defect shall be discarded and another test specimen obtained to verify conformance to the tensile strength requirements.

## 7. Dimensions and Tolerances

7.1 The permissible variation in diameter of the coppered wire as represented by the test specimens shall be as indicated in Specification A 510.

## 8. Coating Requirements

8.1 Due to the nature of the process, the thickness of the copper coating is extremely thin. Therefore, there is no requirement for thickness of coating; the requirement is that the coating be continuous.

8.2 The coppered wire as represented by the test specimens shall be capable of being wrapped in a close helix at a rate not exceeding 15 turns/min around a cylindrical steel mandrel having a diameter equal to the diameter of the coated wire without cracking or flaking the copper coating to such an extent that any copper can be removed by rubbing with the bare

fingers. Loosening or detachment during the adhesion test of superficial, small particles of copper formed by mechanical polishing of the surface of the coppered wire shall not be considered cause for rejection.

## 9. Workmanship

9.1 The coppered wire shall be free of slivers, scale, and other imperfections that would be detrimental to intended use. The copper coating shall be continuous and reasonably smooth. To ensure large continuous length coils, welds may be present in the finished wire.

## 10. Number of Tests and Retests

10.1 A lot shall consist of all of the coils of wire of the same size, type and class, and shall be offered for inspection at one time. A wire sample of sufficient length, approximately 4 ft. (1.2 m), shall be cut from either end of each coil selected for tests described in Sections 6, 8 and 9.

10.2 The number of test specimens taken from the ends of coils during production to assure compliance with Sections 6 and 7 varies with the quality control procedures and the manufacturing facilities of each manufacturer, but is generally not less than 10 % of the coils produced. For the purpose of final product testing, one specimen from every ten coils or fraction thereof in a lot shall be selected at random, or a total of seven specimens, whichever is less.

10.3 Should one or more of the wire specimens fail any requirement, the lot shall be subjected to retest. For retest purposes the original lot shall be regrouped into 50 coil lots or fractions thereof. Each lot shall be tested for the property in which the original sample failed to comply at a frequency of 10 % or more so that the total number of tests is at least double the original. Any lot that exhibits a failure shall be rejected. If during retesting an additional quality parameter is observed to be defective, the lot of 50 is subject to rejection for that cause. The manufacturer may test each coil in the failed lot for the property in which failure occurred and reject only the nonconforming coils.

## 11. Inspection

11.1 The manufacturer shall afford the inspector representing the purchaser all reasonable facilities to satisfy that the material is being furnished in accordance with this specification. All tests and inspections shall be made at the place of manufacture prior to shipment, unless otherwise specified, and shall be so conducted as not to interfere with the operation of the works.

## 12. Rejection and Rehearing

12.1 Any rejection by the purchaser shall be reported to the manufacturer within a reasonable time from receipt of material.

12.2 The material must be adequately protected and correctly identified in order that the manufacturer may make a proper investigation.

## 13. Marking, Packaging, and Loading for Shipment

13.1 The size, name of product, grade and condition, ASTM specification number, weight, and name or mark of the manufacturer shall be indicated on a tag securely attached to each coil or package of wire.

**TABLE 1 Tensile Strength Requirements**

Wire Diameter, in. (mm) <sup>A</sup>	Wire Condition		
	Hard Drawn, min, ksi (MPa)	Annealed- in-Proc- ess, max, ksi (MPa)	Annealed, <sup>B</sup> max, ksi (MPa)
Grade 1006			
Less than 0.035 (0.89)	...	95 (655)	60 (415)
0.035 to 0.057 (0.89 to 1.46)	105 (725)	90 (620)	60 (415)
0.058 to 0.085 (1.47 to 2.17)	90 (620)	90 (620)	60 (415)
0.086 to 0.127 (2.18 to 3.27)	80 (550)	85 (585)	60 (415)
0.128 to 0.177 (3.28 to 4.50)	70 (485)	80 (550)	60 (415)
0.178 to 0.250 (4.51 to 6.35)	60 (415)	70 (485)	60 (415)
Grades 1008 and 1010			
Less than 0.035 (0.89)	...	95 (655)	70 (485)
0.035 to 0.057 (0.89 to 1.46)	...	90 (620)	65 (450)
0.058 to 0.085 (1.47 to 2.17)	100 (690)	90 (620)	65 (450)
0.086 to 0.127 (2.18 to 3.27)	85 (585)	90 (620)	65 (450)
0.128 to 0.177 (3.28 to 4.50)	75 (517)	83 (570)	65 (450)
0.178 to 0.250 (4.51 to 6.35)	65 (450)	75 (517)	65 (450)
Grade 1015			
Less than 0.035 (0.89)	...	95 (655)	75 (517)
0.035 to 0.057 (0.89 to 1.46)	...	95 (655)	70 (485)
0.058 to 0.085 (1.47 to 2.17)	105 (725)	95 (655)	70 (485)
0.086 to 0.127 (2.18 to 3.27)	90 (620)	95 (655)	70 (485)
0.128 to 0.177 (3.28 to 4.50)	80 (550)	85 (585)	70 (485)
0.178 to 0.250 (4.51 to 6.35)	70 (485)	78 (540)	70 (485)
Grades 1018 and 1020			
Less than 0.035 (0.89)	...	100 (690)	75 (517)
0.035 to 0.057 (0.89 to 1.46)	...	100 (690)	75 (517)
0.058 to 0.085 (1.47 to 2.17)	...	100 (690)	75 (517)
0.086 to 0.127 (2.18 to 3.27)	105 (725)	100 (690)	75 (517)
0.128 to 0.177 (3.28 to 4.50)	85 (585)	90 (620)	75 (517)
0.178 to 0.250 (4.51 to 6.35)	75 (517)	82 (570)	75 (517)

<sup>A</sup>For the purpose of determining conformance with this specification, an observed value shall be rounded to the nearest 0.001 in. in accordance with the rounding method of Practice E 29.

<sup>B</sup>Annealed denotes annealed at finished size.

13.2 The coil weight, dimensions, and methods of packaging shall be as specified on the purchase order. Unless otherwise specified, loading for shipment shall be in accordance with Practices A 700.

13.3 When specified in the contract or order, and for direct procurement by or direct shipment to the U.S. Government, when Level A is specified, preservation, packaging and packing shall be in accordance with Level A requirements of MIL-STD-163.

13.4 When specified in the contract or order, and for direct procurement by or direct shipment to the U.S. Government,

marking for shipment, in addition to requirements specified in the contract or order, shall be in accordance with MIL-STD-129 for U.S. Military agencies and in accordance with Fed. Std. No. 123 for U.S. Government civil agencies.

#### **14. Keywords**

14.1 copper coated carbon steel wire; coppered wire; steel wire; wire

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*This standard is subject to revision at any time by the responsible technical committee and must be reviewed every five years and if not revised, either reapproved or withdrawn. Your comments are invited either for revision of this standard or for additional standards and should be addressed to ASTM International Headquarters. Your comments will receive careful consideration at a meeting of the responsible technical committee, which you may attend. If you feel that your comments have not received a fair hearing you should make your views known to the ASTM Committee on Standards, at the address shown below.*

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# Standard Specification for Metallic-Coated Steel Marcellled Tension Wire for Use With Chain Link Fence<sup>1</sup>

This standard is issued under the fixed designation A 824; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon ( $\epsilon$ ) indicates an editorial change since the last revision or reapproval.

## 1. Scope

1.1 This specification covers 0.177 in. (4.50 mm) diameter metallic-coated carbon steel marcellled tension wire for use with chain-link fence. The 0.177 in. (4.50 mm) diameter metallic-coated wire shall be produced in accordance with Specification A 817. Three types of coatings are covered:

- 1.1.1 *Type I*—Aluminum-coated (aluminized),
- 1.1.2 *Type II*—Zinc-coated (galvanized), and
- 1.1.3 *Type III*—Zinc-5 % Aluminum Mischmetal (Zn5Al-MM) alloy-coated.

1.2 The values stated in inch-pound units are to be regarded as the standard. The values given in parentheses are for information only.

## 2. Referenced Documents

### 2.1 ASTM Standards:

- A 700 Practices for Packaging, Marking, and Loading Methods for Steel Products for Domestic Shipment<sup>2</sup>
- A 817 Specification for Metallic-Coated Steel Wire for Chain-Link Fence<sup>3</sup>
- A 902 Terminology Relating to Metallic-Coated Steel Products<sup>3</sup>

## 3. Terminology

### 3.1 Definitions:

3.1.1 For definitions of terms used in this specification, refer to Terminology A 902.

3.2 *Definitions of Terms Specific to This Standard:* Description of Term Specific to This Standard:

3.2.1 *marcelling*—a process whereby either a uniform helix or a series of waves is put in a wire to facilitate tensioning the wire when installed to support the top or bottom, or both, of the chain-link fabric (see 5.2.1).

## 4. Ordering Information

4.1 Orders for metallic-coated steel tension wire should

include the following information:

- 4.1.1 Quantity (expressed in number of coils),
- 4.1.2 Name of product,
- 4.1.3 Type of coating (see 5.3),
- 4.1.4 Class of coating if applicable (see 5.3.2 and 5.3.3),
- 4.1.5 Packaging requirements (see Section 14),
- 4.1.6 Certification or test report, or both, if specified (see Section 13), and
- 4.1.7 ASTM designation and year of issue.

NOTE 1—A typical ordering description is as follows: 20 coils metallic-coated steel tension wire, Type II, Class 2, in 100-lb coils, to ASTM A 824 – \_\_\_\_.

## 5. Materials and Manufacture

5.1 The steel rod from which the wire is drawn shall be manufactured by the open-hearth, electric-furnace, or basic-oxygen process.

5.2 The 0.177 in. (4.50 mm) diameter wire shall be cold-drawn, metallic-coated at finished size to produce the specified mechanical properties per Specification A 817, then marcellled as specified in 5.2.1.

5.2.1 Marcelling shall produce a helix or series of waves in the wire with the offset distance from the wire axis to the wave peaks or the helix not less than 0.125 in. (3.18 mm) (measured to the center of the wire). The pitch (distance between successive points on the waves or helix) shall be not more than 12 in. (305 mm). Prior to making measurements of the marcelling, curvature from coiling shall be removed by the application of a 500-lbf (2225-N) tensile load. Maintain the load while measuring the offset distance and pitch. Measurements shall be made on a section of wire with a length at least two times the pitch length.

5.2.1.1 Measurement of offset distance may be performed by placing a straightedge against two adjacent peaks or corresponding points on a helix, measuring the distance to the inside of the wire 180° opposite, and dividing the value by two.

5.3 The 0.177 in. (4.50 mm) diameter wire shall be furnished with one of three types of coating, per Specification A 817 as specified:

5.3.1 *Type I—Aluminum-Coated (Aluminized)*, with coating weight specified.

5.3.2 *Type II—Zinc-Coated (Galvanized)*, in three classes of coating weights as specified.

<sup>1</sup> This specification is under the jurisdiction of ASTM Committee F14 on Fences and is the direct responsibility of Subcommittee F14.40 on Chain Link Fence and Wire Accessories.

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<sup>2</sup> *Annual Book of ASTM Standards*, Vol 01.05.

<sup>3</sup> *Annual Book of ASTM Standards*, Vol 01.06.



5.3.3 *Type III—Zinc-5 % Aluminum-Mischmetal Alloy Coated (Zn-5Al-MM)*, in two classes of coating weights as specified.

## 6. Mechanical Properties

6.1 The breaking strength shall meet the requirement of Specification A 817 for 0.177 in. (4.50 mm) diameter wire.

## 7. Size and Tolerance

7.1 The diameter shall meet the requirements of Specification A 817 for 0.177 in. (4.50 mm) diameter wire.

NOTE 2—It is recognized that the surfaces of heavy metallic coatings, particularly those produced by the hot-dip process, are not perfectly smooth. If the tolerance specified is rigidly applied to such irregularities that are inherent to the product, unjustified rejections of wire that would actually be satisfactory for use would occur. Therefore, it is intended that this tolerance be used in gaging the uniform areas of the coated wire.

## 8. Weight of Coating

8.1 The weight of coating shall meet the requirements of Specification A 817 for the Type and Class of coating specified.

## 9. Adherence of Coating

9.1 The adherence of coating shall meet the requirements of Specification A 817 for 0.177 in. (4.50 mm) wire.

## 10. Number of Tests and Retests

10.1 A lot shall consist of all of the coils of wire of the same size, type, and class, and shall be offered for inspection at one time. A wire sample of sufficient length, approximately 4 ft (1.2 m), shall be cut from either end of each coil selected for tests described in Sections 6, 8, and 9.

10.2 The number of test specimens taken from the ends of coils during production to ensure compliance with Sections 6 and 7 varies with the quality control procedures and the manufacturing facilities of each manufacturer, but is generally not less than 10 % of the coils produced. For the purpose of final product testing, one specimen from every ten coils or fraction thereof in a lot shall be selected at random, or a total of seven specimens, whichever is less.

10.3 Should one or more of the wire specimens fail any requirement, the lot shall be subjected to retest. For retest purposes the original lot shall be regrouped into 50 coil lots or fractions thereof. Each lot shall be tested for the property in which the original sample failed to comply at a frequency of 10 % or more so that the total number of tests is at least double the original. Any lot that exhibits a failure shall be rejected. If during retesting an additional quality parameter is observed to be defective, the lot of 50 is subject to rejection for that cause. The manufacturer may test each coil in the failed lot for the property in which failure occurred and reject only the nonconforming coils.

10.4 If any test specimen shows the presence of a weld or an obvious defect, it may be discarded and another specimen substituted.

10.5 Test specimens shall also be tested for compliance with marcelling dimensions (see 5.2.1). For this purpose, the test specimen shall contain at least three peaks and three valleys.

## 11. Inspection

11.1 Unless otherwise specified in the contract or purchase order, the producer is responsible for the performance of all inspection and test requirements of this specification. Except as otherwise specified in the contract or purchase order, the producer may use his own or any other suitable facilities for the performance of the inspection and test requirements unless disapproved by the purchaser at the time the order is placed. The purchaser shall have the right to perform any of the inspections and tests prescribed in this specification when such inspections and tests are deemed necessary to ensure that the material conforms to prescribed requirements.

## 12. Rejection and Rehearing

12.1 Material that fails to conform to the requirements of this specification may be rejected. Rejections should be reported to the producer or supplier promptly and in writing. In case of dissatisfaction with the results of the test, the producer or supplier may make claim for a rehearing.

12.2 The material must be adequately protected and correctly identified in order that the producer or supplier may make a proper investigation.

## 13. Certification

13.1 When specified in the purchase order or contract, a producer's or supplier's certification shall be furnished to the purchaser that the material was manufactured, sampled, tested, and inspected in accordance with this specification and has been found to meet the requirements. When specified in the contract or purchase order, a report of the test results shall be furnished.

## 14. Packaging, Package Marking, and Loading

14.1 Marking shall be by a tag securely attached to each coil of tension wire and shall show the identity of the producer, quantity, type of coating, class of coating (if applicable), and ASTM designation.

14.2 Packaging of the coils of wire shall be agreed upon between the producer and the purchaser. This agreement may include coil dimensions and weight.

14.3 Unless otherwise specified, the packaging, package marking, and loading shall be in accordance with Practices A 700.

## 15. Keywords

15.1 chain link fence; marcelled wire; metallic coated steel wire; steel wire; wire



## A 824

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# Standard Specification for Post-Applied Coatings, Pavings, and Linings for Corrugated Steel Sewer and Drainage Pipe<sup>1</sup>

This standard is issued under the fixed designation A 849; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

*This standard has been approved for use by agencies of the Department of Defense.*

## 1. Scope

1.1 This specification covers post-applied coatings, pavings, and linings for corrugated steel pipe and corrugated steel structural plate pipe, pipe-arches, and arches coated, paved, or lined with specified materials over either metallic coatings or metallic coatings with polymer coatings. This specification includes asphalt, polymerized asphalt, polymer, mastic, and emulsion coatings and asphalt and concrete pavements and linings applied to the pipe in the producing plant, as well as, asphalt and mastic coatings applied in the field. Field-applied concrete pavements and linings are covered by Specification A 979/A 979 M. The pipe to which the coatings are applied is described in Specifications A 760/A 760M, A 761/A 761M, and A 762/A 762M.

1.2 There is no cleaning operation currently included in pipe coating practice. However, experience has shown that a clean substrate provides good adherence for both cold- and hot-applied post coatings. The performance of post coating or lining, or both, will depend on the surface cleanliness over which it is applied.

1.3 The values stated in inch-pound units are to be regarded as standard. The values given in brackets are for information only.

1.4 The following safety hazards caveat pertains only to the test methods portions, Sections 11 and 12, of this specification. *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

## 2. Referenced Documents

### 2.1 ASTM Standards:

A 185 Specification for Steel Welded Wire, Fabric, Plain, for Concrete Reinforcement<sup>2</sup>

A 615/A 615M Specification for Deformed and Plain Billet-Steel Bars for Concrete Reinforcement<sup>2</sup>

A 742/A 742M Specification for Steel Sheet, Metallic-Coated and Polymer Precoated for Corrugated Steel Pipe<sup>3</sup>

A 760/A 760M Specification for Corrugated Steel Pipe, Metallic-Coated for Sewers and Drains<sup>3</sup>

A 761/A 761M Specification for Corrugated Steel Structural Plate, Zinc-Coated, for Field-Bolted Pipe, Pipe-Arches, and Arches<sup>3</sup>

A 762/A 762M Specification for Corrugated Steel Pipe, Polymer Precoated for Sewers and Drains<sup>3</sup>

A 862 Practice for Application of Bituminous (Asphalt) Coatings to Corrugated Steel Sewer and Drainage Pipe<sup>3</sup>

A 885/A 885M Specification for Steel Sheet, Zinc and Aramid Fiber Composite Coated for Corrugated Steel Sewer, Culvert, and Underdrain Pipe<sup>3</sup>

A 926 Test Method for Comparing the Abrasion Resistance of Coating Materials for Corrugated Metal Pipe<sup>3</sup>

A 979/A 979M Specification for Concrete Pavements and Linings Installed in Corrugated Steel Structures in the Field<sup>3</sup>

C 31/C 31M Practice for Making and Curing Concrete Test Specimens in the Field<sup>4</sup>

C 33 Specification for Concrete Aggregates<sup>4</sup>

C 39 Test Method for Compressive Strength of Cylindrical Concrete Specimens<sup>4</sup>

C 150 Specification for Portland Cement<sup>5</sup>

C 309 Specification for Liquid Membrane-Forming Compounds for Curing Concrete<sup>4</sup>

C 595 Specifications for Blended Hydraulic Cements<sup>5</sup>

C 618 Specification for Coal Fly Ash and Raw or Calcined Natural Pozzolan for Use as a Mineral Admixture in Portland Cement Concrete<sup>4</sup>

C 670 Practice for Preparing Precision and Bias Statements for Test Methods of Construction Materials<sup>4</sup>

D 5 Test Method for Penetration of Bituminous Materials<sup>6</sup>

D 6 Test Method for Loss on Heating of Oil and Asphaltic Compounds<sup>7</sup>

D 20 Test Method for Distillation of Road Tars<sup>6</sup>

<sup>1</sup> This specification is under the jurisdiction of ASTM Committee A05 on Metallic Coated Iron and Steel Products and is the direct responsibility of Subcommittee A05.17 on Corrugated Steel Pipe Specifications.

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<sup>2</sup> Annual Book of ASTM Standards, Vol 01.04.

<sup>3</sup> Annual Book of ASTM Standards, Vol 01.06.

<sup>4</sup> Annual Book of ASTM Standards, Vol 04.02.

<sup>5</sup> Annual Book of ASTM Standards, Vol 04.01.

<sup>6</sup> Annual Book of ASTM Standards, Vol 04.03.

<sup>7</sup> Annual Book of ASTM Standards, Vol 04.04.

- D 36 Test Method for Softening Point of Bitumen (Ring-and-Ball Apparatus)<sup>7</sup>
- D 70 Test Method for Density of Semi-Solid Bituminous Materials (Pycnometer Method)<sup>6</sup>
- D 92 Test Methods for Flash and Fire Points by Cleveland Open Cup<sup>8</sup>
- D 1005 Test Methods for Measurement of Dry-Film Thickness of Organic Coatings Using Micrometers<sup>9</sup>
- D 1187 Specification for Asphalt-Base Emulsions for Use as Protective Coatings for Metal<sup>7</sup>
- D 2042 Test Method for Solubility of Asphalt Materials in Trichloroethylene<sup>6</sup>
- D 4402 Test Method for Viscosity Determinations of Unfilled Asphalts Using the Brookfield Thermosel Apparatus<sup>7</sup>

**3. Terminology**

3.1 *Definitions:*

3.1.1 *fabricator, n*—refers to the producer of the pipe who generally applies the post coatings, pavings, and linings, except for those pipes that are coated in the field.

3.1.2 *lining, n*—for *corrugated metal pipe*, a layer of nonmetallic material applied to the interior of a fabricated pipe, of sufficient thickness to fill and cover the corrugations.

3.1.3 *manufacturer, n*—refers to the producer of the sheet.

3.1.4 *paving, n*—for *corrugated metal pipe*, a lining applied only to a portion of the interior circumference, usually the lower portion as installed.

3.1.5 *post coating, n*—for *corrugated metal pipe*, a layer of nonmetallic material applied to the interior or exterior surface of the pipe, or both, after fabrication of the pipe.

3.1.6 *Discussion—Coating* is generally used to refer to a layer or layers of material applied to the base metal in sheet form prior to fabrication into pipe. *Post coating* applies to a layer of nonmetallic material applied after fabrication into pipe. Where the context is clear, *coating* may be used in place of *post coating*.

3.1.7 *purchaser, n*—refers to the purchaser of the finished product.

**4. Significance and Use**

4.1 Post-applied coatings, linings, and pavements are used to improve hydraulic characteristics, corrosion resistance, or abrasion resistance, or a combination thereof. Generally, coatings improve corrosion resistance and are especially effective on the outside (soil side) of the pipe. While coatings improve abrasion resistance to varying degrees, pavements generally are used where abrasion is a significant consideration. Pavements improve abrasion resistance, protect the metallic and other coatings, and increase corrosion resistance. Smooth pavements, even though they typically cover only the invert of the pipe, improve hydraulic flow characteristics. Full linings and pavements, generally, provide all three benefits.

4.2 *Applications:*

4.2.1 Asphalt, polymer-modified asphalt, and polymer provide excellent corrosion resistance to the outside (soil side) of

the pipe. These materials provide varying degrees of internal (water side) corrosion protection depending on the severity of abrasive flow conditions. Polymer-modified asphalt and polymer coatings provide longer-term protection than asphalt in more abrasive conditions.

4.2.2 Asphalt pavements are used for abrasive conditions. Where conditions involve repeated high flow velocities moving a heavy bed load of gravel or rocks, or both, concrete pavements are appropriate (see Specification A 979/A 979M).

4.2.3 Full asphalt linings enhance hydraulics while providing a completely “paved” interior. Full concrete linings are high-strength concrete that provides a lining similar in thickness to asphalt linings. They enhance hydraulic performance and offer abrasion protection, which is not as effective as the abrasion protection offered by a thicker concrete pavement.

**5. Classification**

5.1 The post-applied coatings, pavings, and linings are described in this section as a two-step classification procedure. The first classification is the type of coating, paving, or lining material to be used, for example, hot-applied asphalt, concrete, cold-applied mastic, cold-applied emulsion, polymer, or combination thereof. The second is a coating, paving, and lining type giving the physical location of the coating or lining on the pipe (see Table 1).

5.2 *Material Classes:*

5.2.1 *Class A*—Asphalt,

5.2.2 *Class PA*—Polymer modified asphalt, hot applied,

5.2.3 *Class C*—Concrete,

5.2.4 *Class M*—Mastic, either asphalt base or tar base, cold applied,

5.2.5 *Class P*—Polymer, and

5.2.6 *Class E*—Asphaltic emulsion.

5.3 *Coating, Paving, and Lining Types:*

5.3.1 *Fully Coated*—A uniform coating applied to the interior and exterior of the pipe.

5.3.2 *Half Coated*—A uniform coating applied to the interior and exterior of the pipe covering at least 50 % of the circumference on the lower portion of the pipe as installed.

5.3.3 *Exterior Coated*—A uniform coating applied to the exterior of the pipe.

5.3.4 *Interior Coated*—A uniform coating applied to the interior of the pipe .

5.3.5 *Invert Coating*—A uniform coating on the lower portion of the interior of the pipe as installed (the invert) to provide abrasion and corrosion resistance without filling the corrugations.

**TABLE 1 Location and Material Class**

Physical Location	A	PA	C Concrete	M/E Cold- Applied <sup>A</sup>	P Polymer
	Asphalt, Hot- Applied	Polymerized Asphalt, Hot-Applied			
Interior-coated	—	—	—	M/E	P
Exterior-coated	—	—	—	M/E	P
Fully-coated	A	PA	—	M/E	P
Half-coated	A	PA	—	M/E	P
Fully-lined	A	—	C	—	—
Invert-paved	A	PA	C	—	P
Invert-coated	—	PA	—	—	P

<sup>A</sup>May be plant or field applied.

<sup>8</sup> Annual Book of ASTM Standards, Vol 05.01.

<sup>9</sup> Annual Book of ASTM Standards, Vol 06.01.

5.3.6 *Invert Paved*—A paving on the lower portion of the interior of the pipe as installed (the invert) to provide an abrasion-resistant smooth flow line.

5.3.7 *Fully Lined*—A lining filling the corrugations on the full interior of the pipe to provide a smooth interior.

## 6. Ordering Information

6.1 The pipe to be coated shall be described as to the applicable standard (Specification A 760/A 760M, A 761/A 761M, or A 762/A 762M), including all detailed ordering provisions of that specification.

6.2 Orders for pipe coatings to this specification shall include the following information as necessary to adequately describe the desired product,

6.2.1 Class of material,

6.2.2 Type of coating, paving, or lining,

6.2.3 If post coating is to be applied in the plant or in the field (Note 1).

NOTE 1—Class M (mastic) and Class E (emulsions) coatings are suitable for either plant application or field application.

6.2.4 For Class M, whether asphalt base or tar base material,

6.2.5 For concrete *invert paved* material Class C, amount of reinforcement (see 7.2.2.5),

6.2.6 ASTM designation and year of issue,

6.2.7 Certification, if required, on the post coating, and,

6.2.8 Any special requirements.

## 7. Material Requirements

7.1 *Material Class A (Asphalt Material)*—The asphalt material shall be applied in accordance with Practice A 862 and shall meet the following requirements as applied to a pipe:

7.1.1 *Softening Point*—200°F [93°C] min.

7.1.2 *Penetration (Original Material)*—35 to 65 dmm.

7.1.3 *Penetration (Residue from Loss on Heating)*—85 % of original penetration, min.

7.1.4 *Flash Point*—450°F [232°C] min.

7.1.5 *Solubility*—99 % min.

7.1.6 *Specific Gravity*—0.98 min at 77°F [25°C].

7.1.7 *Loss on Heating*—1 % max.

7.1.8 *Shock*—The asphalt shall be considered acceptable if not more than one of the four test specimens shows a crack. Test as described in 11.2.

7.1.9 *Flow*—The asphalt shall be considered acceptable if the flow does not exceed  $\frac{3}{8}$  in. [9.5 mm] for either of the two test specimens. Test as described in 11.3.

7.1.10 *Imperviousness*—There shall not be any loosening or separation of the asphalt coating from the substrate at the end of 48 h when tested as described in 11.4.

7.2 *Material Class C (Concrete Material)*—Full concrete linings shall meet the requirements of 7.2.1. Concrete paved inverts shall meet the requirements of 7.2.2.

7.2.1 *Concrete Linings*—Full concrete linings shall cover 100 % of the pipe circumference. Linings shall be placed by a machine that, in one or more passes, completely fills the corrugation and provides a minimum  $\frac{1}{8}$  in. [3.2 mm] concrete thickness over the corrugation crests. Hand placement methods are acceptable for lining fittings and elbows when machine placement is not practical and the above results are achieved.

The lining shall conform to the shape of the pipe and have a troweled surface finish meeting the requirements of 9.1.2.1.

7.2.1.1 The concrete shall be composed of cement, fly ash (when used), fine aggregates, and water that are well mixed and of such consistency as to produce a dense, homogeneous, nonsegregated lining. In no case shall the proportions of portland cement, blended cement, or portland cement plus pozzolanic material in the mixture be less than 470 lb/yd<sup>3</sup> [279 kg/m<sup>3</sup>] of concrete. The concrete mix shall provide a minimum seven day compressive strength of 5000 psi [34.5 MPa] when tested in accordance with Practice C 31 and Test Method C 39. Concrete linings shall be cured to meet the requirements of 7.2.3. All concrete shall have a water-cement ratio not exceeding 0.50 by weight.

7.2.1.2 *Cement*—Cement shall conform to the requirements of Specification C 150, Type I or II or Specification C 595, Type IP. When Type IP cement is used, no fly ash shall be used in the mix.

7.2.1.3 *Fly Ash*—Fly ash shall conform to the requirements of Specification C 618, Class F or Class C. When fly ash is used, it shall not exceed 20 % by weight of the total cementitious materials in the mix.

7.2.1.4 *Aggregates*—Aggregates shall conform to the requirements of Specification C 33 except that the requirement for gradation and uniformity of gradation shall not apply. The aggregate shall be well graded with 100 % passing the No. 16 [1.18 mm] sieve with no more than 5 % passing the No. 100 [150 μm] sieve.

7.2.1.5 Only potable water shall be used.

7.2.2 *Concrete Pavements*—Special pavement designs that meet or exceed the requirements of this specification shall be fully detailed in the purchase documents. In lieu of a special design, pavements shall cover the bottom 25 % of a round pipe's circumference and the 40 % of the circumference of a pipe arch that constitutes the invert. Pavements shall conform to the shape of the pipe and have either a screeded or troweled surface finish as specified in the purchase documents. The troweled finish shall meet the requirements of 9.1.2.1.

7.2.2.1 The pavement shall provide a minimum 3 in. [76.2 mm] thickness over the corrugation crests, when concrete with a minimum 28-day compressive strength of 3250 psi [22.4 MPa] is used. Alternatively, the pavement shall provide a minimum 1  $\frac{1}{2}$  in. [38.1 mm] thickness over the corrugation crests, when concrete with a minimum 28-day compressive strength of 9600 psi [66.2 MPa] is used. Concrete compressive strength shall be determined in accordance with Practice C 31 and Test Method C 39. All concrete pavements shall be cured to meet the requirements of 7.2.3.

7.2.2.2 *Cement*—The cement to be used shall be Type II portland cement conforming to Specification C 150 with alkali content not more than 0.60 % expressed as Na<sub>2</sub>O, or Type IP (MS) portland pozzolan cement conforming to Specification C 595. When Type IP cement is used, no fly ash shall be used in the mix.

7.2.2.3 *Fly Ash*—Fly ash shall conform to the requirements of Specification C 618, Class F or Class C. When fly ash is used, it shall not exceed 20 % by weight of the total cementitious materials in the mix.



7.2.2.4 *Aggregates*—The aggregates shall conform to the requirements prescribed in Specification C 33.

7.2.2.5 *Steel Reinforcement*—When steel reinforcement is required (special pavement designs), it shall be billet-steel bars conforming to Specification A 615, Grade 40 or Grade 60, or welded wire fabric reinforcement conforming to Specification A 185. Special pavement designs using reinforcement shall consider adequate concrete cover over the reinforcing steel for the intended application.

7.2.2.6 Only potable water shall be used.

7.2.3 Curing operations shall begin immediately after placing the lining or pavement and continue for a minimum of 72 h. The pipe shall be closed with airtight end covers and the concrete kept wet via an intermediate water source or a liquid membrane-forming compound conforming to Specification C 309 applied to the concrete surface. The manufacturer is responsible for adequate cure time, conditions, and shipment precautions to meet the applicable requirements of 7.2.1.1 and 7.2.2.1 and 9.1.2.

7.3 *Material Class M (Asphalt Mastic or Tar Base Mastic)*—The tar base mastic material shall conform to the requirements in Table 2. The asphalt mastic material shall have the following physical characteristics:

7.3.1 *Asphalt Base*—Oxidized petroleum asphalts.

7.3.2 *Solvent*—Rapid drying petroleum solvents.

7.3.3 *Fillers*—Mineral stabilizers and fillers.

7.3.4 *Consistency*—Material shall be furnished in consistency for application by trowel, brush, or spray, as specified.

7.3.5 *Physical Properties*—As described in Table 3.

7.4 *Material Class PA (Polymer Modified Asphalt)*—The polymer modified asphalt shall meet the following requirements as applied to the pipe:

7.4.1 *Softening Point*—200°F [93°C] minimum when tested in accordance with 11.1.1.

7.4.2 *Penetration*—25 to 50 dmm when tested in accordance with 11.1.1.

7.4.3 *Flash Point*—500°F [260°C] minimum when tested in accordance with 11.1.1.

7.4.4 *Loss on Heating*—1 % maximum when tested in accordance with 11.1.1.

7.4.5 *Shock*—No more than one specimen shall crack when tested in accordance with 11.2.

TABLE 2 Tar Base Material, Cold-Applied Requirements

Physical Properties	Requirement	Method
Sag test	no sag <sup>A</sup>	applied at the rate of 60 ft <sup>2</sup> per gal [1.47 m <sup>2</sup> /L] to a smooth metal surface
Ash, mass, %	15–25	loss of ignition
Distillation, mass, %		
32–302°F [0–150°C]	0	
302–455°F [150–235°C]	20–30	
Distillation residue		
Softening point, °F [°C]	205–240 [96–115]	Test Method D 36
Penetration, (77°F [25°C], 100 g, 5 s) dmm	5–25	Test Method D 5
Drying time, h	24–48	surface dry under normal atmospheric conditions

<sup>A</sup>No statement is made about either the precision or the bias of the sag test because the result merely states whether there is conformance to the criteria for success specified in the procedure.

TABLE 3 Asphalt Mastic, Cold-Applied Physical Properties

	Trowel Grade		Spraying Grade		Brushing Grade	
	min	max	min	max	min	max
Solids, weight %	63	68	61	66	60	65
Weight [mass], lb/gal [kg/L]	8.7 [1.04]	8.9 [1.07]	8.3 [0.99]	9.3 [1.11]	8.2 [0.98]	8.5 [1.02]
Dry to touch, h	...	4	...	4	...	4
Dry hard, 1/16 in., h	...	48	...	48	...	48
Flow test <sup>A</sup>	...	...	...	...	...	...
Acid and alkali resistance <sup>B</sup>	...	...	...	...	...	...

<sup>A</sup>Shifting or sagging of lines is cause for rejection.

<sup>B</sup>Panel surface shall remain free of any pitting or rusting.

7.4.6 *Flow*—The polymer modified asphalt shall be acceptable if the flow of either of the two samples does not exceed 1/4 in. [6.4 mm] when tested in accordance with 11.3.

7.4.7 *Imperviousness*—There shall be no disbonding of the polymer modified asphalt from the substrate in 48 h when tested in accordance with 11.4.

7.4.8 *Abrasion Resistance*—No more than 10 grid squares shall have exposed metal that is visible to the naked eye prior to 3 000 000 revolutions when tested in accordance with 11.5.

7.4.9 *Brookfield Viscosity Measured at 380°F [193°C]*—800 to 2000 cps when determined in accordance with 11.6.

7.5 *Material Class P (Polymer)*—The polymer material shall conform to the requirements of Specification A 742/A 742M.

7.6 *Material Class E (Asphaltic Emulsion)*—Cold-applied asphaltic emulsions shall conform to the requirements of Specification D 1187.

8. Materials and Manufacture

8.1 *Pipe Fabrication*—All pipe post-coated under this specification shall be fabricated in accordance with the requirements of Specification A 760/A 760M, A 761/A 761M, or A 762/A 762M. Steel sheet composite-coated for corrugated steel sewer pipe (Specification A 885) shall be fabricated in accordance with the requirements for riveted or lock-seam pipe of Specification A 760/A 760M and only post-coated with Class A coating material *fully coated*, with or without being *invert paved* or *fully lined* (see 8.3, 8.4, and 8.6).

8.2 *Pipe Preparation*—The coatings of the types described in this specification shall be applied to pipe which is essentially free from all moisture, dirt, oil, grease, or other foreign matter.

8.3 *Fully Coated, Half-Coated, Exterior-Coated, Interior-Coated Types with Asphalt, Polymerized Asphalt, Mastic, and Asphaltic Emulsions (Classes A, PA, M, and E)*—The coating shall be applied to a minimum thickness of 0.05 in. [1.3 mm] measured on the crest of corrugations, on the top of ribs (for exterior coating on Type IR pipe), or on the smooth inside surface (for interior coating on Type IA Pipe, or interior or exterior of Type IR pipe). Material Classes A and PA are used only for *fully coated* and *half-coated* types. Material Class M is permitted for use for all four coating types.

8.4 *Invert Paved Type with Asphalt and Polymerized Asphalt (Classes A and PA)*—The material shall be applied to fill the corrugations and provide a minimum thickness of 1/8 in. [3.2 mm] above the crest of corrugations for at least 25 % of

the circumference of round pipe and 40 % of the circumference of pipe arch (the invert as installed) (Note 2).

NOTE 2—For pipe fabricated in accordance with the requirements of Specification A 760/A 760M, pipe should first be coated with Class A or PA material to a minimum thickness of 0.05 in. [1.3 mm] before placing *fully lined* or *invert paved* material to ensure good adhesion.

8.5 *Invert Paved Type with Concrete Material (Class C)*—The concrete material shall meet the requirements of 7.2.2. The concrete shall be placed after the pipe has been installed and backfilled. The coating shall have a minimum thickness of 3 in. [75 mm], and shall cover at least 25 % of the circumference of round pipe and 40 % of the circumference of pipe arch (the invert as installed). When concrete with a compressive strength of 9600 psi [65 MPa] is used the minimum coating thickness may be reduced to 1½ in. [38 mm].

8.6 *Fully Lined Type with Asphalt Material (Class A)*—The material shall be applied to fill the corrugations and provide a minimum thickness of ⅛ in. [3.2 mm] above the crests of corrugations on the pipe interior. The lining shall provide a smooth surface over the entire interior of the pipe (see Note 2).

8.7 *Fully Lined Type with Concrete Material (Class C)*—The concrete material shall meet the requirements of 7.2.1. The concrete lining shall be plant applied by a machine which places and mechanically trowels the concrete in the pipe while one moves relative to the other. The rate of concrete placement and relative rate of travel of pipe and machine shall be mechanically regulated so as to produce a homogenous, nonsegregated lining throughout. The lining shall have a minimum thickness of ⅛ in. [3.2 mm] above the crests of the corrugations.

8.8 *Fully Coated, Half-Coated, Exterior-Coated, and Interior-Coated Types with Polymer Material (Class P)*—The material shall be uniformly applied to the surfaces to be coated to a minimum thickness of 0.010 in. [0.25 mm] measured on the crest of corrugations, on the top of ribs (for exterior coating on Type IR pipe), or on the smooth surface (for interior coating on Type IA pipe, or interior or exterior on Type IR pipe).

8.9 *Invert Coated Type with Polymer Material (Class P)*—The material shall be applied to provide a minimum thickness of 0.05 in. [1.3 mm] for at least 25 % of the circumference of round pipe and 40 % of the circumference of pipe arch (the invert as installed).

8.10 *Invert Paved Type with Polymer Material (Class P)*—The material shall be applied to provide a minimum thickness of 0.05 in. [1.3 mm] above the crests of the corrugations for at least 25 % of the circumference of round pipe and 40 % of the circumference of pipe arch (the invert as installed).

**9. Workmanship, Finish, and Appearance**

9.1 The completed pipe shall show careful, finished workmanship in all particulars.

9.1.1 The following defects shall be considered as constituting poor workmanship for post coatings, pavings, and linings using asphalt, emulsion, mastic, polymerized asphalt, or polymer materials: coatings or linings that are bruised, broken, disbanded, or otherwise damaged.

9.1.2 The following defects shall be considered as constituting poor workmanship for concrete linings and pavements: concrete containing sandpockets, voids or chipped or spalled

areas; cracks that produce spalled areas or cause loosening of the lining or pavement; troweled surface finishes that do not have an acceptable level of smoothness.

NOTE 3—Cracks are inherent in concrete linings because of the rigid lining in a flexible shell. They typically will heal autogenously when kept wet. Cracks are not a reason for concern unless they produce spalls or cause loosening of the lining material.

9.1.2.1 To determine the level of smoothness of troweled concrete surface finishes, measure the gaps between the concrete surface and a 12 in. [305 mm] straight edge laid on the surface, parallel to the axis of the pipe, using a predetermined random sampling plan agreed upon between the purchaser and the fabricator. The finish is acceptable for smoothness if 90 % of the gaps are ¼ in. [6.35 mm] or less.

9.2 Pipes containing damaged coatings, pavements, or linings shall be repaired by the fabricator to the satisfaction of the purchaser.

**10. Repairs to Post-Coating, Paving, and Lining**

10.1 Materials used to repair damaged areas on previously coated pipe shall be compatible with and capable of being applied to the previous coating as recommended by the manufacturer of the original material (see Note 4). Repair coatings shall be of equal thickness to the previous coating as a minimum and shall have equal adherence.

NOTE 4—Asphalt should be repaired with asphalt and coal tar with coal tar.

10.1.1 Damage to polymer precoating or metallic coatings shall be repaired in accordance with Specification A 760/A 760M, A 761/A 761M, or A 762/A 762M as appropriate.

10.1.2 Repair to damaged concrete linings and pavements shall be made with a grout consisting of one part (by weight) cement to two parts washed, dry concrete sand. The grout shall be mixed with a minimum amount of water that will give a workable mix. The damaged area shall be cleaned of any dirt or loose material. After rinsing the area to be repaired with water, the grout shall be hand troweled to the same thickness and shall conform to the contour of the existing lining.

**11. Test Methods for Sampling and Testing Asphalt and Polymerized Asphalt Materials**

11.1 Obtain samples of the asphalt or polymerized asphalt coating by gathering strippings, sufficient to make a minimum 10-oz [0.3-kg] sample, from the inside of one or more lengths of pipe, preferably near the top as installed, or from the dip tank during the dipping process. Care shall be taken in sampling to avoid contamination.

11.1.1 Test the asphalt samples in accordance with the following ASTM test methods:

	Test Method
Softening point	D 36
Penetration	D 5, using conditions of 77°F [25°C], 100 g, and 5 s
Flash point	D 92
Solubility	D 2042
Specific gravity	D 70
Loss on heating	D 6

11.2 *Shock Test:*

11.2.1 *Apparatus:*

11.2.1.1 *Rigid Metal Anvil or Base Plate*, not less than ½ in. [12.7 mm] thick resting on a solid foundation.

11.2.1.2 *Hammer*, weighing 2000 g arranged to fall freely in suitable guides upon a plunger.

11.2.1.3 *Plunger*, weighing 1000 g sliding freely in a vertical sleeve, the lower end of the plunger being spherical in shape with a radius of ½ in. [12.7 mm].

11.2.1.4 Means for raising the hammer and dropping it through a distance of 5⅞ in. [130 mm] upon the head of the plunger.

11.2.2 *Test Specimens*—Prepare four test specimens in the form of disks 1¾ in. [44.5 mm] in diameter and ⅜ in. [9.5 mm] thick. Heat on a hot plate the container with approximately 4 oz [110 g] of the bituminous sample until the sample becomes fluid. Pour the fluid sample into a brass mold or molds treated with a release agent. Exercise care to melt the sample at the lowest possible temperature and to stir it thoroughly until it is homogeneous and free from air bubbles. Mold the test specimens separately or pour the material into one cylinder 1¾ in. in diameter and of appropriate length to cut four specimens from it with a wire cutter. Split brass molds, coated with a release agent having an inside diameter of 1¾ in. and slightly tapered outside surfaces, and held together by slip rings, are suitable for molding the test specimens.

11.2.3 *Procedure*—Remove the molds after the asphalt has cooled to room temperature. Cut the four specimens to thickness (if necessary) and cool for a period of at least 1 h in a bath of ice and salt brine at a temperature of 30°F [−1.0°C]. Remove the specimens from the bath one at a time and quickly place them on the anvil of the test apparatus. Center them under the plunger with the hammer tripped to fall through a height of 5⅞ in. [130 mm] upon the head of the plunger. Not more than 8 s shall elapse from the time each specimen is removed from the bath until the hammer strikes the plunger. Examine specimens for evidence of a crack. If it is difficult to determine visually whether a specimen has cracked, remove the specimen from the test apparatus and subject it to a slight bending. Also, samples should be cut and checked for air entrapment.

11.2.4 *Precision*—The shock test described in this test method is defined as a determination that at least three of four separate specimens comprising a single test sample will exhibit no cracking to yield an acceptable result. Analysis of an interlaboratory study (a blind study carried out by 9 laboratories in 4 different materials with 3 replicates of each material) reveals a pass/fail ratio for tests on the same material ranging from 0.22 to 1.45, with an overall pass/fail ratio for all 108 samples (27 samples of each of 4 materials) of 0.54. Further in each of 11, out of the total of 36 cases, where 3 replicate samples of the same material were tested in the same laboratory, the same laboratory obtained passing results on one of the 3 replicate samples and failing results on the other 2 replicate samples, or vice versa.

11.2.5 *Bias*—Since there is no accepted reference material suitable for determining the bias for the procedure in the test method for measuring shock, no statement on bias is being made.

### 11.3 *Flow Test:*

11.3.1 *Apparatus*—The apparatus for making the test shall

consist of corrugated brass plate approximately 0.03 in. [0.8 mm] thick, 8 in. [200 mm] long, and 4 in. [100 mm] wide, with corrugations running lengthwise of the plate, and a metal support to hold the plate on a 45° angle with the horizontal. The corrugations shall have a crest to crest dimension of ⅝ in. [15.9 mm] and a depth of ⅜ in. [4.8 mm]. A line shall be scribed 6 in. [150 mm] from the lower edge.

11.3.2 *Test Specimens*—Test specimens shall be in the form of cylinders ⅜ in. [9.5 mm] in diameter and ¾ in. [19.0 mm] in length. Two specimens shall be used for each test. Make the specimens by pouring the asphalt from the specimens for the shock test into split, treated brass molds.

11.3.3 With the corrugated plate held at an angle of 45° to the horizontal, lay each test specimen in a corrugation so that its lower end will rest exactly along the line scribed 6 in. [150 mm] from the bottom edge of the plate. Place the test apparatus in an oven maintained at a temperature 150 ± 2°F [65.6 ± 1°C]. After 4 h in the oven, remove the apparatus and specimens and allow them to cool to room temperature. Measure the distance from the bottom of the corrugated plate to the lower edge of the test specimens. This distance subtracted from 6 in. [150 mm] is reported as the amount of flow.

### 11.3.4 *Precision:*

11.3.4.1 *Single-Operator Precision (Flow Test)*—The single-operator coefficient of variation for a single test result (a test result in this method has been defined as the measurements on two separate specimens) has been found to be 65 % (Note 5). Therefore, two properly conducted tests by the same operator (each consisting of measurements on two specimens from the same sample) shall not differ by more than 184 % (Note 5) of their average. The range (difference between the highest and lowest) of the two individual measurements comprising a test result should not exceed 260 % (Note 6) of the average of the two.

11.3.4.2 *Multilaboratory Precision (Flow Test)*—The multilaboratory coefficient of a variation of a single test result (a test result in this method has been defined as the measurements on two separate specimens) has been found to be 97 % (Note 5). Therefore, results of two properly conducted tests in different laboratories on the same bituminous coating should not differ by more than 275 % (Note 5) of their average.

NOTE 5—These numbers represent respectively the (1s %) and (d2s %) limits described in Practice C 670.

NOTE 6—Calculate as described in the paragraph on precision of individual measurements averaged to obtain a test result in Practice C 670.

NOTE 7—These precision statements are based on results of an interlaboratory test program using three replicates of each of four materials. Nine laboratories participated in the tests.

11.3.5 *Bias*—Since there is no accepted reference material suitable for determining the bias for the procedure in the test method for measuring flow, no statement on bias is being made.

11.4 *Imperviousness Test*—Hold in separate valleys of the coated corrugated steel pipe for a period of 48 h, a 25 % by volume solution of sulfuric acid, a 25 % by weight solution of sodium hydroxide, and a saturated solution of sodium chloride. This test may be made on an uncut section of pipe provided provision is made to prevent excessive evaporation of the three test solutions.

11.4.1 *Precision and Bias*—No statement is made about either the precision or the bias of the imperviousness test since the result only states whether there is conformance to the criteria for success specified in the procedure.

11.5 Test the abrasion resistance of polymerized asphalt in accordance with Test Method A 926, using test method alternative 2.

11.6 Test the Brookfield viscosity of polymerized asphalt in accordance with Test Method D 4402.

## 12. Test Methods for Sampling and Testing Asphalt Mastic, Cold Applied

12.1 Take a representative sample of 1 gal [4 L] from each lot of asphalt mastic furnished.

12.2 *Solids Content*—In an aluminum drying dish, weigh a 9-g sample of material to an accuracy of 0.01 g. Heat the sample at  $325 \pm 5^\circ\text{F}$  [ $163 \pm 3^\circ\text{C}$ ] until constant weight is obtained (approximately 24 to 48 h). Cool the sample, reweigh, and calculate percentage of solids as follows:

$$\text{solids, \%} = \frac{A}{B} \times 100$$

where

A = weight of material after heating, g and

B = weight of material before heating, g.

12.3 *Flow Property at Elevated Temperature*—Apply a coating of the material approximately  $\frac{1}{16}$  in. [1.6 mm] thick, on a degreased flat steel panel, 0.024 in. [0.60 mm] thick. Score horizontally across the width of the surface parallel lines spaced  $\frac{1}{2}$  in. [12.7 mm] apart. After air drying for a period of 48 h, suspend the panel in a vertical position in an oven at  $150 \pm 5^\circ\text{F}$  [ $66 \pm 3^\circ\text{C}$ ] for 24 h. After removal of the panel, inspect the surface of the material for shifting or sagging of the lines. Any shifting or sagging of the lines shall be considered failure.

12.4 *Acid and Alkali Resistance*—The coating of a test specimen prepared in accordance with 12.3 shall show no signs of attack when immersed for 24 h in each of the following solutions: 10 % by weight of sulfuric acid, 10 % by weight hydrochloric acid, and 10 % by weight of sodium hydroxide. After removal of the mastic by suitable solvent cleaning, the panel surface shall be free from any pitting or rusting.

12.5 *Precision and Bias*—No statement is made about either the precision or the bias of 12.3 and 12.4 because the result merely states whether there is conformance to the criteria for success specified in the procedure.

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## 13. Inspection

13.1 The purchaser or his representative shall have free access to the fabricating plant or construction site, if the coating is field-applied, for inspection, and every facility shall be extended to the purchaser for this purpose. This inspection shall include an examination of the pipe for the items in 9.1 and the specific requirements of this specification applicable to the kind of coating or lining.

13.2 On a random basis samples shall be taken for analysis and bituminous coating measurements for check purposes. These samples will be secured from post-coated pipe or from the dip tank during the dipping process. The thickness of bituminous coating shall be measured in accordance with Test Methods D 1005.

13.3 The fabricator shall furnish test specimens to demonstrate the compressive strength of the concrete used in concrete linings or pavements as required by the purchase documents.

## 14. Rejection

14.1 Pipe coatings failing to conform to the specific requirements of this specification, or that shows poor workmanship in general, or poor workmanship in limited areas that have not been repaired in accordance with Section 10, shall be subject to rejection. This requirement applies not only to the individual pipe, but to any shipment as a whole where a substantial number of pipe have defective coatings.

## 15. Certification

15.1 When specified in the purchase order or contract, a fabricator's certification shall be furnished to the purchaser stating that samples representing each coating lot have been tested and inspected in accordance with this specification and have been found to meet the requirements for the material and coating described in the order. When specified in the order, a report of the test results shall be furnished. For polymer coatings, the results of tests indicated as qualification tests may be typical values instead of test results from the specific lot.

## 16. Keywords

16.1 asphalt-coated steel pipe; coatings—corrugated steel pipe; corrugated steel sewer/drain pipe; drainage system—sewer/drainage pipe (steel); linings—corrugated steel pipe; pavings—corrugated steel pipe; pipe coatings; pipe line coatings/linings/paving; pipe linings; pipe paving; steel pipe coatings/linings/paving; steel pipe/corrugated steel



# Standard Specification for Metallic-Coated Steel Smooth High-Tensile Fence and Trellis Wire<sup>1</sup>

This standard is issued under the fixed designation A 854/A 854M; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon ( $\epsilon$ ) indicates an editorial change since the last revision or reapproval.

## 1. Scope

1.1 This specification covers 12 ½ -gauge (0.099-in.) [2.5-mm] Class 3 metallic-coated steel wire suitable for use in parallel-wire fence, trellis, and similar structures that are typically nonelectrified. Two types of coatings are covered, as follows:

1.1.1 *Type I*—Zinc-coated (galvanized), and

1.1.2 *Type II*—Zinc-5 % aluminum mischmetal (Zn-5Al-MM) alloy coated.

1.2 This specification is applicable to orders in either inch-pound units (as A 854) or acceptable SI units (as A 854M). Inch-pound units and SI units are not necessarily equivalent.

## 2. Referenced Documents

### 2.1 *ASTM Standards:*

A 90/A90M Test Method for Weight (Mass) of Coating on Iron and Steel Articles with Zinc or Zinc-Alloy Coatings<sup>2</sup>

A 370 Test Methods and Definitions for Mechanical Testing of Steel Products<sup>3</sup>

A 700 Practices for Packaging, Marking, and Loading Methods for Steel Products for Domestic Shipment<sup>4</sup>

B 6 Specification for Zinc<sup>5</sup>

B 750 Specification for Zinc-5 % Aluminum-Mischmetal Alloy (UNS Z 38510) in Ingot Form for Hot Dip Coating<sup>5</sup>

E 29 Practice for Using Significant Digits in Test Data to Determine Conformance with Specifications<sup>6</sup>

E 47 Test Methods for Chemical Analysis of Zinc Die-Casting Alloys<sup>7</sup>

E 1277 Method for Chemical Analysis of Zinc-5 % Aluminum-Mischmetal Alloy by ICP Argon Plasma Spectrometric Method<sup>8</sup>

<sup>1</sup> This specification is under the jurisdiction of ASTM Committee A05 on Metallic Coated Iron and Steel Products and is the direct responsibility of Subcommittee A05.12 on Wire Specifications.

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<sup>2</sup> *Annual Book of ASTM Standards*, Vol 01.06.

<sup>3</sup> *Annual Book of ASTM Standards*, Vol 01.03.

<sup>4</sup> *Annual Book of ASTM Standards*, Vol 01.05.

<sup>5</sup> *Annual Book of ASTM Standards*, Vol 02.04.

<sup>6</sup> *Annual Book of ASTM Standards*, Vol 14.02.

<sup>7</sup> *Annual Book of ASTM Standards*, Vol 03.05.

<sup>8</sup> *Annual Book of ASTM Standards*, Vol 03.06.

### 2.2 *Military Standards:*<sup>9</sup>

MIL-STD 129 Marking for Shipment and Storage

MIL-STD 163 Steel Mill Products, Preparation for Shipment and Storage

### 2.3 *Federal Standard:*<sup>10</sup>

Fed. Std. No. 123 Marking for Shipment (Civil Agencies)

### 2.4 *International Lead Zinc Research Organization Standard:*<sup>11</sup>

Gf-1 Standard Practice for Determination of Cerium and Lanthanum Compositions in Galfan Alloy (5 % Al-0.04 % La-0.04 % Ca-Bal/SHG Zn) Class 3 Coating

## 3. Classification

3.1 The wire is furnished in Class 3 coating.

3.2 The wire is furnished in three grades according to tensile strength, as follows:

3.2.1 *Grade 200*—Minimum tensile strength, 200 ksi [1380 MPa].

3.2.2 *Grade 180*—Minimum tensile strength, 180 ksi [1240 MPa].

3.2.3 *Grade 140*—Minimum tensile strength, 140 ksi [970 MPa].

## 4. Ordering Information

4.1 Orders for material purchased under this specification shall include the following information:

4.1.1 Quantity (number of coils or weight).

4.1.2 Name of material (high-tensile fence wire).

4.1.3 Coated wire diameter (Section 8).

4.1.4 Type of Coating (1.1.1 or 1.1.2),

4.1.5 Class of coating (3.1).

4.1.6 Grade or tensile strength (3.2).

4.1.7 Nominal weight or length of coils and tolerance.

4.1.8 Packaging, marking, and loading, if other than standard (Section 14).

4.1.9 Certification, if required (Section 13).

<sup>9</sup> Available from Standardization Documents Order Desk, Bldg. 4 Section D, 700 Robbins Ave., Philadelphia, PA 19111-5094, Attn: NPODS.

<sup>10</sup> Available from U.S. Government Printing Office, Washington, DC, 20402.

<sup>11</sup> Available from International Lead Zinc Research Organization, P.O. Box 12036, Research Triangle Park, NC 27709.

#### 4.1.10 ASTM designation and year of issue.

NOTE 1—A typical ordering description is as follows: 400 coils high-tensile fence wire, 12½ gage, 0.099 in., zinc-coated, Class 3, Grade 200, in 100-lb plus 5 minus 0 lb weight coils, to ASTM A 584.

### 5. Materials and Manufacture

5.1 The steel rod from which the wire is drawn shall be manufactured by the open-hearth, electric-furnace, or basic oxygen process.

5.2 The wire shall be cold-drawn then metallic-coated at finished size to produce the specific mechanical properties.

5.3 The wire shall be furnished with one of two types of coatings, specified as follows:

5.3.1 *Type I*—Zinc-coated (galvanized) with coating weight as specified in 7.1.

5.3.2 *Type II*—Zinc-5 % aluminum-mischmetal alloy coated (Zn-5Al-MM) with coating weight as specified in 7.1.

5.4 Type I coating may be produced by either a hot-dip or an electrolytic process at the option of the producer. Type II coating shall be produced by a hot-dip process.

5.5 Slab zinc, if used for Type I coating, shall be one of the appropriate grades that are described in Specification B 6.

5.6 The ingot used for Type II shall conform to Specification B 750.

5.6.1 *Method of Analysis*—The determination of chemical composition shall be made in accordance with suitable chemical (Test Method E 47 for tin), ICP argon plasma spectrometric (Test Method E 1277), or other methods. In case of dispute the results secured by Test Method E 1277 shall be the basis of acceptance.

5.6.2 A standard practice for X-ray fluorescence spectrometry for determination of cerium and lanthanum in a zinc-5 % aluminum-mischmetal alloy has been established by the International Lead Zinc Research Organization (Standard Practice GF 1). In case of dispute, the results secured by Test Method E 1277 shall be the basis of acceptance.

### 6. Mechanical Requirements

#### 6.1 Tension Test:

6.1.1 *Requirements*—The material as represented by the test specimens shall have tensile strengths and meet elongation requirements as shown in Table 1.

6.1.2 *Test Method*—The tension test shall be made in accordance with Test Methods and Definitions A 370, Annex 4.

6.1.3 The diameter used in calculation of tensile strength shall be the actual diameter, including the coating, determined in accordance with 8.3 of this specification.

#### 6.2 Ductility Test:

6.2.1 *Requirements*—The material as represented by the test specimens shall not fracture when wrapped at a rate not exceeding 15 turns/min in a close helix of at least two turns

around a cylindrical mandrel with a diameter of  $2d$  for Grade 200 or  $1d$  for Grades 180 and 140, where  $d$  is the coated wire diameter.

6.2.2 *Test Method*—The wrap test shall be in accordance with Test Methods and Definitions A 370, Annex 4.

6.2.3 Any cracking or flaking of the coating material during this test shall not be construed to constitute failure of the test.

#### 6.3 Adherence of Coating Test:

6.3.1 *Requirements*—The material as represented by the test specimens shall withstand wrapping at a rate not exceeding 15 turns/min in a close helix around a cylindrical mandrel with a diameter of  $4d$ , without cracking or flaking the coating to such an extent that any of the coating metal can be removed by rubbing with the bare fingers.

6.3.2 *Test Method*—The adherence of coating test shall be made in accordance with the wrapping test of Test Methods and Definitions A 370, Annex 4.

6.3.3 Loosening or detachment during the adherence test of superficial, small particles of coating material formed by mechanical polishing of the surface of the coated wire shall not be considered cause for rejection.

### 7. Weight of Coating

7.1 *Requirements*—The material as represented by the test specimens shall have a minimum weight of metallic coating of  $0.80 \text{ oz/ft}^2 [244 \text{ g/m}^2]$  of uncoated wire surface.

7.2 *Test Method*—The weight of metallic coating shall be determined in accordance with Test Method A 90.

### 8. Dimensions and Tolerances

8.1 *Size*—The diameter of the coated wire shall be 0.099 in. [2.5 mm].

8.2 *Tolerance*—The permissible tolerance in the coated wire shall be  $\pm 0.004 \text{ in. } [\pm 0.10 \text{ mm}]$ .

8.3 *Test Method*—Using a micrometer or other suitable instrument, determine the greatest and least measurement at the same cross-section, with each measurement to the nearest 0.001 in. [0.01 mm]. The average of these two measurements shall be considered the diameter of the test specimen.

### 9. Workmanship, Finish, and Appearance

9.1 The coated wire shall be free of slivers, scale, and other imperfections not consistent with good commercial practice. The coating shall be continuous and reasonably uniform.

9.2 Electric-welded butt joints are permitted during the drawing process.

9.3 No welds are permitted after drawing.

### 10. Number of Tests and Retests

10.1 A lot for the purpose of testing shall consist of all the coils of wire of the same diameter, class, and grade offered for shipment at one time.

10.2 One test specimen shall be taken from each 10 000 lb [4540 kg] or fraction thereof. Test specimens shall be taken from either end of coil. Each specimen shall be tested for compliance with Sections 6 and 8. At least half of the specimens shall be tested for compliance with Section 7.

**TABLE 1 Tensile Strength and Elongation**

Grade	Minimum Tensile Strength		Permanent Elongation in 10 in. [250 mm], min, %
	ksi	[MPa]	
200	200	[1380]	2.5
180	180	[1240]	3.0
140	140	[970]	3.5

10.3 If any test specimen exhibits obvious imperfections or shows the presence of a weld, it shall be discarded and another specimen substituted.

10.4 Should one or more of the test specimens fail any of the tests specified, the nonconforming coil or coils may be removed and the balance of the lot subjected to retests. For retest purposes two additional coils for each 10 000 lb [4540 kg] in the lot shall be sampled and tested for the property in which the original sample failed to comply.

10.5 Should any of the retest specimens fail to meet the mechanical or coating properties specified, the lot represented by the test specimens may be rejected.

10.6 Instead of rejecting the entire lot as provided in 10.5, the producer may test specimens from every coil in the lot for the property in which failure occurred and resubmit those coils meeting the specification requirements.

## 11. Inspection

11.1 Unless otherwise specified in the contract or purchase order, the manufacturer is responsible for the performance of all inspection and test requirements specified in this specification. Except as otherwise specified in the contract or purchase order, the manufacturer may use his own or any other suitable facilities for the performance of the inspection and test requirements unless disapproved by the purchaser at the time the order is placed. The purchaser shall have the right to perform any of the inspections and tests set forth in this specification when such inspections and tests are deemed necessary to ensure that the material conforms to prescribed requirements.

## 12. Rejection and Rehearing

12.1 Material that fails to conform to the requirements of this specification may be rejected. Rejection should be reported to the producer or supplier promptly and in writing. In case of dissatisfaction with the results of the test, the producer or supplier may make claim for a rehearing.

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12.2 The material must be adequately protected and correctly identified in order that the producer or supplier may make a proper investigation.

## 13. Certification

13.1 When specified in the purchase order or contract, a producer's or supplier's certification shall be furnished to the purchaser that the material was manufactured, sampled, tested, and inspected in accordance with this specification and has been found to meet the requirements. When specified in the purchase order or contract, a report of the test results shall be furnished.

## 14. Packaging and Marking

14.1 The coil weight, dimensions, and methods of packaging shall be agreed upon between the manufacturer and the purchaser.

14.2 Unless otherwise specified, packaging, marking, and loading for shipment shall be in accordance with Practices A 700.

14.3 When specified in the contract or order, and for direct procurement by or direct shipment to the U.S. Government, when Level A is specified, preservation, packaging, and packing shall be in accordance with Level A requirement of MIL-STD-163.

14.4 When specified in the contract or order, and for direct procurement by or direct shipment to the U.S. Government, marking for shipment, in addition to requirements specified in the contract or order, shall be in accordance with MIL-STD-129 for U.S. Military agencies and in accordance with Fed. Std. No. 123 for U.S. government civil agencies.

## 15. Keywords

15.1 fencing material; metallic-coated steel wire; steel wire—high tensile; steel wire—zinc-5 % aluminum alloy coated; steel wire—zinc coated; zinc coatings—steel wire products; zinc-5 % aluminum alloy coatings—steel wire products



# Standard Specification for Zinc-5 % Aluminum-Mischmetal Alloy-Coated Steel Wire Strand<sup>1</sup>

This standard is issued under the fixed designation A 855/A 855M; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

## 1. Scope\*

1.1 This specification covers five grades of zinc-5 % aluminum-mischmetal (Zn-5 Al-MM) alloy-coated, steel wire strand, composed of a number of round, steel wires, with four weights of Zn-5 Al-MM alloy coatings, suitable for use as guys, messengers, span wires, and for similar purposes. The product is intended for applications requiring corrosion resistance and formability.

1.2 The five grades covered are as follows:

1.2.1 Utilities,

1.2.2 Common,

1.2.3 Siemens-Martin,

1.2.4 High-strength, and

1.2.5 Extra high-strength,

1.2.6 Minimum breaking strengths of strand for each grade are described in Section 7.

1.3 The four weights of coatings are: Class 1 and Classes A, B, and C. Minimum weights of Zn-5 Al-MM alloy are described in Section 10.

1.4 This specification is applicable to orders in either inch-pound units (as A 855) or acceptable SI units (as A 855M). Inch-pound units and SI units are not necessarily equivalent.

## 2. Referenced Documents

2.1 *ASTM Standards*:<sup>2</sup>

A 90/A 90M Test Method for Weight of Coating on Zinc-Coated (Galvanized) Iron or Steel Articles

A 902 Terminology Relating to Metallic Coated Steel Products

B 750 Specification for Zinc-5 % Aluminum-Mischmetal Alloy (UNS Z 38510) in Ingot Form for Hot-Dip Coatings

<sup>1</sup> This specification is under the jurisdiction of ASTM Committee A05 on Metallic Coated Iron and Steel Products and is the direct responsibility of Subcommittee A05.12 on Wire Specifications.

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<sup>2</sup> For referenced ASTM standards, visit the ASTM website, [www.astm.org](http://www.astm.org), or contact ASTM Customer Service at [service@astm.org](mailto:service@astm.org). For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

E 47 Method for Chemical Analysis of Zinc Die-Casting Alloys

E 1277 Test Method for Chemical Analysis of Zinc-5 % Aluminum-Mischmetal Alloy by ICP Argon Plasma Spectrometric Method

2.2 *Other Standard*:

GF-1 Standard Practice for Determination of Cerium and Lanthanum Compositions in Galfan Alloy (5-Al-0.04 % La-0.04 % Ce-Bal SHG Zn)<sup>3</sup>

## 3. Terminology

3.1 *Definitions*—For definitions of terms used in this specification refer to Terminology A 902.

3.2 *Definitions of Terms Specific to This Standard*:

3.2.1 *strand*—the designation of the finished strand shall be expressed as the nominal diameter of the strand, the number of the wires in the strand and the minimum breaking strength of the strand (see Section 7), and the class of coating (see Section 10).

## 4. Ordering Information

4.1 Orders for material under this specification shall include the following information:

4.1.1 Quantity of strand in feet [metres],

4.1.2 Nominal strand diameter, number of wires, grade, and minimum breaking strength of strand (Section 6 and Table 1),

4.1.3 Weight (class) of Zn-5 Al-MM alloy coating (Section 10 and Table 2), and

4.1.4 Length of strand in coils or on reels (Section 18).

4.1.5 ASTM designation and year of issue as A 855 for inch pound and A 855M for SI units.

## 5. Materials and Manufacture

5.1 *Base Metal*—The base metal shall be steel made by any commercially accepted steel making process and of such quality and purity that, when drawn to the size of wire specified and coated with Zn-5 Al-MM alloy, the finished strand and the

<sup>3</sup> Available from International Lead Zinc Research Organization, 2525 Meridian Parkway, P.O. Box 12036, Research Triangle Park, NC 27709-2036.

\*A Summary of Changes section appears at the end of this standard.



**TABLE 1 Physical Properties of Zn-5 Al-MM Alloy-Coated Steel Wire Strand**

NOTE—The numbers in boldface indicate sizes and grades most commonly used and readily available.

Nominal Diameter of Strand, in. [mm]	Number of Wires in Strand	Nominal Diameter of Coated Wires in Strand, in. [mm]	Approximate Weight of Strand, lb/1000 ft [kg/km]	Minimum Breaking Strength of Strand, lbf [kN]				
				Utilities Grade <sup>A</sup>	Common Grade	Siemens-Martin Grade	High-Strength Grade	Extra High-Strength Grade
1/8 [3.18]	7	0.041 [1.04]	32 [48]	...	<b>540 [2.402]</b>	910 [4.048]	1330 [5.916]	1830 [8.140]
5/32 [3.97]	7	0.052 [1.32]	51 [76]	...	<b>870 [3.870]</b>	1470 [6.539]	2140 [9.519]	2940 [13.078]
3/16 [4.76]	7	0.062 [1.57]	73 [109]	...	<b>1 150 [5.115]</b>	1 900 [8.452]	2 850 [12.677]	3 990 [17.748]
1/4 [6.35]	7	0.065 [1.65]	80 [119]	<b>2400 [10.676] (1)<sup>B</sup></b>	...	...	...	...
5/32 [5.56]	3	0.104 [2.64]	88 [131]	...	1400 [6.228]	2340 [10.409]	3500 [15.569]	4900 [21.796]
3/32 [5.56]	7	0.072 [1.83]	98 [146]	...	1 540 [6.850]	2 560 [11.387]	3 850 [17.126]	5 400 [24.020]
1/4 [6.35]	3	0.120 [3.05]	117 [174]	<b>3150 [14.012] (2)<sup>B</sup></b>	1860 [8.274]	3040 [13.523]	4730 [21.040]	6740 [29.981]
1/4 [6.35]	3	0.120 [3.05]	117 [174]	<b>4500 [20.017] (3)<sup>B</sup></b>	...	...	...	...
1/4 [6.35]	7	0.080 [2.03]	121 [180]	...	<b>1900 [8.452]</b>	<b>3150 [14.012]</b>	4750 [21.129]	6650 [29.581]
9/32 [7.14]	3	0.130 [3.30]	137 [204]	...	2080 [9.252]	3380 [15.035]	5260 [23.398]	7500 [33.362]
9/32 [7.14]	7	0.093 [2.36]	164 [244]	<b>4600 [20.462] (1)<sup>B</sup></b>	2570 [11.432]	4250 [18.905]	6400 [28.469]	8950 [39.812]
5/16 [7.94]	3	0.145 [3.68]	171 [255]	<b>6500 [28.913] (3)<sup>B</sup></b>	2490 [11.076]	4090 [18.193]	6350 [28.246]	9100 [40.479]
5/16 [7.94]	7	0.104 [2.64]	205 [305]	...	<b>3200 [14.234]</b>	5350 [23.798]	<b>8000 [35.586]</b>	11 200 [49.820]
5/16 [7.94]	7	0.109 [2.77]	225 [335]	<b>6000 [26.689] (1)<sup>B</sup></b>	...	...	...	...
3/8 [9.52]	3	0.165 [4.19]	220 [328]	<b>8500 [37.810] (3)<sup>B</sup></b>	3330 [14.813]	5560 [24.732]	8360 [37.187]	11 800 [52.489]
3/8 [9.52]	7	0.120 [3.05]	273 [407]	<b>11 500 [51.155] (4)<sup>B</sup></b>	<b>4250 [18.905]</b>	<b>6950 [30.915]</b>	10 800 [48.040]	15 400 [68.503]
7/16 [11.11]	7	0.145 [3.68]	399 [595]	<b>18 000 [80.068] (4)<sup>B</sup></b>	<b>5700 [25.355]</b>	<b>9350 [41.591]</b>	<b>14 500 [64.499]</b>	20 800 [92.523]
1/2 [12.70]	7	0.165 [4.19]	517 [770]	<b>25 000 [111.206] (4)<sup>B</sup></b>	<b>7400 [32.917]</b>	<b>12 100 [53.823]</b>	<b>18 800 [83.627]</b>	26 900 [119.657]
1/2 [12.70]	19	0.100 [2.54]	504 [751]	...	7620 [33.895]	12 700 [56.492]	19 100 [84.961]	26 700 [118.768]
9/16 [14.29]	7	0.188 [4.78]	671 [1000]	...	9600 [42.703]	15 700 [69.837]	24 500 [108.981]	35 000 [155.688]
9/16 [14.29]	19	0.113 [2.87]	637 [949]	...	9640 [42.881]	16 100 [71.616]	24 100 [107.202]	33 700 [149.905]
5/8 [15.88]	7	0.207 [5.26]	813 [1211]	...	11 600 [51.599]	19 100 [84.961]	29 600 [131.667]	42 400 [188.605]
5/8 [15.88]	19	0.125 [3.18]	796 [1186]	...	11 000 [48.930]	18 100 [80.513]	28 100 [124.995]	40 200 [178.819]
3/4 [19.05]	19	0.150 [3.81]	1155 [1721]	...	16 000 [71.172]	26 200 [116.543]	40 800 [181.487]	58 300 [259.331]
7/8 [22.22]	19	0.177 [4.50]	1581 [2356]	...	21 900 [97.416]	35 900 [159.691]	55 800 [248.211]	79 700 [354.523]
1 [25.40]	19	0.200 [5.08]	2073 [3089]	...	28 700 [127.664]	47 000 [209.066]	73 200 [325.610]	104 500 [464.839]
1 [25.40]	37	0.143 [3.63]	2057 [3065]	...	28 300 [125.885]	46 200 [205.508]	71 900 [319.827]	102 700 [456.832]
1 1/8 [28.58]	37	0.161 [4.09]	2691 [4010]	...	36 000 [160.136]	56 900 [262.000]	91 600 [407.457]	130 800 [581.827]
1 1/4 [31.75]	37	0.179 [4.55]	3248 [4840]	...	44 600 [198.391]	73 000 [324.720]	113 600 [505.318]	162 200 [721.502]

<sup>A</sup> The utilities grade is used principally by communication and power and light industries.

<sup>B</sup> Refer to elongation requirements specified in Section 8.

**TABLE 2 Elongation Requirements for Grades of Strand**

Grade of Strand	Elongation in 24 in. [610 mm], min, %
Utilities Grade (1) <sup>A</sup> and Common Strand	10
Utilities Grade (2) <sup>A</sup> and Siemens-Martin	8
Utilities Grade (3) <sup>A</sup> and High-Strength	5
Utilities Grade (4) <sup>A</sup> and Extra High-Strength	4

<sup>A</sup> See Table 1, Footnote B.

individual wires shall be of uniform quality and have the properties and characteristics as prescribed in this specification.

5.2 *Coating Bath Analysis*—The bath metal used in continuous hot-dip Zn-5 Al-MM alloy-coating shall meet the chemical composition limits specified in Specification B 750.

5.2.1 For a two-step coating operation where the first coating is zinc (hot-dip galvanized or electrogalvanized) the

final bath may have an aluminum content of up to 7.2 %, to prevent depletion of the aluminum content of the bath.

5.2.2 *Method of Analysis*—The determination of chemical composition shall be made in accordance with suitable chemical (see Test Method E 47 for tin) ICP Argon Plasma Spectrometric (see Test Method E 1277) or other methods. In case of dispute, the results secured by Test Method E 1277 shall be the basis of acceptance.

5.2.3 A standard practice of X-ray fluorescence spectrometry for determination of cerium and lanthanum in a zinc-5 % aluminum-mischmetal alloy has been established by the International Lead Zinc Research Organization (see Standard Practice GF-1). In case of dispute, the results secured by Test Method E 1277 shall be the basis of acceptance.

## 6. Stranding

6.1 Unless otherwise specified, strand shall have a left lay. A left lay is defined as a counter-clockwise twist away from the

observer. All wires shall be stranded with uniform tension. Stranding shall be sufficiently close to ensure no appreciable reduction in diameter when stressed to 10 % of the minimum breaking strength.

6.2 The 3-wire strand shall consist of three wires concentrically twisted with a uniform pitch of not less than 14 nor more than 20 times the specified nominal diameter of the strand.

6.3 The 7-wire strand shall consist of a center wire with a 6-wire layer concentrically twisted over it with a uniform pitch of not more than 16 times the specified nominal diameter of the strand.

6.4 The 19-wire strand shall consist of a center wire with a 6-wire layer concentrically twisted over it, having a right lay and a uniform pitch of not more than 16 times the nominal diameter of this 7-wire core. The nominal diameter of this 7-wire core shall be considered to be three times the nominal diameter of the wires. A 12-wire outer layer, having a left lay shall be concentrically twisted over the 7-wire core and shall have a uniform pitch of not more than 16 times the specified nominal diameter of the strand.

6.5 The 37-wire strand shall consist of a center wire with a 6-wire layer concentrically twisted over it having a left lay and a uniform pitch of not more than 16 times the nominal diameter of this 7-wire inner core. The nominal diameter of this 7-wire inner core shall be considered to be three times the nominal diameter of the wire. An intermediate layer of 12 wires having a right lay shall be concentrically twisted over this 7-wire core and shall have a uniform pitch of not more than 16 times the nominal diameter of this 19-wire core. The nominal diameter of this 19-wire core shall be considered as five times the nominal diameter of the wires. An 18-wire outer layer, having a left lay shall be concentrically twisted over the 19-wire core and shall have a uniform pitch of not more than 16 times the specified nominal diameter of the strand.

6.6 All wires in the strand shall lie naturally in their true positions in the completed strand and, when the strand is cut, the ends shall remain in position to be readily replaced by hand and then remain in position. This may be accomplished by any means or process, such as preforming, post forming, or form setting.

## 7. Breaking Strength and Weight

7.1 The approximate weight per unit length of strand and the minimum breaking strength of the finished strand shall be as specified in Table 1.

7.2 A test in which the breaking strength is below the minimum specified and which may have been caused by the slipping of the specimen in the jaws of the testing machine, by breaking within the jaws or within 1 in. [25.4 mm] of the jaws, or by the improper socketing of a specimen shall be disregarded and another sample from the same coil or reel shall be tested. Tests shall be made on lengths of strand that do not contain wire joints or splices.

## 8. Elongation

8.1 The elongation of the strand in 24 in. [610 mm] shall be not less than that specified in Table 3.

**TABLE 3 Nominal Diameters and Minimum Weights of Coating for Zn-5 Al-MM Alloy-Coated Steel Wires<sup>A</sup>**

Nominal Diameter of Coated Wire in the Strand, in. [mm]	Minimum Weight of Coating, oz/ft <sup>2</sup> [g/m <sup>2</sup> ] of Uncoated Wire Surface			
	Class 1 <sup>B</sup>	Class A <sup>C</sup>	Class B <sup>C</sup>	Class C <sup>C</sup>
0.041 [1.04]	0.15 [46]	0.40 [122]	0.80 [244]	1.20 [366]
0.052 [1.32]	0.15 [46]	0.40 [122]	0.80 [244]	1.20 [366]
0.062 [1.57]	0.15 [46]	0.50 [153]	1.00 [305]	1.50 [458]
0.065 [1.65]	0.15 [46]	0.50 [153]	1.00 [305]	1.50 [458]
0.072 [1.83]	0.15 [46]	0.50 [153]	1.00 [305]	1.50 [458]
0.080 [2.03]	0.30 [92]	0.60 [183]	1.20 [366]	1.80 [549]
0.093 [2.36]	0.30 [92]	0.70 [214]	1.40 [427]	2.10 [641]
0.100 [2.54]	0.30 [92]	0.70 [214]	1.40 [427]	2.10 [641]
0.104 [2.64]	0.30 [92]	0.80 [244]	1.60 [488]	2.40 [732]
0.109 [2.77]	0.30 [92]	0.80 [244]	1.60 [488]	2.40 [732]
0.113 [2.87]	0.30 [92]	0.80 [244]	1.60 [488]	2.40 [732]
0.120 [3.05]	0.30 [92]	0.85 [259]	1.70 [519]	2.55 [778]
0.125 [3.18]	0.30 [92]	0.85 [259]	1.70 [519]	2.55 [778]
0.130 [3.30]	0.30 [92]	0.85 [259]	1.70 [519]	2.55 [778]
0.143 [3.63]	0.40 [122]	0.90 [275]	1.80 [549]	2.70 [824]
0.145 [3.68]	0.40 [122]	0.90 [275]	1.80 [549]	2.70 [824]
0.150 [3.81]	0.40 [122]	0.90 [275]	1.80 [549]	2.70 [824]
0.161 [4.09]	0.40 [122]	0.90 [275]	1.80 [549]	2.70 [824]
0.165 [4.19]	0.40 [122]	0.90 [275]	1.80 [549]	2.70 [824]
0.177 [4.50]	0.40 [122]	0.90 [275]	1.80 [549]	2.70 [824]
0.179 [4.55]	0.40 [122]	0.90 [275]	1.80 [549]	2.70 [824]
0.188 [4.78]	0.40 [122]	1.00 [305]	2.00 [610]	3.00 [915]
0.200 [5.08]	0.40 [122]	1.00 [305]	2.00 [610]	3.00 [915]
0.207 [5.26]	0.40 [122]	1.00 [305]	2.00 [610]	3.00 [915]

<sup>A</sup> For intermediate sizes of wire in the strand, the weight designations are the same as for the next finer size shown in this table.

<sup>B</sup> Class 1 coating applies to "common" grade of strand only.

<sup>C</sup> Class A, B, and C coatings apply to all grades of strand.

8.2 The elongation shall be determined as the percent increase in separation between the jaws of the testing machine from the position after application of the initial load to the position at the initial failure in the test specimen. The separation of the jaws of the testing machine shall be approximately 2 ft when under an initial load equal to 10 % of the required minimum breaking strength of the strand. The elongation values shall be recorded only for specimens that break over 1 in. from the jaws of the testing machine. Additional samples shall be taken from the same coil or reel when the previous tests are to be disregarded.

8.3 Elongation tests shall be made on lengths of strand that do not contain wire joints or splices.

## 9. Ductility of Steel

9.1 The Zn-5 Al-MM alloy-coated wire shall not fracture when wrapped at a rate not exceeding 15 turns per minute in a close helix of at least two turns around a cylindrical mandrel. The mandrel diameter for testing Common and Siemens-Martin Grade strand shall be equal to the nominal diameter of the individual wires of the strand. The mandrel diameter for Utilities, High-Strength, and Extra-High Strength Grade strand, shall be equal to three times the nominal diameter of the individual wires of the strand.

## 10. Weight of Coating

10.1 The weight of Zn-5 Al-MM alloy-coating shall be not less than specified in Table 2.

10.2 The weight of the Zn-5 Al-MM coating shall be determined by a stripping test in accordance with Test Method A 90/A 90M.

**11. Adherence of Coating**

11.1 The Zn-5 Al-MM alloy-coated wire shall be capable of being wrapped at a rate not exceeding 15 turns per minute in a close helix of at least two turns around a cylindrical mandrel equal to three times the nominal diameter of the wire under test, without cracking or delaminating, the alloy coating to such an extent that any coating can be removed by rubbing with the bare fingers. Loosening or detachment during the adhesion test of superficial, small particles of the Zn-5 Al-MM alloy-coating formed by mechanical polishing of the surface of the coated wire shall not be considered cause for rejection.

**12. Joints and Splices**

12.1 Electric-welded butt joints made prior to the start of cold drawing of the wire are permitted; however, no electric-welded butt joints shall be made during the cold drawing operation. Electric-welded butt joints of the wire shall be permitted only as specified in 12.2.

12.2 In 3-wire strand, there shall be no joints made in the individual finished wire. In 7-wire strand, joints made in individual finished wires shall be acceptable provided there is not more than one joint in any 150-ft [45.7-m] section of the completed strand and the location of each joint is marked on the strand with paint or some other distinguishing mark. Factory joints made in the individual finished wires of 19 and 37-wire strand shall be kept well spaced and at a minimum in number.

12.3 Joints in the wires composing the strand shall be either the brazed-lap type or electric-butt-welded type. When the brazed type of joint is used, the length of the lap shall be not less than three times the diameter of the wire and the overlapping faces shall be smooth, clean, properly fluxed, and completely covered by the brazing metal. When the electric-welded type of joint is used, care shall be taken to prevent injury to the wire during electric-butt welding. All joints shall be well made and shall be coated with zinc or zinc alloy after completion so that the joints shall have protection from corrosion equivalent to that of zinc alloy-coated wire.

12.4 There shall be no strand joints or strand splices in any length of the completed strand unless specifically permitted by the purchaser.

**13. Permissible Variation in Size**

13.1 The diameter of the Zn-5 Al-MM alloy-coated wire forming the strand specified in Table 1 shall be within the limits prescribed in Table 4.

**14. Workmanship**

14.1 The Zn-5 Al-MM alloy-coated wire shall be free of imperfections not consistent with good commercial practice. The coating shall be continuous and reasonably uniform.

**15. Sampling**

15.1 Sampling for determination of compliance of this specification shall be performed on each lot of material. A lot shall consist of all the strand of one size and one grade in each shipment. The number of samples to be taken shall be as follows:

**TABLE 4 Permissible Variations in Diameter of Individual Zn-5 Al-MM Alloy-Coated Steel Wires**

Nominal Diameter of Coated Wires in the Strand, in. [mm]	Permissible Variations, ±in. [mm]
0.041 to 0.060 [1.04 to 1.52]	0.002 [0.05]
0.061 to 0.090 [1.55 to 2.29]	0.003 [0.08]
0.091 to 0.120 [2.31 to 3.05]	0.004 [0.10]
0.121 and over [3.07 and over]	0.005 [0.13]

<sup>A</sup> It is recognized that the surfaces of heavy coatings, particularly those produced by the hot-dip process, are not perfectly smooth and devoid of irregularities. If the tolerances shown in Table 4 are rigidly applied to such irregularities that are inherent to the product, unjustified rejections of wire that would actually be satisfactory for use could occur. Therefore, it is intended that these tolerances be used in gaging the uniform areas of the coated wire.

	Number of Samples
5000 ft [1524 m] or less	1
Over 5000 to 30 000 ft [1524 to 9144 m]	2
Over 30 000 to 150 000 ft [9144 to 45 720 m]	3
Over 150 000 ft [45 720 m]	4

15.2 Each sample taken shall be subjected to all tests prescribed in Sections 6, 7, and 8.

15.3 In addition to the strand testing in 15.2, the individual wires shall be tested. The number of individual wires to be selected from each sample of strand and tested to determine compliance with Sections 9, 10, 11, and 13 shall be as follows:

15.3.1 *3-Wire Strand*—Three wires.

15.3.2 *7-Wire Strand*—Four wires.

15.3.3 *19-Wire Strand*—Three wires from each layer (total of six wires).

15.3.4 *37-Wire Strand*—Three wires from each layer (total of nine wires).

15.3.5 Individual wire samples selected for compliance to Section 13 shall be discarded if any distortion of the wire occurred during the stranding operation.

15.4 Instead of testing the wires from the complete strand in accordance with 15.3, the producer may elect to establish compliance with Sections 9, 10, 11, and 13 of this specification by tests made on the wires prior to standing, unless otherwise stipulated by the purchaser. However, if the producer makes this election, the purchaser still reserves the right to test wires from the completed strand for compliance.

**16. Inspection**

16.1 The manufacturer shall afford the inspector representing the purchaser all reasonable facilities to satisfy him that the material is being furnished in accordance with this specification. All tests and inspection shall be made at the place of manufacturer prior to shipment, unless otherwise specified, and shall be so conducted as not to interfere unnecessarily with the operation of the works.

**17. Rejection**

17.1 If the wire or strand fails in the first test to meet any requirement of this specification, two additional tests shall be made on samples of wire or strand from the same coil or reel. If failure occurs in either of these tests, the lot of wire or strand shall be rejected.

## 18. Packaging and Marking

18.1 Wire strand shall be furnished in standard lengths (see 18.1.1) and in compact coils or on reels (see 18.1.2) as specified by the purchaser; otherwise, lengths shall be as agreed upon at the time of purchase. Only one length of strand shall be furnished in each coil or on each reel. Lengths of strand may vary between the standard (nominal) length and 10 % over the standard (nominal) length, unless otherwise specified by the purchaser.

18.1.1 Standard lengths of strand are as follows: 250, 500, 1000, 2500, and 5000 ft [76, 152, 305, 760, and 1520 m].

18.1.2 Standard practice is to furnish all strand  $\frac{7}{16}$  in. [11.11 mm] and over in diameter on reels in lengths of 1000 ft [305 m] and over. Strand lengths of less than 1000 ft are regularly furnished in coils.

18.2 Each coil or reel shall have a strong weather-resistant tag securely fastened to it showing the length, nominal diameter, number of wires, grade of the strand, class of coating, ASTM designation A 855 or A 855M, and the name or mark of the manufacturer. If additional information is required on the tag, it shall be so specified at the time of purchase.

## 19. Keywords

19.1 steel-wire strand; wire; zinc-5 % aluminum-mischmetal alloy coated steel wire strand

## SUMMARY OF CHANGES

Committee A05 has identified the location of selected changes to this standard since the last issue (A 855/A 855M - 98) that may impact the use of this standard.

*A 855/A 855M - 03:*

- (1) Renumbered sections to meet Form and Style requirements.
- (2) Editorial changes were made in paragraphs 2.1, 3.2.1, 4.1.3, 7.1, 10.1, 10.2, 11.1, 14.1, 15.4, 18.2, and Table 1.
- (3) Changed Type 1 to Class 1 in paragraph 1.3 and Table 3.
- (4) Added paragraph 4.1.5.
- (5) Changed “base metal” in paragraph 5.1 to “any commer-

cially accepted steel making process.”

- (6) Incorporated Note 1 into paragraph 15.3.5.
- (7) Incorporated Note 2 into paragraph 11.1.
- (8) Changed Section 14 from “Finish” to “Workmanship.”
- (9) Changed “kg/304.8 m” to “kg/km” in Column 4 heading and changed the metric values in Column 4 in Table 1.
- (10) Added Summary of Changes section.

*ASTM International takes no position respecting the validity of any patent rights asserted in connection with any item mentioned in this standard. Users of this standard are expressly advised that determination of the validity of any such patent rights, and the risk of infringement of such rights, are entirely their own responsibility.*

*This standard is subject to revision at any time by the responsible technical committee and must be reviewed every five years and if not revised, either reapproved or withdrawn. Your comments are invited either for revision of this standard or for additional standards and should be addressed to ASTM International Headquarters. Your comments will receive careful consideration at a meeting of the responsible technical committee, which you may attend. If you feel that your comments have not received a fair hearing you should make your views known to the ASTM Committee on Standards, at the address shown below.*

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# Standard Specification for Zinc-5 % Aluminum-Mischmetal Alloy-Coated Carbon Steel Wire<sup>1</sup>

This standard is issued under the fixed designation A 856/A 856M; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

## 1. Scope\*

1.1 This specification covers soft, medium, and hard temper zinc-5 % aluminum-mischmetal (Zn-5 Al-MM) alloy-coated carbon steel wire in coils for general use. The product is intended for applications requiring corrosion resistance, drawability, and formability.

1.2 This specification is applicable to orders in either inch-pound units (as A 856) or acceptable SI units [as A 856M]. Inch-pound units and SI units are not necessarily equivalent; therefore, each system shall be used independently of the other, without combining values in any way.

1.3 This specification references notes and footnotes which provide explanatory material. These notes and footnotes (excluding those in tables and figures) shall not be considered as requirements of this specification.

## 2. Referenced Documents

### 2.1 ASTM Standards:<sup>2</sup>

- A 90/A 90M Test Method for Weight [Mass] of Coating on Iron and Steel Articles with Zinc-Alloy Coatings
- A 700 Practices for Packaging, Marking, and Loading Methods for Steel Products for Domestic Shipment
- A 902 Terminology Relating to Metallic Coated Steel Products
- B 117 Test Method of Salt Spray (Fog) Testing
- B 750 Specification of Zinc-5 % Aluminum-Mischmetal Alloy (UNS Z38510) in Ingot Form for Hot-Dip Coatings
- E 8 Test Methods of Tension Testing of Metallic Materials
- E 29 Practice for Using Significant Digits in Test Data to Determine Conformance with Specification
- E 47 Test Methods for Chemical Analysis of Zinc Die-Casting Alloys
- E 1277 Test Method for Chemical Analysis of Zinc-5 % Aluminum-Mischmetal Alloy by the ICP Argon Plasma

<sup>1</sup> This specification is under the jurisdiction of ASTM Committee A05 on Metallic Coated Iron and Steel Products and is the direct responsibility of Subcommittee A05.12 on Wire Specifications.

Current edition approved October 1, 2003. Published December 2003. Originally approved in 1986. Last previous edition approved in 1998 as A 856/A 856M - 98.

<sup>2</sup> For referenced ASTM standards, visit the ASTM website, [www.astm.org](http://www.astm.org), or contact ASTM Customer Service at [service@astm.org](mailto:service@astm.org). For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

### Spectrometric Method

### 2.2 Military Standards:<sup>3</sup>

- MIL-STD-129 Marking for Shipment and Storage
- MIL-STD-163 Steel Mill Products Preparation

### 2.3 Federal Standards:<sup>3</sup>

- Fed Std. No. 123 Marking for Shipment (Civil Agencies)

### 2.4 Other Standards:<sup>4</sup>

- GF-1 Standard Practice for Determination of Cerium and Lanthanum Compositions in Galfan Alloy (5–Al-0.04 % La-0.04 % Ce-Ba1 SHG Zn)

## 3. Terminology

3.1 *Definitions*—See Terminology A 902 for definitions of general terminology relating to metallic coated steel products.

## 4. Classification

4.1 *Temper*—The wire is classified with regard to mechanical properties by temper, which is related to tensile strength and stiffness. The temper designations are soft, medium, and hard.

4.2 *Coating Classes*—Zn-5AL-MM alloy coating on the wire is classified in a number of classes (1, 3 or A, 60, B, 100, and C) (see Table 1).

## 5. Ordering Information

5.1 Orders for material under this specification shall include the following information:

- 5.1.1 Quantity (weight),
- 5.1.2 Coated wire diameter,
- 5.1.3 Class of coating (see 4.2)
- 5.1.4 Temper (soft, medium, or hard) (see Table 2),
- 5.1.5 Packaging requirements, and
- 5.1.6 ASTM designation and year of issue, as A 856-\_\_\_\_ for inch-pound units or A 856M-\_\_\_\_ for SI units.

NOTE 1—A typical ordering description is as follows: 50 000 lb, 0.120-in. diameter Zn-5 Al-MM alloy-coated wire, Coating Class 60, Soft Temper in 600-lb coils on tubular carriers to ASTM A 856-\_\_\_\_ or [50 000 kg, 3.00-mm diameter Zn-5 Al-MM alloy-coated wire, Coating Class 1,

<sup>3</sup> Available from Standardization Documents Order Desk, Bldg. 4 Section D, 700 Robbins Ave., Philadelphia, PA 19111–5094, Attn: NPODS

<sup>4</sup> Available from International Lead Zinc Research Organization 2525 Meridian Parkway, P.O. Box 12036, Research Triangle Park, NC 27709-2036.

\*A Summary of Changes section appears at the end of this standard.

**TABLE 1 Minimum Weight of Zn-5 AL-MM Alloy Coating per Unit Area of Uncoated Wire Surface, oz/ft<sup>2</sup> [g/m<sup>2</sup>]**

Wire Diameter in. [mm] <sup>A</sup>	Class 1 oz/ft <sup>2</sup> [g/m <sup>2</sup> ]	Class 3 or A Coating, oz/ft <sup>2</sup> [g/m <sup>2</sup> ]	Class 60 Coating, oz/ft <sup>2</sup> [g/m <sup>2</sup> ]	Class B Coating, oz/ft <sup>2</sup> [g/m <sup>2</sup> ]	Class 100 Coating, oz/ft <sup>2</sup> [g/m <sup>2</sup> ]	Class C Coating, oz/ft <sup>2</sup> [g/m <sup>2</sup> ]
0.035 [0.89]	0.15 [46]	0.45 [137]	n/a	0.90 [275]	n/a	1.35 [412]
0.041 [1.04]	0.15 [46]	0.50 [153]	n/a	1.00 [305]	n/a	1.50 [458]
0.048 [1.22]	0.15 [46]	0.55 [168]	n/a	1.10 [335]	n/a	1.65 [503]
0.054 [1.37]	0.20 [61]	0.60 [183]	n/a	1.20 [366]	n/a	1.80 [549]
0.062 [1.57]	0.20 [61]	0.65 [198]	n/a	1.20 [366]	n/a	1.80 [549]
0.072 [1.83]	0.20 [61]	0.65 [198]	n/a	1.20 [366]	n/a	1.80 [549]
0.076 [1.93]	0.25 [76]	0.70 [214]	.60 [183]	1.40 [427]	1.00 [305]	2.10 [641]
0.080 [2.03]	0.25 [76]	0.70 [214]	.60 [183]	1.40 [427]	1.00 [305]	2.10 [641]
0.092 [2.34]	0.28 [85]	0.75 [229]	.60 [183]	1.50 [458]	1.00 [305]	2.25 [686]
0.099 [2.51]	0.28 [85]	0.80 [244]	.60 [183]	1.60 [488]	1.00 [305]	2.40 [732]
0.106 [2.69]	0.30 [92]	0.80 [244]	.60 [183]	1.60 [488]	1.00 [305]	2.40 [732]
0.120 [3.05]	0.30 [92]	0.85 [259]	.60 [183]	1.70 [519]	1.00 [305]	2.55 [778]
0.135 [3.43]	0.30 [92]	0.85 [259]	.60 [183]	1.70 [519]	1.00 [305]	2.55 [778]
0.148 [3.76]	0.35 [107]	0.90 [275]	.60 [183]	1.80 [549]	1.00 [305]	2.70 [824]
0.162 [4.11]	0.35 [107]	0.90 [275]	.60 [183]	1.80 [549]	1.00 [305]	2.70 [824]
0.177 [4.50]	0.44 [134]	0.90 [275]	.60 [183]	1.80 [549]	1.00 [305]	2.70 [824]
0.192 [4.88]	0.50 [153]	1.00 [305]	.60 [183]	2.00 [610]	1.00 [305]	3.00 [915]
0.207 [5.26] and larger	0.53 [162]	1.00 [305]	.60 [183]	2.00 [610]	1.00 [305]	3.00 [915]

<sup>A</sup> Coating weights [mass] for diameters other than those shown in Table 1 are the coating weights [mass] for the next smaller diameter.

**TABLE 2 Tensile Strength for Temper Designation<sup>A</sup>**

Wire Diameter, in. [mm]	Soft, ksi [MPa]	Medium, ksi [MPa]	Hard, ksi [MPa]
0.035 to under 0.080 [0.20 to under 2.00]	75 [515], max	70 to 100 [485 to 690]	90 to 120 [820 to 825]
0.080 to under 0.106 [2.00 to under 2.50]	75 [515], max	70 to 95 [485 to 655]	85 to 115 [585 to 795]
0.106 to 0.176 [2.50 to under 4.70], incl	70 [485], max	65 to 90 [450 to 620]	80 to 110 [550 to 760]
Over 0.176 [4.70]	70 [485], max	60 to 85 [415 to 585]	75 to 105 [515 to 725]

<sup>A</sup>For the purpose of determining conformance with this specification, an observed value shall be rounded to the nearest 1 ksi in accordance with the rounding method of Practice E 29.

Soft Temper in 1000-kg coils on tubular carriers to ASTM A 856M-\_\_\_\_].

## 6. Materials and Manufacture

6.1 The steel from which the wire is produced shall be made by any commercially accepted steelmaking process.

6.2 *Coating Bath Analysis*—The bath metal used in continuous hot-dip Zn-5 Al-MM alloy-coated wire shall meet the chemical composition limits specified in Specification B 750.

6.2.1 For a two-step coating operation where the first coating is zinc (hot-dip galvanizing or electrogalvanizing) the final bath shall be permitted to have an aluminum content of up to 7.2 % to prevent depletion of the aluminum content of the bath.

6.2.2 *Method of Analysis*—The determination of chemical composition shall be made in accordance with suitable chemical (see Test Method E 47 for tin), ICP Argon Plasma Spectrometric (see Test Methods E 1277), or other methods. In case of dispute, the results secured by Text Methods E 1277 shall be the basis of acceptance.

6.2.3 A standard practice for X-ray fluorescence spectrometry for determination of cerium and lanthanum in a zinc-5 % aluminum-mischmetal alloy has been established by the International Lead Zinc Research Organization (Standard Practice GF-1). In case of dispute, the results secured by Test Methods E 1277 shall be the basis of acceptance.

## 7. Mechanical Properties

7.1 The Zn-5 Al-MM alloy coated wire as represented by the test specimens tested in accordance with Test Methods E 8 shall conform to the tensile strength requirements prescribed in Table 2.

7.2 Test specimens found to contain a weld or obvious imperfections shall be discarded and another test specimen obtained to verify conformance to the tensile strength requirements.

## 8. Coating Tests

8.1 *Weight of Coating*—The Zn-5 Al-MM alloy-coated wire when tested in accordance with Test Method A 90/A 90M shall conform to the requirements of Table 1 for minimum weight of coating for the class required.

NOTE 2—A typical ratio of 0.20 oz/ft<sup>2</sup> [61 g/m<sup>2</sup>] equals 200 to 240 h as salt spray test in accordance with Test Method B 117 may be used.

8.2 *Adherence of Coating*—The Zn-5 Al-MM alloy-coated wire as represented by the test specimens shall be capable of being wrapped in a close helix at a rate not exceeding 15 turns/min around a cylindrical steel mandrel having a diameter as prescribed in Table 3 without cracking or delaminating the coating to such an extent that any coating is removed when rubbed with the bare fingers. Loosening or detachment during

**TABLE 3 Mandrel Diameters for Test for Adherence of Zn-5 Al-MM Alloy-Coating**

Wire Diameter, in. [mm]	Mandrel Diameters for Coating Classes	
	Class 1	All Other Classes
0.035 to under 0.076 [0.20 to under 1.90]	1d <sup>A</sup>	2d <sup>A</sup>
0.076 to under 0.148 [1.90 to under 3.70]	1d	3d
0.148 to 0.500, incl [over 3.70]	2d	4d

<sup>A</sup>d = nominal wire diameter being tested.

the adhesion test of superficial, small particles of Zn-5 Al-MM alloy formed by mechanical polishing of the surface of the coated wire shall not be considered cause for rejection.

## 9. Permissible Variations

9.1 The permissible variation in diameter of the Zn-5 Al-MM alloy-coated wire as represented by the test specimens shall meet the requirements shown in Table 4.

## 10. Workmanship, Finish, and Appearance

10.1 The Zn-5 Al-MM alloy-coated wire shall be free of slivers, scale, and other imperfections not consistent with good commercial practice. The coating shall be continuous and reasonably uniform. To ensure large continuous length coils, welds are permitted in the finished wire.

## 11. Number of Tests and Retests

11.1 The number of test specimens taken from the ends of coils during production to ensure compliance with Sections 7, 9, and 8 vary with the quality control procedures and the manufacturing facilities of each manufacturer but is generally not less than 10 % of the coils produced. For the purpose of final product testing, one specimen from every ten coils or fraction thereof in a lot shall be selected at random or a total of seven specimens, whichever is less.

11.2 A wire sample of sufficient length, approximately 4 ft [1.2 m], shall be cut from either end of each coil selected for tests described in Sections 7, 9, and 8.

11.3 If one or more of the wire specimens fail any requirement, the lot shall be subjected to retest. For retest purposes, the original lot shall be regrouped into 50 coil lots or fractions thereof. Each lot shall be 10 % tested for the property in which the original sample failed to comply. The number of samples thus selected shall be at least twice the number of the original sampling. Any lot that exhibits a failure shall be rejected.

**TABLE 4 Diameter Tolerance for Zn-5 Al-MM Alloy-Coated Wire in Coils<sup>A,B</sup>**

Wire Diameter, in. [mm]	Tolerance, Plus and Minus, in. [mm]	
	Class 1	All Other Classes
0.035 to under 0.076 [0.20 to under 1.90]	0.002 [0.05]	0.002 [0.05]
0.076 to 0.500, inclusive [1.90 to 12.7], inclusive	0.003 [0.08]	0.004 [0.10]

<sup>A</sup>For the purpose of determining conformance with this specification, an observed value shall be rounded to the nearest 0.001 in. [0.01 mm] in accordance with the rounding method of Practice E 29.

<sup>B</sup>It is recognized that the surface of heavy alloy coatings, particularly those produced by the hot-dip method, are not perfectly smooth and devoid of irregularities. The tolerances shown in Table 4 shall not be rigidly applied to such irregularities that are inherent to the product so that unjustified rejections of wire that are actually satisfactory for use do not occur. Therefore, it is intended that these tolerances be used in gaging the uniform areas of the Zn-5 Al-MM alloy-coated wire.

11.3.1 The manufacturer has the option of testing each coil in the failed lot for the property in which the failure occurred, rejecting the nonconforming coils. The coils which conform for the property tested shall be accepted.

## 12. Inspection

12.1 Unless otherwise specified in the purchase order or contract, the manufacturer is responsible for the performance of all inspection and test requirements specified in this specification. Except as otherwise specified in the purchase order or contract, the manufacturer shall use his own or any other suitable facilities for the performance of the inspection and test requirements, at his option, unless disapproved by the purchaser at the time the order is placed. The purchaser shall have the right to perform any of the inspections and tests set forth in this specification when such inspections and tests are deemed necessary to ensure that the material conforms to prescribed requirements.

## 13. Rejection and Rehearing

13.1 Material that fails to conform to the requirements of this specification is subject to rejection. Rejection shall be reported to the producer or supplier promptly and in writing. In case of dissatisfaction with the results of the test, the producer or supplier shall make claim for a rehearing.

## 14. Certification

14.1 When specified in the purchase order or contract, a producer's or supplier's certification shall be furnished to the purchaser that the material was manufactured, sampled, tested, and inspected in accordance with this specification and has been found to meet the requirements. When specified in the purchase order or contract, a report of the test results shall be furnished.

## 15. Packaging and Marking

15.1 Unless otherwise specified, packaging, marking, and loading for shipment shall be in accordance with Practices A 700.

15.2 When specified in the contract or order, and for direct procurement by or direct shipment to the U.S. Government, when Level A is specified, preservation, packaging, and packing shall be in accordance with the Level A requirement of MIL-STD-163.

15.3 When specified in the contract or order, and for direct procurement by or direct shipment to the U.S. Government, marking for shipment, in addition to requirements specified in the contract or order, shall be in accordance with MIL-STD-129 for U.S. military agencies and in accordance with Fed. Std. No. 123 for U.S. Government civil agencies.

## 16. Keywords

16.1 steel wire; wire; zinc-5 % aluminum-mischmetal alloy-coated carbon steel wire; zinc-5 % aluminum-mischmetal alloy coated steel wire

**SUMMARY OF CHANGES**

Committee A05 has identified the location of selected changes to this standard since the last issue (A 856/A 856M - 98) that may impact the use of this standard.

*A 856/A 856M - 03:*

- (1) Renumbered sections to meet Form and Style requirements.
- (2) Changed coating classes from “20, 40, 60, 80, 100, 120” to

- “Class 1, 3 or A, 60, B, 100, and C” in 4.2 and Tables 1, 3, 4.
- (3) Editorial changes in 7.2 and 8.2
- (4) Added Summary of Changes section.

*ASTM International takes no position respecting the validity of any patent rights asserted in connection with any item mentioned in this standard. Users of this standard are expressly advised that determination of the validity of any such patent rights, and the risk of infringement of such rights, are entirely their own responsibility.*

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# Standard Practice for Application of Asphalt Coatings to Corrugated Steel Sewer and Drainage Pipe<sup>1</sup>

This standard is issued under the fixed designation A 862/A 862M; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon ( $\epsilon$ ) indicates an editorial change since the last revision or reapproval.

## 1. Scope \*

1.1 This practice covers the post coating of corrugated steel pipe and corrugated structural steel plate with asphalt materials. This practice is intended for shop-applied coating only.

1.2 The values stated in either inch-pound units or SI units shall be regarded separately as standard. The values stated in each system are not exact equivalents; therefore, use each system independently of the other, without combining values in any way. The SI units are shown in brackets in the text for clarity, but they are the applicable values when the application is to be performed using SI units.

1.3 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

## 2. Referenced Documents

### 2.1 ASTM Standards:

A 849 Specification for Post-Applied Coatings, Pavings, and Linings for Corrugated Steel Sewer and Drainage Pipe<sup>2</sup>

## 3. Significance and Use

3.1 Asphalt coating is used to provide additional protection for corrugated steel products (product) in corrosive or abrasive environments, or both.

## 4. Classification

4.1 This practice covers three separate and distinct classifications of coatings. The general conditions under which these coatings are used are described in Specification A 849.

4.1.1 *Classification A, Asphalt Coated*—A uniform coating is applied to the interior and exterior of the product.

### 4.1.2 *Asphalt Coated with Paved Invert:*

4.1.2.1 *Classification B1, Asphalt, Half Coated with Paved Invert*—A uniform coating is applied to the interior and exterior of the pipe covering at least 50 % of the circumference

on the lower portion of the pipe as installed, and then a paving is applied on the lower portion of the interior of the pipe as installed (the invert) to provide a smooth flow line.

4.1.2.2 *Classification B2, Asphalt, Fully Coated with Paved Invert*—A uniform coating is applied to the interior and exterior of the pipe, and then a paving is applied on the lower portion of the interior of the pipe as installed (the invert) to provide a smooth flow line.

4.1.3 *Classification C, Asphalt Coated and Lined*—A uniform coating is applied to the interior and exterior of the pipe, and then a lining is applied to fill the corrugations on the full interior of the pipe to provide a smooth interior.

NOTE 1—This coating is sometimes referred to as any of the following: asphalt coated and lined, asphalt coated and fully paved, asphalt coated and 100 % paved, or asphalt coated smooth flow. The term “bituminous” is sometimes used instead of asphalt.

## 5. Materials

5.1 The coating and lining material shall be in conformance with the requirements for asphalt material in Specification A 849.

## 6. Tank Control and Maintenance

6.1 *Tank Temperature*—The asphalt temperature in the tank shall be maintained between 392 and 410°F [200 and 210°C] during the coating operation.

### 6.2 *Tank Cleanliness:*

6.2.1 The asphalt in the tank shall be kept free of contaminants such as dirt, drum paper, and asphalt drippings from the shop floor.

6.2.2 The asphalt tank shall be cleaned as necessary with a minimum frequency of once per year.

6.2.3 The foam that results from the inadvertent introduction of moisture to the tank shall be skimmed off or moved to the side of the tank before inserting or extracting the product.

## 7. Procedure

7.1 *Coating Application*—Apply the asphalt coating by inserting the product into the bath twice; the first application results in a thin coating to achieve very good adherence, and the second achieves the coating thickness required by Specification A 849.

7.1.1 Steel surfaces shall be free of dirt, grease, dust, and moisture before placement in the asphalt bath. The product

<sup>1</sup> This practice is under the jurisdiction of ASTM Committee A-5 on Metallic Coated Iron and Steel Products and is the direct responsibility of Subcommittee A05.17 on Corrugated Steel Pipe Specifications.

Current edition approved Nov. 10, 1998. Published March 1999. Originally published as A 862 – 86. Last previous edition A 862 – 93.

<sup>2</sup> *Annual Book of ASTM Standards*, Vol 01.06.

shall be prepared immediately prior to the coating operation.

7.1.2 Rotate large structures in the tank to ensure that all surfaces are coated.

7.1.3 The product must remain in the tank until it achieves a minimum temperature of 375°F [190°C]. The specific time requirements will depend on factors unique to each operation and the product being coated. The time to reach the required temperature is dependent on the initial temperature of the product, the steel thickness, the size of the product, and the volume of the tank.

7.1.4 The following table contains minimum immersion times:

Steel Thickness, in. [mm]	Time, min
0.052 [1.32]	2 to 2.5
0.064 [1.63]	2.5 to 3
0.079 [2.01]	3.5 to 5
0.109 [2.77]	5 to 6
0.138 [3.50]	6.5 to 8
0.168 [4.27]	8 to 14

7.1.5 Cool the product to ambient temperature before application of the second coating.

7.1.6 Insert the product a second time to provide the minimum thickness on each surface.

#### 7.2 Paving:

7.2.1 Pave the interior of the coated pipe by applying the hot asphalt from the tank to the interior surface of the pipe to provide a thickness over the crest of the corrugation as required by Specification A 849. Pump the hot asphalt to the pipe by appropriate mechanical means, not by transfer with buckets. The asphalt used for paving shall be a least 395°F [200°C] to ensure good adhesion to the coated pipe. Pave the pipe as soon as possible after coating to avoid poor adhesion associated with the accumulation of dirt and other residue on the coating surface.

NOTE 2—Steam, hot oil jacketing, or high-temperature electric tape is recommended to keep the asphalt system free flowing. For further information on the selection of application equipment, consult a producer of asphalt products.

7.2.2 Place end dams of wood or heavy paper at the ends of the pipe to retain the asphalt in the pipe. Three or more applications are usually required for most operations.

#### 7.3 Smooth Lining:

7.3.1 Line the interior of the pipe that has been coated by covering the corrugations with hot asphalt. Provide a thickness over the crest of the corrugations as required by Specification A 849.

7.3.2 Spray the hot asphalt, taken from the tank, while rotating the pipe on a powered rotary device to provide a uniform smooth lining.

#### 7.4 Storage and Handling:

7.4.1 Store and handle the coated product properly to avoid bruising, scaling, or scuffing of the asphalt coating. At the fabricator's option, spray inorganic materials such as lime (whitewash), chalk, or silica dust on the exterior asphalt surfaces after cooling to prevent removal of the tacky coating when sections of pipe are stored in contact with each other. These inorganic coatings also help to lower the surface temperature of the pipe during storage.

7.4.2 Install and backfill asphalt-coated corrugated steel product as soon as possible to avoid the damage due to infrared radiation. Infrared radiation volatilizes the thin oils in the asphalt which dries the coating and promotes cracking. Product installed in situations where prolonged exposure to the sun's rays is unavoidable (that is, aerial sewer), and cracking of the asphalt coating is possible, shall be coated with supplemental coatings such as aluminum-rich paints.

7.5 Repair—Repair damaged coatings with a cold-applied asphalt mastic material described in Specification A 849.

## 8. Keywords

8.1 asphalt coated steel pipe; asphalt coating; asphalt coating repair; coating application; corrugated steel pipe; paved invert; protective coatings; smooth lined

## SUMMARY OF CHANGES

This section identifies the principal changes to this standard that have been incorporated since the last issue.

(1) General revisions have been made to the text to better organize it and to clarify meanings.

(2) Coating classifications describe the application of the coating rather than the use of the product.

(3) General conditions under which the coatings can be used are described in Specification A 849.

(4) The coating classification "Asphalt Coated with Paved Invert" has been split into two subclassifications.


(5) The term "bituminous" has been replaced by the term "asphalt" in all cases, since there are some bituminous materials that are carcinogenic and the actual material used is asphalt.

(6) The term "product" has been used as the general descriptor for the material being coated. This was done to differentiate between cases where only pipe is the product being coated and where corrugated structural plate can be coated.

(7) A section describing "General Requirements" has been removed, since the items listed were detailed in the subsequent paragraphs.

(8) The keywords paragraph has been significantly revised.

(9) A Summary of Changes has been added.

 **A 862/A 862M**

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Designation: A 875/A 875M – 02a

## Standard Specification for Steel Sheet, Zinc-5 % Aluminum Alloy-Coated by the Hot-Dip Process<sup>1</sup>

This standard is issued under the fixed designation A 875/A 875M; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon ( $\epsilon$ ) indicates an editorial change since the last revision or reapproval.

<sup>1</sup> This specification is under the jurisdiction of ASTM Committee A05 on Metallic-Coated Iron and Steel Products and is the direct responsibility of Subcommittee A05.11 on Sheet Specifications.

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### 1. Scope

1.1 This specification covers steel sheet, in coils and cut lengths, metallic-coated by the hot-dip process, with zinc-5 % aluminum alloy coating. The Zn-5Al alloy coating also contains small amounts of elements other than zinc and aluminum that are intended to improve processing and the characteristics of the coated product.

1.2 The coating is produced as two types: zinc-5 % aluminum-mischmetal alloy (Type I) and zinc-5 % aluminum-0.1 % magnesium alloy (Type II), and in two coating structures (classes). The coated sheet is produced in several coating designations (coating weight [mass]).

1.3 The material is intended for applications requiring corrosion resistance, formability, and paintability.

1.4 The steel sheet is produced in a number of designations, types, grades, and classes designed to be compatible with differing application requirements.

1.5 Coated sheet material furnished under this specification shall conform to the applicable requirements of the latest issue of Specification A 924/A 924M, unless otherwise provided herein.

1.6 This specification is applicable to orders in either inch-pound units (as A 875) or metric (SI) units [as A 875M]. Values in inch-pound and SI units are to be regarded separately as standard. Within the text, the SI units are shown in brackets. The values stated in each system are not exact equivalents. Therefore, each system shall be used independently of the other.

1.7 Unless the order specifies the “M” specification designation (SI units), the material shall be furnished to inch-pound units.

1.8 The text of this specification references notes and footnotes that provide explanatory material. These notes and footnotes, excluding tables and figures, shall not be considered as requirements of this specification.

1.9 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

### 2. Referenced Documents

#### 2.1 ASTM Standards:

A 90/A 90M Test Method for Weight [Mass] of Coating on Iron and Steel Articles with Zinc or Zinc-Alloy Coatings<sup>2</sup>

A 902 Terminology Relating to Metallic Coated Steel Products<sup>2</sup>

A 924/A 924M Specification for General Requirements for Steel Sheet, Metallic-Coated by the Hot-Dip Process<sup>2</sup>

B 750 Specification for Zinc-5 % Aluminum-Mischmetal Alloy (UNS Z38510) in Ingot Form for Hot-Dip Coatings<sup>3</sup>

E 47 Test Methods for Chemical Analysis of Zinc Die-Casting Alloys<sup>4</sup>

E 517 Test Method for Plastic Strain Ratio<sup>5</sup>

E 646 Test Method for Tensile Strain-Hardening Exponents (n-Values) of Metallic Sheet Materials<sup>5</sup>

E 1277 Test Method for Chemical Analysis of Zinc-5 Aluminum-Mischmetal Alloys by ICP Emission Spectrometry<sup>6</sup>

#### 2.2 ISO Standard:

<sup>2</sup> Annual Book of ASTM Standards, Vol 01.06.

<sup>3</sup> Annual Book of ASTM Standards, Vol 02.04.

<sup>4</sup> Discontinued 1997; see Annual Book of ASTM Standards, Vol 03.05.

<sup>5</sup> Annual Book of ASTM Standards, Vol 03.01.

<sup>6</sup> Annual Book of ASTM Standards, Vol 03.06.

ISO 14788 Continuous Hot-Dip Zinc-5 % Aluminum Alloy Coated Steel Sheet and Coils<sup>7</sup>

2.3 Other Document:

GF-1 Standard Practice for Determination of Cerium and Lanthanum Compositions in Galfan Alloy (5 % Al-0.4 % La-0.4 % Ce-Bal SHG ZN)<sup>8</sup>

### 3. Terminology

3.1 *Definitions*—See Terminology A 902 for definitions of general terminology relating to metallic-coated steel products.

3.2 *Definitions of Terms Specific to This Standard:*

3.2.1 *minimized coating structure, n*—a coating characterized by a finer metallurgical coating structure obtained by a treatment designed to restrict the formation of the normal coarse grain structure formed during solidification of the Zn-5Al alloy coating.

3.2.2 *regular coating structure, n*—the normal coating structure resulting from unrestricted grain growth during normal solidification of the Zn-5Al alloy coating.

3.3 *Abbreviations:*

3.3.1 *MM*—mischmetal.

3.3.2 *Zn-5Al*—zinc-5 % aluminum.

3.3.3 *Zn-5Al-MM*—zinc-5 % aluminum-mischmetal.

3.3.4 *Zn-5Al-Mg*—zinc-5 % aluminum-0.1 % magnesium.

### 4. Classification

4.1 The material is classified in terms of the base metal and in terms of the coating.

4.2 *Base Metal Classifications:*

4.2.1 The material is available in the designations as follows:

4.2.1.1 Commercial Steel (CS Types A, B, and C),

4.2.1.2 Forming Steel (FS Types A and B),

4.2.1.3 Deep Drawing Steel (DDS),

4.2.1.4 Extra Deep Drawing Steel (EDDS),

4.2.1.5 Structural Steel (SS),

4.2.1.6 High Strength-Low Alloy Steel (HSLAS Type A), and

4.2.1.7 High Strength-Low Alloy Steel (HSLAS Type B).

4.2.2 Structural Steel and High Strength Low Alloy Steel are available in several grades based on mechanical properties. Structural Steel Grade 50 [340] is available in three classes based on tensile strength.

4.3 *Coating Classifications:*

4.3.1 The coating is available in two types, as follows:

4.3.1.1 *Type I*—Zinc-5 % aluminum-mischmetal (Zn-5Al-MM), and

4.3.1.2 *Type II*—Zinc-5 % aluminum-0.1 % magnesium (Zn-5Al-Mg).

4.3.2 The coating is available in two coating classes, or structures, as follows:

4.3.2.1 *Class A*—Minimized coating structure, and

4.3.2.2 *Class B*—Regular coating structure.

4.3.3 The coating is available in several coating designations, or weights [masses] of coating, as shown in Table 1.

4.3.3.1 The coated sheet is available with the same or different coating designations on each surface.

### 5. Ordering Information

5.1 Zinc-5 % aluminum alloy-coated sheet in coils and cut lengths is produced to thickness requirements expressed to 0.001 in. [0.01 mm]. The thickness of the sheet includes both the base metal and the coating.

5.2 Orders for coated sheet to this specification shall include the following information, as necessary, to adequately describe the desired product.

5.2.1 Name of material (steel sheet, Zn-5Al alloy coated),

5.2.2 Designations of sheet steel [CS (Type A, B, or C), FS (Type A or B), DDS, EDDS, SS, or HSLA (Type A or B)].

5.2.2.1 When a CS Type is not specified, Type B will be furnished.

5.2.2.2 When a F5 type is not specified, F5 Type B will be furnished.

5.2.3 Structural or High Strength-Low Alloy Steel designation and, as required, type, grade, or class, or combination thereof.

5.2.4 ASTM designation number and year of issue, as A 875—\_\_\_\_ for inch-pound units or A 875M—\_\_\_\_ for SI units,

5.2.5 Coating type (I or II) (see 4.3.1),

5.2.6 Coating designation (see 4.3.3),

<sup>7</sup> Available from International Lead Zinc Research Organization, Inc., 2525 Meridian Parkway, P.O. Box 12036, Research Triangle Park, NC 27709-2036. American National Standards Institute (ANSI), 25 W. 43rd St., 4th Floor, New York, NY 10036.

<sup>8</sup> Available from International Lead Zinc Research Organization, Inc., 2525 Meridian Parkway, P.O. Box 12036, Research Triangle Park, NC 27709-2036.

**TABLE 1 Weight [Mass] of Coating Requirements<sup>A, B, C</sup>**

NOTE 1—The coating thickness may be estimated from the coating weight [mass] by using Table .

Coating Designation	Minimum Requirements <sup>D</sup>		
	Triple-Spot Test		Single-Spot Test
	Inch-Pound Units		
	Total Both Sides, oz/ft <sup>2</sup>	One Side, oz/ft <sup>2</sup>	Total Both Sides, oz/ft <sup>2</sup>
GF235	2.35	0.80	2.00
GF210	2.10	0.72	1.80
GF185	1.85	0.64	1.60
GF165	1.65	0.56	1.40
GF140	1.40	0.48	1.20
GF115	1.15	0.40	1.00
GF90	0.90	0.32	0.80
GF75	0.75	0.26	0.65
GF60	0.60	0.20	0.50
GF45	0.45	0.14	0.35
GF30	0.30	0.10	0.25
GF01	no minimum	no minimum	no minimum
SI Units			
	Total Both Sides, g/m <sup>2</sup>	One Side, g/m <sup>2</sup>	Total Both Sides, g/m <sup>2</sup>
ZGF700	700	238	595
ZGF600	600	204	510
ZGF450	450	154	385
ZGF350	350	120	300
ZGF275	275	94	235
ZGF225	225	78	195
ZGF180	180	60	150
ZGF135	135	45	113
ZGF90	90	30	75
ZGF001	no minimum	no minimum	no minimum

<sup>A</sup> The coating designation number is the term by which this material is specified. Because of the many variables and changing conditions that are characteristic of continuous hot-dip coating lines, the zinc-5 % aluminum alloy coating is not always evenly divided between the two surfaces of a coated sheet; nor is it always evenly distributed from edge to edge. However, the minimum triple- spot average coating [mass] on any one side shall not be less than 40 % of the single-spot requirement.

<sup>B</sup> As it is an established fact that the atmospheric corrosion resistance of zinc-5 % aluminum alloy-coated sheet products is a function of coating thickness (weight [mass]), the selection of thinner (lighter) coating designations will result in reduced corrosion performance of the Zn-5Al coating. For example, the heavier zinc-5 % aluminum alloy coatings perform adequately in bold atmospheric exposure whereas the lighter coatings are often further coated with paint or a similar barrier coating for increased corrosion resistance. Because of this relationship, material carrying the statement “meets ASTM A 875/A 875M requirements” should also specify the particular coating type and designation.

<sup>C</sup> The corrosion performance of Type I Zn-5Al-MM coated sheet products is nonlinear as the corrosion rate decreases with time, due to the formation of a characteristic passivation layer.

<sup>D</sup> No minimum value means that there are no established minimum requirements for triple- and single-spot tests.

- 5.2.7 Class of coating structure (for example, Class A—Minimized, etc.) (see 4.3.2),
- 5.2.8 Chemically treated or not chemically treated,
- 5.2.9 Oiled or not oiled,
- 5.2.10 Extra smooth (if required),
- 5.2.11 Phosphatized (if required),
- 5.2.12 Dimensions (show thickness, width, flatness requirements and length, if cut lengths). The purchaser shall specify the appropriate table of thickness tolerances in Specification A 924/A 924M that applies to the order, that is, the table of thickness tolerances for 3/8-in. [10-mm] edge distance, or the table of thickness tolerances for 1-in. [25-mm] edge distance.
- 5.2.13 Coil size requirements (specify maximum outside diameter (OD), acceptable inside diameter (ID), and maximum weight [mass]),
- 5.2.14 Packaging,
- 5.2.15 Certification, if required, and heat analysis and mechanical property report,
- 5.2.16 Application (part identification and description), and
- 5.2.17 Special requirements (if any).

NOTE 1—Typical ordering descriptions are as follows:

Steel sheet, Zn-5Al alloy coated to ASTM A 875-\_\_\_\_, Commercial Steel—CS Type B, Type I coating, designation GF 115, Class A (minimized coating structure), chemically treated, oiled, 0.040 min by 34 by 117 in., for stock tanks.

Steel sheet, Zn-5Al alloy coated to ASTM A 875M-\_\_\_\_, Structural Steel—SS Grade 230, Type II coating, designation ZGF 275, Class B (regular coating structure), chemically treated, not oiled, phosphatized, 1.00 nominal by 900 mm by coil, 1200 mm max OD, 600 mm ID, 9000 kg max, for roof deck.

NOTE 2—The purchaser should be aware that there are variations in manufacturing practices among the producers and therefore is advised to establish the producer’s standard (or default) procedures for thickness tolerances.

## 6. Chemical Composition

### 6.1 Base Metal:

6.1.1 The heat analysis of the base metal shall conform to the requirements shown in Table 2 for CS (Types A, B, and C), FS (Types A and B), DDS, and EDDS and Table 3 for SS and HSLAS (Types A and B).

6.1.2 Each of the elements listed in Tables 2 and 3 shall be included in the report of heat analysis. When the amount of copper, nickel, chromium, or molybdenum is less than 0.02 %, report the analysis either as <0.02 % or the actual determined value. When the amount of vanadium, titanium, or columbium is less than 0.008 %, report the analysis either as <0.008 % or the actual determined value.

6.1.3 See Specification A 924/A 924M for cast and product analysis procedures.

### 6.2 Coating Bath Analysis:

6.2.1 The bath metal used in continuous hot-dip Zn-5Al-MM alloy coating of Type I shall meet the chemical composition limits specified in Specification B 750.

6.2.2 The bath metal used in the continuous hot-dip Zn-5Al-Mg alloy coating of Type II shall conform to the requirements of Table 4.

### 6.3 Methods of Analysis:

6.3.1 *Coating Bath Metal*—The determination of chemical composition shall be made in accordance with suitable chemical (Test Method E 47 for tin), ICP argon plasma spectrometric (Test Method E 1277), or other methods. In case of dispute, the results secured by Test Method E 1277 shall be the basis of acceptance.

6.3.1.1 A practice for X-ray fluorescence spectrometry for the determination of cerium and lanthanum in a zinc-5 % aluminum-mischmetal has been established by the International Lead Zinc Research Organization, as Practice GF-1.

6.3.2 In case of dispute, the results secured by Test Method E 1277 shall be the basis of acceptance.

## 7. Mechanical Properties

7.1 Structural steel and high-strength low-alloy steel shall conform to the mechanical property requirements of Table 5 for the type, grade or class, or combination thereof, specified.

7.2 The typical mechanical properties for CS (Types A, B, and C), FS (Types A and B), DDS, and EDDS steel sheet designations are listed in Table 6. These mechanical property values are nonmandatory. They are solely to provide the purchaser with as much information as possible to make an informed decision on the steel to be specified. Values outside these ranges are to be expected.

7.3 When base metal mechanical properties are required, all tests shall be conducted in accordance with the methods specified in Specification A 924/A 924M.

**TABLE 2 Chemical Requirements<sup>A</sup>**

Designation	Composition, %—Heat Analysis Element, Maximum, Unless Otherwise Shown												
	C	Mn	P	S	Al	Cu	Ni	Cr	Mo	V	Cb	Ti <sup>B</sup>	N
CS Type A <sup>C,D,E</sup>	0.10	0.60	0.030	0.035	...	0.20	0.20	0.15	0.06	0.008	0.008	0.025	...
CS Type B <sup>F,C</sup>	0.02 to 0.15	0.60	0.030	0.035	...	0.20	0.20	0.15	0.06	0.008	0.008	0.025	...
CS Type C <sup>C,D,E</sup>	0.08	0.60	0.10	0.035	...	0.20	0.20	0.15	0.06	0.008	0.008	0.025	...
FS Type A <sup>C,G</sup>	0.10	0.50	0.020	0.035	...	0.20	0.20	0.15	0.06	0.008	0.008	0.025	...
FS Type B <sup>F,C</sup>	0.02 to 0.10	0.50	0.020	0.030	...	0.20	0.20	0.15	0.06	0.008	0.008	0.025	...
DDS <sup>D,E</sup>	0.06	0.50	0.020	0.025	0.01 min.	0.20	0.20	0.15	0.06	0.008	0.008	0.025	...
EDDS <sup>H</sup>	0.02	0.40	0.020	0.020	0.01 min	0.20	0.20	0.15	0.06	0.10	0.10	0.15	...

<sup>A</sup>Where an ellipsis (. . .) appears in this table, there is no requirement, but the analysis shall be reported.

<sup>B</sup>For steels containing more than 0.2% carbon, titanium is permitted to 0.025% provided the ratio of % titanium to % nitrogen does not exceed 3.4.

<sup>C</sup>When a deoxidized steel is required for the application, the purchaser has the option to order CS and FS to a minimum of 0.01 % total aluminum.

<sup>D</sup>Steel is permitted to be furnished as a vacuum degassed or chemically stabilized steel, or both, at the producer’s option.

<sup>E</sup>For carbon levels less than or equal to 0.02%, vanadium, columbium, or titanium, or combinations thereof are permitted to be used as stabilizing elements at the producer’s option. In such cases, the applicable limit for vanadium and columbium shall be 0.10% and for titanium 0.15%.

<sup>F</sup>For CS and FS, specify Type B to avoid carbon levels below 0.02 %.

<sup>G</sup>Shall not be furnished as a stabilized steel.

<sup>H</sup>Shall be furnished as a stabilized steel.

**TABLE 3 Chemical Requirements<sup>A</sup>**

Designation	Composition, %—Heat Analysis Element, maximum, Unless Otherwise Shown											
	C	Mn	P	S	Cu	Ni	Cr	Mo	V	Cb	Ti <sup>B</sup>	N
<b>SS:</b>												
Grade 33 [230]	0.20	...	0.04	0.04	0.20	0.20	0.15	0.06	0.008	0.008	0.025	...
Grade 37 [255]	0.20	...	0.10	0.04	0.20	0.20	0.15	0.06	0.008	0.008	0.025	...
Grade 50 [340] (Class 1 and 2)	0.25	...	0.20	0.04	0.20	0.20	0.15	0.06	0.008	0.008	0.025	...
Grade 50 [340] (Class 3)	0.25	...	0.04	0.04	0.20	0.20	0.15	0.06	0.008	0.008	0.025	...
Grade 80 [550]	0.20	...	0.04	0.04	0.20	0.20	0.15	0.06	0.008	0.008	0.025	...
<b>HSLAS Type A<sup>C</sup></b>												
Grade 50 [340]	0.20	1.20	...	0.035	0.20	0.20	0.15	0.16	0.01 min	0.005 min	0.01 min	...
Grade 60 [410]	0.20	1.35	...	0.035	0.20	0.20	0.15	0.16	0.01 min	0.005 min	0.01 min	...
Grade 70 [480]	0.20	1.65	...	0.035	0.20	0.20	0.15	0.16	0.01 min	0.005 min	0.01 min	...
Grade 80 [550]	0.20	1.65	...	0.035	0.20	0.20	0.15	0.16	0.01 min	0.005 min	0.01 min	...
<b>HSLAS Type B<sup>C,D</sup></b>												
Grade 50 [340]	0.15	1.20	...	0.035	0.20	0.20	0.15	0.16	0.01 min	0.005 min	0.01 min	...
Grade 60 [410]	0.15	1.20	...	0.035	0.20	0.20	0.15	0.16	0.01 min	0.005 min	0.01 min	...
Grade 70 [480]	0.15	1.65	...	0.035	0.20	0.20	0.15	0.16	0.01 min	0.005 min	0.01 min	...
Grade 80 [550]	0.15	1.65	...	0.035	0.20	0.20	0.15	0.16	0.01 min	0.005 min	0.01 min	...

<sup>A</sup>Where an ellipsis (. . .) appears in this table, there is no requirement, but the analysis shall be reported.

<sup>B</sup>Titanium is permitted to 0.025 % provided the ratio of % titanium to % nitrogen does not exceed 3.4.

<sup>C</sup>HSLAS and HSLAS-F steels commonly contain the strengthening elements columbium, vanadium, and titanium added singly or in combination. The minimum requirements only apply to the microalloy elements selected for strengthening of the steel.

<sup>D</sup>The producer has the option to treat HSLAS Type B steels by means of small alloy additions to effect sulfide inclusion control.

**TABLE 4 Chemical Requirements, Coating Bath, Type II<sup>A</sup>**

Element	Composition, weight %
Aluminum	4.5–6.2
Magnesium	0.06–0.15
Others, total, max <sup>B</sup>	0.01
Zinc <sup>C</sup>	remainder <sup>C</sup>

<sup>A</sup> By agreement between the purchaser and the supplier, analysis may be required and limits established for elements not specified in Table 4.

<sup>B</sup> Except iron.

<sup>C</sup> For information only. Quantitative determination of the element is not required.

## 7.4 Bending Properties:

7.4.1 *Minimum Cold-Bending Radii*—Structural steel and high-strength, low-alloy steel, low-alloy sheet steels are commonly fabricated by cold bending. There are many interrelated factors that affect the ability of a steel to cold form over a given radius under shop conditions. These factors include: thickness, strength level, degree of restraint, relationship to rolling direction, chemistry, and microstructure. Appendix X1 lists the suggested minimum inside radius for 90° cold bending for structural steel and high-strength, low-alloy steel. They presuppose “hard way” bending (bend axis parallel to rolling direction) and reasonably good shop forming practices. Where possible, the use of larger radii or “easy way” bends are recommended for improved performance.

7.4.2 Fabricators should be aware that cracks may initiate upon bending a sheared edge. This is not considered to be a fault of the steel but is rather a function of the induced cold-work.

## 8. Coating Properties

### 8.1 Coating Weight [Mass]

8.1.1 Coating weight [mass] shall conform to the requirements as shown in Table 1 for the specific coating designation.

8.1.2 Use the following relationships to estimate the coating thickness from the coating weight [mass].

8.1.2.1 1 oz/ft<sup>2</sup> coating weight = 1.82 mils coating thickness, and

8.1.2.2 6.60 g/m<sup>2</sup> coating weight = 1 μm coating thickness.

### 8.2 Coating Weight [Mass] Tests:

8.2.1 Coating weight [mass] tests shall be performed in accordance with the requirements stated in Specification A 924/A 924M.

8.2.2 The referee method to be used shall be Test Method A 90/A 90M.

8.3 *Coating Bend Test*—The bend test specimens of coated sheet designated by the prefix GF [ZGF] shall be capable of being bent through 180° in any direction without flaking of the coating on the outside of the bend only. The coating bend test inside diameter shall have a relation to the thickness of the specimen as shown in Table 7. Flaking of the coating within 0.25 in. [6 mm] of the edge of the bend specimen shall not be cause for rejection.

## 9. Dimensions and Permissible Variations

9.1 All dimensions and permissible variations shall comply with the requirements of Specification A 924/A 924M.



**TABLE 5 Mechanical Requirements, Base Metal (Longitudinal)**
**Inch-Pound Units**

Designation	Type	Grade	Yield Strength, min, ksi	Tensile Strength, min, psi <sup>A</sup>	Elongation in 2 in., min, % <sup>A</sup>
SS	<i>B</i>	33	33	45	20
		37	37	52	18
		40	40	55	16
		50 (Class 1)	50	65	12
		50 (Class 2)	50	...	12
		50 (Class 3)	50	70	12
HSLAS	<i>D</i>	80 <sup>A</sup>	80 <sup>C</sup>	82	...
		50	50	60 <sup>E</sup>	20
		60	60	70 <sup>E</sup>	16
		70	70	80 <sup>E</sup>	12
HSLAS	<i>C</i>	80	80	90 <sup>E</sup>	10
		50	50	60 <sup>E</sup>	22
		60	60	70 <sup>E</sup>	18
		70	70	80 <sup>E</sup>	14
		80	80	90 <sup>E</sup>	12

**SI Units**

Designation	Type	Grade	Yield Strength, min, MPa	Tensile Strength, min, MPa <sup>A</sup>	Elongation in 50 mm, min, % <sup>A</sup>
SS	<i>E</i>	230	230	310	20
		255	255	360	18
		275	275	380	16
		340 (Class 1)	340	450	12
		340 (Class 2)	340	...	12
		340 (Class 3)	340	480	12
HSLAS	<i>D</i>	550 <sup>D</sup>	550 <sup>C</sup>	570	...
		340	340	410 <sup>E</sup>	20
		410	410	480 <sup>E</sup>	16
		480	480	550 <sup>E</sup>	12
HSLAS	<i>C</i>	550	550	620 <sup>E</sup>	10
		340	340	410 <sup>E</sup>	22
		410	410	480 <sup>E</sup>	18
		480	480	550 <sup>E</sup>	14
		550	550	620 <sup>E</sup>	12

<sup>A</sup> Where an ellipsis ( . . . ) appears in this table, there is no requirement.

<sup>B</sup> No type has been established for Structural Steel (SS).

<sup>C</sup> As there is no discontinuous yield curve, the yield point should be taken as the stress at 0.5 % elongation under load or 0.2 % offset.

<sup>D</sup> For sheet thicknesses of 0.028 in. and thinner, no tension test is required if the hardness result is Rockwell B 85 or higher.

<sup>E</sup> If a higher tensile strength is required, the user should consult the producer.

**TABLE 6 Typical Ranges of Mechanical Properties (Nonmandatory) (Longitudinal Direction)<sup>A, B</sup>**

Designation	Yield Strength		Elongation in 2 in. [50 mm], %	<i>r<sub>m</sub></i> Value <sup>C</sup>	<i>n</i> Value <sup>D</sup>
	ksi	[MPa]			
CS Type A	25/50	[170/345]	≥20	<i>E</i>	<i>E</i>
CS Type B	30/50	[205/345]	≥20	<i>E</i>	<i>E</i>
CS Type C	25/55	[170/380]	≥15	<i>E</i>	<i>E</i>
FS Type A and B <sup>F</sup>	25/45	[170/310]	≥26	1.0/1.4	0.17/0.21
DDS <sup>G</sup>	20/35	[140/240]	≥32	1.4/1.8	0.19/0.24
EDDS <sup>H</sup>	15/25	[105/170]	≥40	1.6/2.1	0.22/0.27

<sup>A</sup> The typical mechanical property values presented here are nonmandatory. They are intended solely to provide the purchaser with as much information as possible to make an informed decision on the steel to be specified. Values outside of these ranges are to be expected. The purchaser may negotiate with the supplier if a specific range or a more restrictive range is required for the application.

<sup>B</sup> These typical mechanical properties apply to the full range of steel sheet thicknesses. The yield strength tends to increase and some of the formability values tend to decrease as the sheet thickness decreases.

<sup>C</sup> *r<sub>m</sub>* Value—Average plastic strain ratio as determined by method in Specification E 517.

<sup>D</sup> *n* Value—Strain-hardening exponent as determined by method in Specification E 646.

<sup>E</sup> No typical mechanical properties have been established.

<sup>F</sup> The FS designation encompasses the properties of the previous DQ grade.

<sup>G</sup> The DDS designation encompasses the properties of the previous DQSK grade.

<sup>H</sup> EDDS Sheet will be free from changes in mechanical properties over time, (that is, nonaging).

**10. Keywords**

10.1 coatings, metallic; steel sheet, zinc alloy coated; steel sheet, zinc coated; zinc alloys; zinc-coated steel; zinc-5 % aluminum alloy-coated steel; zinc-5 % aluminum-mischmetal alloy-coated steel; zinc-5 % aluminum-0.1 % magnesium alloy-coated steel

**TABLE 7 Coating Bend Test Requirements for Zinc-5 % Aluminum Alloy Coatings**

Ratio of the Inside Bend Diameter to Thickness of the Specimen (Any Direction)													
Coating Designation <sup>A</sup>	CS, FS, DDS, EDDS			SS, Grade <sup>B</sup>			Coating Designation <sup>A</sup>	HSLAS, Type A, Grade <sup>B</sup>		HSLAS, Type B, Grade			
	Sheet Thickness, in. [mm]			33 [230]	37 [255]	40 [275]		50 [340]	60 [410]	50 [340]	60 [410]	70 [480]	80 [550]
	through 0.039 [1.0]	over 0.039 [1.0] through 0.079 [2.0]	over 0.078 [3.0]										
GF235 [ZGF700]	2	3	3	3	3	3	GF115 [ZGF350]	1½	3	1	1	1½	1½
GF210 [ZGF600]	2	2	2	2	2	2½	GF90 [ZGF275]	1½	3	1	1	1½	1½
GF185	2	2	2	2	2	2½	GF75 [ZGF225]	1½	3	1	1	1½	1½
GF165	2	2	2	2	2	2½	GF60 [ZGF180]	1½	3	1	1	1½	1½
GF140 [ZGF450]	1	1	2	2	2	2½	GF45 [ZGF135]	1½	3	1	1	1½	1½
GF115 [ZGF350]	0	0	1	1½	2	2½	GF30 [ZGF90]	1½	3	1	1	1½	1½
GF90 [ZGF275]	0	0	1	1½	2	2½	GF01 [ZGF001]	1½	3	1	1	1½	1½
GF75 [ZGF225]	0	0	1	1½	2	2½							
GF60 [ZGF180]	0	0	0	1½	2	2½							
GF45 [ZGF135]	0	0	0	1½	2	2½							
GF30 [ZGF90]	0	0	0	1½	2	2½							
GF01 [ZGF001]	0	0	0	1½	2	2½							

<sup>A</sup> If other coatings are required, the user shall consult the producer for availability and suitable bend test requirements.

<sup>B</sup> SS Grades 50 [340] and 80 [550] and HSLAS Type A Grades 70 [480] and 80 [550] are not subject to bend test requirements.

## APPENDICES

### (Nonmandatory Information)

#### X1. BENDING PROPERTIES

X1.1 Table X1.1 contains suggested minimum inside radii for cold bending.

**TABLE X1.1 Suggested Minimum Inside Radii for Cold Bending**

NOTE 1— $t$  = radius equivalent to the steel thickness.

NOTE 2—The suggested radii should be used as minimums for 90° bends in actual shop practice.

Designation	Type	Grade	Minimum Inside Radius for Cold Bending <sup>A</sup>
SS <sup>B</sup>		33 [230]	1½ $t$
		37 [255]	2 $t$
		40 [275]	2 $t$
		50 [340] (Class 1)	not applicable
		50 [340] (Class 2)	not applicable
		50 [340] (Class 3)	not applicable
HSLAS	B	80 [550]	not applicable
		50 [340]	2½ $t$
		60 [410]	3 $t$
		70 [480]	4 $t$
HSLAS	A	80 [550]	4½ $t$
		50 [340]	2 $t$
		60 [410]	2 $t$
		70 [480]	3 $t$
		80 [550]	3 $t$

<sup>A</sup> Bending capability may be limited by the coating designation.

<sup>B</sup> No type has been established for Structural Steel (SS).

## **X2. RATIONALE FOR CHANGES IN PRODUCT DESIGNATIONS**

X2.1 Subcommittee A05.11 has revised the designations used to classify the various products available in each hot-dip coated specification. The previous “quality” designations have been replaced with designations and descriptions more closely related with product characteristics. Many of the former “quality” specifications described the steel only in terms of limited chemical composition, which in some cases was identical for two or more qualities. The former designations also did not reflect the availability of new steels which are the result of the use of new technologies such as vacuum degassing and steel ladle treatments.

X2.2 The former “quality” designators, defined in very broad qualitative terms, did not provide the user with all the information needed to select the appropriate steel for an application. The new designations are defined with technical information such as specific chemical composition limits and typical-nonmandatory mechanical properties. These steel characteristics are important to users concerned with the weldability and formability of the coated steel products. The typical mechanical properties included in the new designation system are those indicated by the tension test. These properties are more predictive of steel formability than other tests such as the hardness test which may not compensate adequately for product variables such as substrate thickness and coating weight.

X2.3 The new designations also provide the user with the flexibility to restrict the steels applied on any order. For example, a user can restrict the application of ultra low carbon steels on an application through the selection of an appropriate “type” designator.

X2.4 There is a limited relationship between the former and current systems of designation. Some of the reasons for this limited relationship are: addition of steels not previously described in ASTM specifications, restrictions placed on ranges of chemical composition, the addition of typical mechanical properties, and the enhanced capability of steel producers to combine chemical composition and processing methods to achieve properties tailored to specific applications.

X2.5 The changes in designation are significant, which may create transition issues that will have to be resolved. Continued dialogue between users and producers will have to be maintained to assist the transition to the new system of designations. A user with concerns about the appropriate coated steel to order for a specific application should consult with a steel supplier or producer.

## **X3. RELATIONSHIP BETWEEN SPECIFICATIONS THAT DESCRIBE REQUIREMENTS FOR A COMMON PRODUCT**

X3.1 Standard ISO 14788 may be reviewed for comparison with this standard. The relationship between the standards may only be approximate; therefore, the respective documents should be consulted for actual requirements. Those who use these documents must determine which specifications address their needs.

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# Standard Specification for Steel Sheet, Zinc Coated by the Electrolytic Process for Applications Requiring Designation of the Coating Mass on Each Surface<sup>1</sup>

This standard is issued under the fixed designation A 879; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon ( $\epsilon$ ) indicates an editorial change since the last revision or reapproval.

## 1. Scope

1.1 This specification covers zinc coatings applied by the electrolytic process to hot-rolled and cold-rolled steel sheet. The coating has a smooth, spangle-free surface. The zinc-coated sheet covered in this specification is produced in a wide range of coating masses to provide coatings that are compatible with the anticipated service life required. The coating mass varies, from very thin coatings that are usually painted to provide good service, to relatively heavy masses that provide good corrosion resistance in the bare (unpainted) condition.

1.2 The product shall be coated on one or both surfaces with equal or differential coating masses on the two surfaces. Sheet coated with equal coating masses on each surface has similar levels of corrosion protection on each surface. Often, however, a higher level of corrosion protection is required on one surface than is required on the other. Thus one surface is specified to have a heavier coating mass than the other. Either surface, when specified to be painted will provide additional corrosion protection as compared to an unpainted surface.

1.3 This coating process has essentially no effect on the base metal mechanical properties and use is permitted on any grade of hot- or cold-rolled steel sheet. The coated sheet is available as Commercial Steel (CS), Drawing Steel (DS), Deep Drawing Steel (DDS), Extra-Deep Drawing Steel (EDDS), Structural Steel (SS), High-Strength Low-Alloy Steel (HSLAS), or High-Strength Low-Alloy Steel with Improved Formability (HSLAS-F).

1.4 The values stated in SI units are to be regarded as the standard.

## 2. Referenced Documents

### 2.1 ASTM Standards:

A 90/A90M Test Method for Weight [Mass] of Coating on Iron and Steel Articles with Zinc or Zinc-Alloy Coatings<sup>2</sup>

<sup>1</sup> This specification is under the jurisdiction of ASTM Committee A05 on Metallic Coated Iron and Steel Products and is the direct responsibility of Subcommittee A05.11 on Sheet Specifications.

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<sup>2</sup> *Annual Book of ASTM Standards*, Vol 01.06.

A 754 Test Method for Coating Thickness by X-Ray Fluorescence<sup>2</sup>

A 917 Specification for Steel Sheet, Coated by the Electrolytic Process for Applications Requiring Designation of the Coating Mass on Each Surface (General Requirements)<sup>2</sup>

B 504 Test Method for Measurement of Thickness of Metallic Coatings by the Coulometric Method<sup>3</sup>

## 3. Classification

3.1 Coating shall be designated in accordance with Specification A 917. The letter G shall be used to designate pure zinc coatings.

## 4. Ordering Information

4.1 Orders for products to this specification shall include the following information, as necessary to adequately describe the desired product:

4.1.1 Name of product (electrolytic zinc-coated steel sheet).

4.1.2 ASTM designation and year of issue.

4.1.3 Base metal type (hot rolled or cold rolled).

4.1.4 Base metal designation (Commercial Steel (CS), Drawing Steel (DS), Deep Drawing Steel (DDS), Extra Deep Drawing Steel (EDDS), Structural Steel (SS), High-Strength Low-Alloy Steel (HSLAS), or High-Strength Low-Alloy Steel with Improved Formability (HSLAS-F)).

4.1.5 Formability type, strength, grade or class, or combination, thereof, as required for structural or high-strength low-alloy steels.

4.1.6 Coating designation (see 3.1).

4.1.7 Surface treatments required (see Note 1).

NOTE 1—Steel short is available without surface treatment (dry) or with surface treatments designated as chemical treatment, oiled, or phosphatized. Unless otherwise specified sheet is furnished oiled.

4.1.8 Dimensions [show thickness (minimum or nominal), width, and length, if cut length].

4.1.9 Coil size (must include inside diameter, outside diameter, and maximum coil weight).

4.1.10 Application (part name and description).

<sup>3</sup> *Annual Book of ASTM Standards*, Vol 02.05.

4.1.11 Special Requirements, is applicable.

4.1.12 Certification, if required, heat analysis and mechanical property report.

## 5. Coating Mass

5.1 Coating mass shall conform to the requirements for coating designation (mass and type) as given in Specification A 917 and in Table 1 for the specific coating designation. The mass of the coating is the single spot value on each surface of the sheet in grams per square metre.

### 5.2 Coating Mass Tests:

5.2.1 The weigh-strip-weigh method (see Test Method A 90/A 90M) is a destructive test that determines coating mass by measuring the difference in weight between a coated and a

stripped (uncoated) sample. If one surface is protected suitably during the initial stripping, coating mass can be determined for each surface independently. Conversion of the coating mass to coating thickness is possible only if the density of the coating is known precisely.

5.2.2 Coating thickness measurements by X-ray fluorescence (see Test Method A 754) is a nondestructive test that determines coating mass by converting X-ray fluorescence measurements to coating mass values. This method is readily adaptable to the continuous monitoring of coating mass during coating. Thus modern electroplating facilities are frequently equipped with X-ray fluorescence gages that provide feedback to control the coating mass. These devices may be used as a basis for determining suitability for shipment provided that they have been calibrated properly.

5.2.3 Measurement by Coulometric Method (see Test Method B 504) is a destructive test that determines lighter coating mass applications.

5.3 The referee method to be used shall be as agreed upon between the producer and the consumer. In the absence of such agreement, Test Method A 90/A 90M shall be used as the referee method.

**TABLE 1 Coating Mass per Surface, g/m<sup>2</sup>,<sup>A</sup> for Steel Sheet, Zinc Coated by the Electrolytic Process<sup>B</sup>**

Coating Designation <sup>C</sup>	Minimum	Maximum
00G	no coating	no coating
20G	20	40
40G	40	70
60G	60	90
70G	70	110
90G	90	130
98G	98	140

<sup>A</sup>Conversion for coating mass in ounces per square foot is g/m<sup>2</sup> × 0.00328.

<sup>B</sup>The product shall be coated on at least one surface; therefore, the combination 00/00 shall not be specified.

<sup>C</sup> See Specification A 917.

## 6. Keywords

6.1 electrolytic zinc coated; zinc coated; zinc coated steel sheet

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# Standard Specification for Steel Sheet, Zinc and Aramid Fiber Composite Coated for Corrugated Steel Sewer, Culvert, and Underdrain Pipe<sup>1</sup>

This standard is issued under the fixed designation A 885/A 885M; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

## 1. Scope

1.1 This specification covers steel sheet, composite coated, used in the manufacture of corrugated pipe used for sewers, culverts, and underdrains. The composite coating consists of a layer of aramid nonwoven fabric bonded by molten zinc to the steel sheet, to act as a bonding medium for asphalt coatings later applied to fabricated products. Material for this use is furnished in coils, flat in cut lengths, and corrugated in cut lengths.

1.2 The values stated in either inch-pound units or SI units are to be regarded separately as the standard. Within the text, the SI units are shown in brackets. The values stated in each system are not equivalents; therefore, each system must be used independent of the other. Combining values from the two systems may result in nonconformance with the specification.

1.3 This specification and some referenced specifications are expressed in both inch-pound and SI units. If the order specifies the applicable “M” specification designation, the product shall be furnished to SI units.

NOTE 1—Steel sheet with other metallic coatings is described in Specification A 929/A 929M.

## 2. Referenced Documents

### 2.1 ASTM Standards:

A 760/A 760M Specification for Corrugated Steel Pipe, Metallic-Coated for Sewers and Drains<sup>2</sup>

A 796 Practice for the Structural Design of Corrugated Steel Pipe, Pipe-Arches, and Arches for Storm and Sanitary Sewers and Other Buried Applications<sup>2</sup>

A 902 Terminology Relating to Metallic Coated Steel Products<sup>2</sup>

A 924/A 924M Specification for General Requirements for Steel Sheet, Metallic-Coated by the Hot-Dip Process<sup>2</sup>

A 929/A929M Specification for Steel Sheet, Metallic-

<sup>1</sup> This specification is under the jurisdiction of ASTM Committee A05 on Metallic Coated Iron and Steel Products and is the direct responsibility of Subcommittee A05.11 on Sheet Specifications.

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<sup>2</sup> Annual Book of ASTM Standards, Vol 01.06.

Coated by the Hot-Dip Process, for Corrugated Steel Pipe<sup>2</sup>  
B 6 Specification for Zinc<sup>3</sup>

D 1682 Test Methods for Breaking Load and Elongation of Textile Fabric<sup>4</sup>

D 3850 Test Method for Rapid Thermal Degradation of Solid Electrical Insulating Materials by Thermogravimetric Method TGA<sup>5</sup>

E 29 Practice for Using Significant Digits in Test Data to Determine Conformance with Specifications<sup>6</sup>

## 3. Terminology

3.1 *Definitions*—For definitions of terms used in this specification, refer to Terminology A 902. The following definitions are as stated in that terminology.

3.1.1 *fabricator, n*—as related to corrugated metal pipe, (1) the organization that produces the finished pipe or (2) for structural plate pipe, the organization that processes flat sheets and other items needed for field assembly of the finished products.

3.1.2 *manufacturer, n*—as related to corrugated metal pipe, the organization that produces the metal sheet from which pipe is made.

3.1.3 *purchaser, n*—as related to corrugated metal pipe, the person or agency that purchases the finished pipe.

3.1.4 *Discussion*—With regard to this specification for sheet for corrugated steel pipe, the fabricator may also be considered as the purchaser of the sheet, where that term is used in this specification. Such interpretation would not restrict the purchaser of the finished pipe from enforcing any provisions of this specification.

### 3.2 Definitions of Terms Specific to This Standard:

3.2.1 *composite coating*—the total coating on top of the steel substrate, including the zinc and the aramid fibers.

3.2.2 *nonwoven fabric*—a fabric that is neither woven, knitted, nor spun, but built up by the interlocking of fibers by chemical bonding agents, or of fusible fibers by mechanical

<sup>3</sup> Annual Book of ASTM Standards, Vol 02.04.

<sup>4</sup> Discontinued—See 1991 Annual Book of ASTM Standards, Vol 07.01.

<sup>5</sup> Annual Book of ASTM Standards, Vol 10.02.

<sup>6</sup> Annual Book of ASTM Standards, Vol 14.02.

works, chemical action, moisture, and heat.

#### 4. Ordering Information

4.1 All sheet, both flat and formed, covered by this specification is ordered only to the specified thicknesses listed in Table 1.

4.2 Orders for material to this specification shall include the following information, as necessary, to describe the desired product adequately:

4.2.1 Name of material (composite-coated steel sheet for corrugated pipe);

4.2.2 ASTM designation and year of issue, as A 885 for inch-pound units or A 885M for SI units;

4.2.3 *Quantity and Dimensions*:

4.2.3.1 *Cut Lengths*—Show the number of sheets; thickness; width, either flat or overall corrugated; length; and pitch and depth of corrugations, if corrugated;

4.2.3.2 *Coiled Sheet*—Show the total weight [mass]; thickness; width; and coil requirements (maximum outside diameter, acceptable inside diameter, and maximum weight [mass] of individual coils);

4.2.4 Certification, if required (see 12.1); and

4.2.5 Special requirements.

NOTE 2—A typical ordering description (inch-pound units) is as follows: composite-coated steel sheet for corrugated pipe in accordance with ASTM A 885, 5000 sheets, 0.064 by 25½ by 60 in. with 2⅔ by ½ in. corrugations, certified.

NOTE 3—A typical ordering description (SI units) is as follows: composite-coated steel sheet for corrugated pipe in accordance with ASTM A 885M, 45 000 kg, 2.77 by 700 mm by coil, 1500 mm max outside diameter, 600 mm inside diameter, 7000 kg max, certified.

#### 5. Materials and Manufacture

5.1 Both sides of the steel sheet shall be coated with a layer of aramid nonwoven fabric applied by pressing the fabric into the molten zinc bonding medium.

NOTE 4—Composite coating weight [mass] tests are not made by the manufacturer, and there are no specified values for the weight [mass] of zinc used for bonding the fabric to the base metal. The primary function of the zinc is to bond the fabric to the base metal. However, in the case of accidental damage to the coating, the zinc bonding layer will also provide galvanic protection to the base metal.

5.2 *Aramid Nonwoven Fabric*—The aramid fabric shall consist of an aramid nonwoven sheet. The ordered weight of fabric shall be 0.75 lb/100 ft<sup>2</sup> [36.5 g/m<sup>2</sup>].

**TABLE 1 Sheet Thickness for Composite-Coated Sheets**

NOTE 1—Thickness is measured on the tangents of corrugations on the sheet not less than ⅜ in. [10 mm] from an edge.

Specified Thickness, <sup>A</sup> with Coating, in. [mm]	Minimum Thickness, without Coating, in. [mm]
0.064 [1.63]	0.054 [1.37]
0.079 [2.01]	0.069 [1.75]
0.109 [2.77]	0.098 [2.49]
0.138 [3.51]	0.126 [3.20]
0.168 [4.27]	0.156 [3.96]

<sup>A</sup>The specified thickness corresponds to specified thicknesses used in pipe design (Practice A 796) and referenced in the pipe specification (Specification A 760/A 760M) and is used here for convenient reference. However, as stated in 9.1, the minimum thickness of composite-coated sheet is based on measurements of uncoated sheet. The thickness of coating on composite-coated sheet may not be the same as on sheets with other metallic coatings.

5.2.1 *Breaking Strength*—The breaking strength of the fabric shall be a minimum of 20 lbf [90 N] in the machine direction and 15 lbf [67 N] in the cross direction when measured in accordance with Test Methods D 1682.

5.2.2 *Thermal Stability*—The fabric shall show less than 10 % weight loss at temperatures up to 752°F [425°C] when analyzed using thermal gravimetric analyses in accordance with Test Method D 3850.

5.3 *Zinc Bonding Medium*—The zinc used for bonding the aramid fabric to the steel sheet shall conform to Specification B 6 and shall be at least equal to the grade designated as “Prime Western.”

#### 6. Chemical Composition

6.1 *Base Metal Analysis*—The base metal cast and product analyses shall conform to the chemical requirements of Table 2.

#### 7. Mechanical Properties

7.1 The base metal for composite-coated sheet shall conform to the mechanical requirements of Table 3.

7.2 Two tension tests shall be made on random samples of the material prior to coating from each cast or heat. When the material from said cast or heat is less than 50 tons [45 Mg], one test is sufficient. When material rolled from one cast or heat differs 0.050 in. [1.25 mm] or more in thickness, one tension test shall be made from both the thickest and thinnest material rolled regardless of the weight [mass] represented. The samples shall be prepared and tested in accordance with the method specified in Specification A 924/A 924M.

#### 8. Aramid Nonwoven Fabric Bond Strength

8.1 There shall be no spalling or cracking of the coating when tested in accordance with 8.2. There shall be no disbonding of the coating at the cut to be made as described in 8.2.

8.2 Cut a 2 by 8-in. [50 by 200-mm] coupon from the sample of composite-coated steel sheet. Bend the coupon 180° over a 0.5-in. [13-mm] diameter mandrel. Make a cut through the composite coating along an element on the outside of the bend to check for aramid fabric adhesion. Perform this test at 0, 77, and 122 ± 2°F [−18, 25, and 50 ± 1°C].

#### 9. Dimensions and Tolerances

9.1 *Thickness*—Sheet thickness shall conform to the dimensions in Table 1. The thickness measurements made on finished sheets shall be made after removal of the composite coating. If corrugated, the measurement shall be made on the tangent part of the corrugation.

9.2 *Length*—Permissible variations in the length of cut-length sheets, both flat and corrugated, shall be in accordance with Specification A 924/A 924M.

**TABLE 2 Chemical Composition**

	Cast Analysis	Product Analysis
Sulfur, max, %	0.05	0.06
Sum of carbon, manganese, phosphorus, sulfur, and silicon, max, %	0.70	0.74

**TABLE 3 Mechanical Requirements (Properties of Flat Sheet Prior to Fabrication)<sup>A</sup>**

Tensile strength, min, <sup>B</sup> ksi [MPa]	45.0 [310]
Yield strength, min, <sup>B</sup> ksi [MPa]	33.0 [230]
Elongation in 2 in. [50 mm], <sup>C</sup> min, %	20

<sup>A</sup>To determine conformance with this specification, round each value for tensile strength and yield strength to the nearest 0.1 ksi [1 MPa] and each value for elongation to the nearest 1 %, both in accordance with the rounding method of Practice E 29.

<sup>B</sup>Yield strength and tensile strength are based on the thickness of the base metal. If tests are made after coating, determine the base metal thickness after stripping the coating from the ends of the specimen contacting the grips of the tension testing machine prior to tensile testing.

<sup>C</sup>The elongation requirement does not apply to material tested after corrugating.

9.3 *Flat Sheet*—Permissible variations in the width and camber of flat materials shall be in accordance with Specification A 924/A 924M. Flatness tolerances shall be in accordance with Specification A 929/A 929M.

#### 9.4 *Corrugated Sheet:*

9.4.1 *Corrugations*—Corrugations shall form smooth continuous curves and tangents. The dimensions of the corrugations shall be in accordance with Table 4.

9.4.2 *Covering Width and Lip Dimension*—The covering width of corrugated sheet shall be in accordance with Table 5. The covering width is the distance between the crests of the extreme corrugations. The lip dimension of corrugated sheet shall be in accordance with Table 6 and is measured along the radial curvature from the crest of the corrugation to the edge of the sheet. There is no established tolerance for overall width since the covering width and lip dimensions are the governing factors for the formed product.

## 10. Testing

10.1 The manufacturer shall make such tests and measurements as deemed necessary to ensure that the coated sheet produced complies with this specification.

10.2 The purchaser may make tests and measurements as determined to be necessary to confirm conformance with this specification.

10.3 *Chemical Analysis of Steel*—Heat analysis (by the manufacturer) and product analysis (by the purchaser) shall be in accordance with Specification A 924/A 924M.

10.4 *Mechanical Testing*—Mechanical property tests shall be conducted on the sheet prior to corrugating or other

**TABLE 4 Corrugation Size**

Nominal Size, in. [mm]	Maximum Pitch, <sup>A</sup> in. [mm]	Minimum Depth, <sup>B</sup> in. [mm]	Radius of Curvature, in. [mm]	
			Nominal	Minimum
2 2/3 by 1/2 [68 by 13]	2 7/8 [73]	0.48 [12]	11/16 [17]	0.5 [13]
3 by 1 [75 by 25]	3 1/4 [83]	0.95 [24]	9/16 [14]	0.5 [13]

<sup>A</sup> Pitch is measured from crest to crest of the corrugations at 90° to the direction of the corrugations.

<sup>B</sup> Depth is measured as the vertical distance from a straight edge resting on the corrugation crests to the bottom of the intervening valley.

**TABLE 5 Covering Width Tolerance for Corrugated Sheet**

Covering Width, in. [mm], incl	Tolerance Over and Under, in. [mm]
To 24 [610]	1/4 [6.4]
Over 24 [610] to 36 [910]	3/8 [9.5]

**TABLE 6 Corrugated Sheet Lip Dimensions**

Nominal Corrugation Size, in. [mm]	Lip Dimensions, <sup>A</sup> in. [mm]
2 2/3 by 1/2 [68 by 12.7]	3/4 [19]
3 by 1 [76 by 25]	7/8 [22]

<sup>A</sup> The tolerance for lip dimensions is +3/16 in. [5 mm], -0.

fabrication, when possible, and shall be in accordance with Specification A 924/A 924M. If tests are made after corrugating, specimens shall be taken on the tangents of corrugations and used for the determination of tensile and yield strengths only.

## 11. Rejection and Rehearing

11.1 Material tested by the purchaser and found not conforming to this specification may be rejected, subject to the rejection and rehearing provisions of Specification A 924/A 924M.

## 12. Certification

12.1 When specified in the purchase order or contract, a manufacturer's certification shall be furnished to the purchaser. The certification shall be in accordance with the provisions of Specification A 924/A 924M and shall include reference to this product specification designation (A 885/A 885M).

12.2 Test results, including the chemical composition and mechanical properties for each heat and coating lot, shall be maintained by the manufacturer for seven years without regard to whether a certification was furnished. The test results shall be made available to the fabricator and purchaser upon request.

## 13. Product Marking

13.1 Each 2 to 5 ft [0.5 to 1.5 m] of sheet in coils or cut lengths shall be identified by showing the following:

13.1.1 Name of manufacturer,

13.1.2 Brand name,

13.1.3 Specified thickness,

13.1.4 Identification symbols relating to a specific heat number and coating lot number, and

13.1.5 ASTM designation number.

13.2 The brand shall be removed or obliterated, or the sheet re-branded "non specification," on each 2 to 5 ft [0.5 to 1.5 m] of sheet in a coating lot or heat where control tests, as prescribed herein, show nonconformance to this specification.

## 14. Keywords

14.1 coatings, composite; coatings, metallic; coatings, zinc; corrugated steel pipe; pipe, corrugated steel; steel sheet, composite-coated; steel sheet, metallic coated; steel sheet, zinc-coated; zinc-coated steel sheet



 **A 885/A 885M**

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## Standard Practice for Conducting Case Studies on Galvanized Structures<sup>1</sup>

This standard is issued under the fixed designation A 896; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon ( $\epsilon$ ) indicates an editorial change since the last revision or reapproval.

### 1. Scope

1.1 This practice sets forth the procedures for conducting case studies of galvanized installations. It is intended for structural members and other permanent parts of the installation, such as railings and other such fabrications.

1.2 Included in this practice are recommendations for the visual inspection of the galvanized structure, measurement of coating thickness, and reporting of results.

1.3 The values stated in SI units are to be regarded as the standard.

1.4 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

### 2. Referenced Documents

#### 2.1 ASTM Standards:

B 499 Test Method for Measurement of Coating Thickness by the Magnetic Method: Nonmagnetic Coatings on Magnetic Basis Metals<sup>2</sup>

E 376 Practice for Measuring Coating Thicknesses by Magnetic-Field or Eddy Current (Electromagnetic) Test Methods<sup>3</sup>

### 3. Significance and Use

3.1 This practice is applicable to galvanized structures exposed to the atmosphere or to plant environments, including buildings, bridges, and industrial plant constructions.

3.2 It provides for the collection of data to document the protection afforded by the galvanized coating.

3.3 Method A for conducting a coating thickness survey aims essentially at an assessment of the general condition of the galvanized structure, at the time of the inspection, by taking thickness measurements on several members of the structure.

3.4 Method B provides for accurate monitoring of the coating thickness decrease as a function of time, at specific locations on the structure, in order to assess the corrosivity of the environment, the effect of orientation, elevation, or other factors.

3.5 Method B is not an alternate procedure to Method A, but is complementary and optional.

### 4. Apparatus

#### 4.1 Surface Preparation:

4.1.1 Water.

4.1.2 Cloths, for washing and drying.

4.1.3 Soft Fiber Bristle Brush.

#### 4.2 Coating Thickness Measurement:

4.2.1 Thickness Gage.

4.2.2 Steel Calibration Plates and Foils.

4.2.3 Permanent Marker.

4.2.4 Tape Measure.

4.2.5 Center Punch.

4.2.6 Hammer.

4.3 *Electronic Magnetic Flux Gage*—The use of an electronic magnetic-flux gage in accordance with Method B 499 is recommended. Instruments with an accuracy of  $\pm 3$  to  $\pm 5$  % are commercially available.

4.3.1 Probes having a constant pressure feature will minimize operator error.

4.3.2 The probe assembly should have a probe support if measurements are to be made on rounded or curved surfaces.

4.4 *Hand-Held Magnetic Gage*—A hand-held magnetic gage using the magnetic attraction principle in accordance with Practice E 376 may be used for Method A.

### 5. General Procedure

#### 5.1 Background Information:

5.1.1 Wherever possible, obtain information on the tonnage and cost of the steel work, the cost of galvanizing, and estimates of alternative coating costs (initial and maintenance) if the steelwork had been coated by another method. Determine if there are areas of the installation which were painted rather than galvanized, or painted over galvanizing.

5.1.2 Determine if any problems were experienced during fabrication, galvanizing, construction, and operation.

<sup>1</sup> This practice is under the jurisdiction of ASTM Committee A05 on Metallic Coated Iron and Steel Products and is the direct responsibility of Subcommittee A05.13 on Structural Shapes and Hardware Specifications.

Current edition approved Sept. 29, 1989. Published November 1989.

<sup>2</sup> *Annual Book of ASTM Standards*, Vol 02.05.

<sup>3</sup> *Annual Book of ASTM Standards*, Vol 03.03.

5.2 Corrosive Environment Identification:

5.2.1 The galvanized installation should be divided according to the various corrosive environments to which it is exposed. For example, plant atmospheres could be categorized with respect to the processing step. Sheltered versus boldly exposed areas can be considered as two different environments.

5.2.2 Pertinent data relating to the corrosive environments should be obtained, such as types of chemical present, concentration of fumes, occurrence of spills, temperature fluctuations, amount of rainfall, or the use of de-icing salts.

5.3 Visual Inspection:

5.3.1 Observe the overall appearance of the galvanized structure, and the appearance of each type of plant environment, if applicable. Note such characteristics as color and spangle of the galvanized coating, the presence of rust or staining, and the condition of other coatings, such as paint. Take note of chemical spills or leaks, the presence of fumes or high humidity, and effects of orientation, elevation, design, or any other factors causing localized or nonuniform corrosion.

5.3.2 The condition of the galvanized coating may vary according to section thickness or geometry of the steel. For example, there may be differences with respect to light versus heavy sections or handrails versus beams.

5.3.3 The use of high silicon steels may be apparent, and should be noted.

5.3.4 Fasteners should be inspected. Look for rust, staining, or mechanical damage.

5.4 Coating Thickness Survey:

5.4.1 Method A:

5.4.1.1 The selection of structural members should be based mainly on the section thickness. A minimum of three representative members from each of the two categories of section thickness, light (bracing) and heavy (column, beam) should be surveyed for each corrosive environment. Selection of suitable locations for coating thickness measurements is at the discretion of the inspector and may be based on factors such as orientation or accessibility. Take measurements in areas where the coating is uniform.

5.4.1.2 Fasteners should be surveyed where their size permits. Measurements should be made on the center of bolt heads, or on the flat parts of bolt heads or nuts.

5.4.1.3 Calibrate the coating thickness gage against proper reference materials before making measurements.

5.4.1.4 Clean the surface, using a fine fiber brush or by washing with water and drying, or both. Avoid removing any of the coating material or the film of basic zinc salts.

5.4.1.5 At each location, make a minimum of five measurements and determine the mean coating thickness.

5.4.2 Method B:

5.4.2.1 A minimum of three locations should be surveyed for each corrosive condition or position of interest. The locations need not be on the same steel member. Selection of suitable locations is at the discretion of the inspector. Take measurements in areas where the coating is uniform.

5.4.2.2 Calibrate the coating thickness gage with proper reference materials before the survey is started. Calibrations should be checked periodically to ensure continued accuracy of measurements and again at the end of the survey.

5.4.2.3 Clean the surface, using a fine fiber bristle brush or by washing with water to remove dirt and dust, or both.

Note: **Caution**—Do not abrade with emery paper or wire brush, or clean in any manner that would tend to remove the zinc coating or the film of basic zinc salts. By removing the basic zinc salts film, corrosion can be accelerated.

5.4.2.4 Twenty-five measurements should be made at each location within an area 50 by 50 mm (2 by 2 in.) square, and the mean ( $X$ ) and the 90 % confidence limit on the mean ( $S_{m90}$ ) should be determined (see Appendix X1). A different test area should be surveyed if  $S_{m90}$  is greater than 6  $\mu\text{m}$  (0.3 mil). If possible, use a template with 25 small holes (approximately 4 mm diameter) in a 5 by 5 grid, with outside corner measurements 50 by 50 mm (2 by 2 in.). Holes should be 12.5 mm (0.5 in.) apart horizontally and vertically. The grid should be centered in a larger square measuring 75 by 75 mm (3 by 3 in.) with outside corners containing small holes (see Fig. 1). Put the template on the cleaned surface and mark the 29 holes with a felt tip marker. Measurements are to be taken starting with the top left and recorded on the report form in the same order as measured on the grid.

5.4.2.5 To make test areas easier to locate for future surveys, center punch the outside corners of the 75 by 75 mm square (3 by 3 in.) so identification marks do not interfere with coating measurements. If punching is not possible, use paint or other permanent marker (less desirable). If possible, take a photographic record to properly document the position of each structural member on which measurements were made in relation to the plant layout.

5.4.2.6 Periodic surveys should be conducted. An initial two-year interval is recommended for the first several years. Depending on the nature of the data collected at the time of the second inspection, longer intervals may be considered.

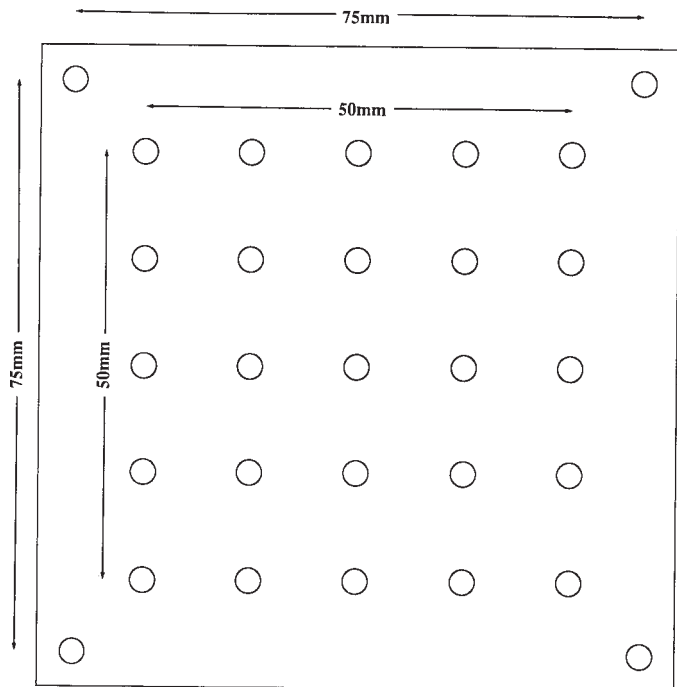


FIG. 1 Template (not to scale)

5.4.2.7 The same thickness gage, or at least the same type of instrument as used in subsequent surveys. The steel calibration plate should be the same for each survey.

**5.5 Photographs:**

5.5.1 Obtain an overall photographic view of the installation, from several angles, if possible.

5.5.2 Photograph each corrosive environment where measurements are made, show the relation of the site to the general plant layout. If possible, show the fumes or chemicals that would normally be present.

5.5.3 Take close-up photographs where appropriate.

5.5.3.1 Include close-up photographs of areas where actual measurements were made.

5.5.3.2 Take close-up photographs of other areas pertinent to the study, such as those areas showing concentrated corrosion, coating damage, staining, etc., that is not typical of the galvanized structure as a whole.

5.5.3.3 Take close-ups of fasteners.

5.5.3.4 Take close-ups of painted or other coated areas.

**6. Report**

6.1 Report sheets are provided in Appendix X2.

6.2 State the name of the company of installation and its location. Describe the type of structure if an industrial plant.

6.3 The inspector should state his or her name, company contact, date of the inspection, and type of thickness measuring equipment used.

6.4 Present any data that is available regarding tonnage and cost of the steel, and comparison costs of galvanizing versus other coating systems.

**6.5 Visual Inspection:**

6.5.1 Report the general appearance of the galvanized structure or installation, and any noticeable changes since the last inspection. Report coating characteristics such as color, spangle, stains, rust, and condition of paint coatings, fasteners, and high silicon steels within each type of environment, if applicable.

6.5.2 Relate the photographs to the locations discussed in the report.

**6.6 Coating Thickness Measurement:**

6.6.1 *Method A*—State the range of average coating thicknesses measured on structural members, including high silicon steels, and on fasteners. Make mention of differences in coating thickness that may arise from such factors as section thickness, orientation, etc.

6.6.2 *Method B*—Provide details about each location at which thickness measurements were made and state the mean and the 90 % confidence interval, rounding to the least significant number of digits.

6.6.3 Relate photographs to the corresponding areas measured.

**APPENDIXES**

**(Nonmandatory Information)**

**X1. CALCULATION OF 90 % CONFIDENCE INTERVAL**

X1.1 The standard deviation,  $s$ , of a series of measurements can be calculated using the following equation:

$$s = \sqrt{\frac{\sum[(X_i - X)^2]}{n - 1}}$$

where:

$X_i$  = each individual reading,

$X$  = mean of group of 25 readings, and

$n$  = number of measurements.

X1.2 The 90 % confidence interval on the mean,  $S_m90$ , can be expressed as follows:

$$S_m90 = \frac{ts}{\sqrt{n}}$$

where:

$s$  = standard deviation, and

$t$  = the  $t$  distribution value for  $n - 1$  degrees of freedom.

X1.2.1 Tables containing values for  $t$  can be found in textbooks on statistics or in most engineering handbooks. For the number of measurements ( $n = 25$ ) prescribed in 5.4.2.4,  $t = 1.711$  for  $n-1$  degrees of freedom and the value of

$$t/\sqrt{n} = 1.711/5 = 0.34.$$

The 90 % confidence interval on the mean for 25 measurements can then be written as  $S_m90 = 0.34 s$ .

X1.2.2 If some number other than 25 measurements is used, the value of  $t$  for  $n-1$  degrees of freedom must be determined from statistical tables.

X1.2.2.1 Calculation of  $X$ ,  $s$ , and  $S_m90$  values can be tedious, and the use of an electronic calculator is recommended.

X1.3 The significance of  $S_m90$  is that there is a 90 % probability that the true value of the mean will lie within the range  $X \pm S_m90$ , the most probable value being  $X$ . A test program involving field measurements has shown that considering a corrosion rate of 2.5  $\mu\text{m}/\text{year}$  (0.1 mil/year), it will be possible to see a significant difference between average coating

thicknesses resulting from surveys carried out ten years apart in time and based on 25 readings.

163, 152, 163, 160  $\mu\text{m}$  (5.6, 6.5, 6.7, 6.1, 6.6, 5.2, 6.4, 6.0, 7.0, 5.6, 6.2, 6.8, 6.0, 5.3, 6.7, 6.1, 6.5, 6.7, 6.5, 5.8, 6.0, 6.4, 6.0, 6.4, 6.3 mil).

*X1.4 Example of Calculations:*

X1.4.2 Mean,  $\bar{X} = 157 \mu\text{m}$  (6.2 mil).

X1.4.1  $X_i =$  142, 165, 170, 155, 168, 132, 163, 152, 179, 142, 157, 173, 152, 135, 170, 155, 165, 170, 165, 147, 152,

X1.4.3 Standard deviation,  $s = 12 \mu\text{m}$  (0.5 mil).

X1.4.4 90 % confidence interval,  $S_{m90} = 4 \mu\text{m}$  (0.2 mil).

**X2. CASE STUDY REPORT SHEET**

X2.1 Fig. X2.1 shows a case study report sheet.



**I. General Information**

Project/Installation Name \_\_\_\_\_

Type of Facility/General Description \_\_\_\_\_

Location \_\_\_\_\_

Company/End User \_\_\_\_\_

Engineer \_\_\_\_\_

Architect \_\_\_\_\_

General Contractor \_\_\_\_\_

Steel Fabricator \_\_\_\_\_

Galvanizer \_\_\_\_\_

Date of Construction \_\_\_\_\_/System \_\_\_\_\_ Tonnage \_\_\_\_\_ Cost \_\_\_\_\_

Galvanized \_\_\_\_\_

Painted \_\_\_\_\_

Paint over galvanized \_\_\_\_\_

Steel specifications/typical sections \_\_\_\_\_

**II. List of Corrosive Environments/Corrosive Agents**

1. \_\_\_\_\_

2. \_\_\_\_\_

3. \_\_\_\_\_

4. \_\_\_\_\_

**III. Comments**

What prompted use of corrosion system(s), engineering objects, cost comparisons with other systems, different or unusual applications, etc.?

\_\_\_\_\_  
\_\_\_\_\_  
\_\_\_\_\_

**IV. Visual Inspection (one report per corrosive environment)**

Project/installation name \_\_\_\_\_

Location \_\_\_\_\_

Inspection Date \_\_\_\_\_/

name firm address phone

Inspector \_\_\_\_\_

Site Contact \_\_\_\_\_

Corrosive Environment \_\_\_\_\_

Steel Sections: heavy \_\_\_\_\_ light \_\_\_\_\_ fasteners \_\_\_\_\_

Overall Appearance \_\_\_\_\_

Apparent Spangle/Heavily Weathered \_\_\_\_\_

Discoloration/Rust Staining \_\_\_\_\_

Silicon Steels \_\_\_\_\_

**FIG. X2.1 Case Study Report Sheet**

Condition of Paints \_\_\_\_\_  
 \_\_\_\_\_  
 \_\_\_\_\_

Effect of Orientation/Elevation \_\_\_\_\_  
 \_\_\_\_\_

Factors Causing Localized Corrosion: chemical spills \_\_\_\_\_  
 fumes \_\_\_\_\_ high humidity \_\_\_\_\_ elevation \_\_\_\_\_  
 other \_\_\_\_\_

List of Photographs and Identification Numbers  
 \_\_\_\_\_  
 \_\_\_\_\_  
 \_\_\_\_\_

Remarks, Changes Since Previous Inspection  
 \_\_\_\_\_  
 \_\_\_\_\_  
 \_\_\_\_\_

**V. Coating Thickness Survey—Method A**

*Procedure*

1. One report per corrosive environment or position.
2. Selection based on section thickness, a minimum of three representative members of each light (bracing) and heavy (column beam).
3. At each location, a minimum of five measurements to determine the mean.

Project/Installation Name \_\_\_\_\_

Location \_\_\_\_\_

Survey Date \_\_\_\_\_/\_\_\_\_\_/\_\_\_\_\_

	name	firm	address	phone
Inspector _____				

Site Contact \_\_\_\_\_

Corrosive Environment \_\_\_\_\_

Gage type \_\_\_\_\_  $\mu\text{m}/\text{mils}$  (circle one) Calibration Plates \_\_\_\_\_

<i>Heavy Member Section/Location</i>	Thickness Readings	Mean
1. _____	_____ : _____	_____
2. _____	_____ : _____	_____
3. _____	_____ : _____	_____

*Light Member*

1. _____	_____ : _____	_____
2. _____	_____ : _____	_____
3. _____	_____ : _____	_____

Fasteners \_\_\_\_\_  
 \_\_\_\_\_

List of Photographs and Identification Numbers  
 \_\_\_\_\_  
 \_\_\_\_\_

**FIG. X2.1 Case Study Report Sheet (continued)**







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## Standard Terminology Relating to Metallic Coated Steel Products<sup>1</sup>

This standard is issued under the fixed designation A 902; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon ( $\epsilon$ ) indicates an editorial change since the last revision or reapproval.

### 1. Scope\*

1.1 This standard is a compilation of terminology related to metallic coatings used in the steel industry, and to the steel on which the coatings are applied. Terms that are generally understood or adequately defined in other readily available sources are not included.

1.2 When a term is used in an ASTM document for which Committee A05 is responsible it is included herein only when judged, after review by Subcommittee A05.18, to be a generally usable term.

1.3 Definitions that are identical to those published by other ASTM committees or other standards organizations are identified with the ASTM standard designation (for example, Terminology B 374) or with the abbreviation of the name of the organization.

1.4 A definition is a single sentence with additional information included in notes. The year the definition was adopted, or the year of latest revision, is appended. The responsible subcommittee reviews the definition for each term at five-year intervals, and prepares revisions as needed.

### 2. Referenced Documents

#### 2.1 ASTM Standards:

- A 641/A 641M Specification for Zinc-Coated (Galvanized) Carbon Steel Wire<sup>2</sup>
- B 374 Terminology Relating to Electroplating<sup>3</sup>
- D 2092 Guide for Preparation of Zinc-Coated Galvanized Steel Surfaces for Painting<sup>4</sup>

### 3. Terminology

#### 3.1 Definitions:

**aluminized coating**, *n*—a coating on steel of aluminum alloy, typically 89 to 99 % aluminum; generally applied to steel sheet and wire by the hot-dip process. (1994)

**barb**, *n*—as related to *barbed wire*, a short length of wire, with exposed ends cut on a bias to produce sharp points. (1995)

**barbed wire**, *n*—a fabricated wire product consisting of two line wires twisted to form a two-wire strand, into which 2-point or 4-point barbs are tightly wrapped and locked into place at specified intervals. (1995)

**base metal**, *n*—as related to *metallic-coated steel*, the steel to which the coating is applied, as distinguished from the coating metal. (1990)

**batch coating**, *n*—of *metallic coated steel products*, the process of discontinuous-sequential passage of steel articles through the various steps of the coating process, such as, cleaning, pickling, fluxing, and coating. (1995)

**breaking strength**, *n*—as related to *wire*, the maximum force developed prior to fracture during tension testing of wire and wire products.

DISCUSSION—In testing of stranded wire products, the maximum force may be developed after fracture of one or more individual wires. (1993)

**carbon steel**, *n*—steel for which (1) no minimum content is specified for chromium, cobalt, molybdenum, nickel, titanium, tungsten, or zirconium, or any other element added to obtain a desired alloying effect; (2) for which the specified minimum for copper does not exceed 0.40 %; (3) for which the specified maximum for any of the following elements does not exceed these percentages: manganese 1.65 %, silicon 0.60 %, or copper 0.60 %; and (4) in which the incidental content of the following elements does not exceed these percentages: nickel, 0.25 %; chromium, 0.20 %; and molybdenum, 0.06 %.

DISCUSSION—Carbon steels typically contain small quantities of certain residual elements from the feed materials. When the quantity of such retained elements exceeds the values listed in (4) above, the characteristics of the steel may differ from that of carbon steel without those elements to a degree that the steel may be unsatisfactory for the intended use. (1998)

**cast analysis**, *n*—Deprecated term. Use preferred term **heat analysis**. (1997)

**check analysis**, *n*—Deprecated term. Use preferred term **product analysis**. (1990)

<sup>1</sup> This terminology is under the jurisdiction of ASTM Committee A05 on Metallic-Coated Iron and Steel Products and is the direct responsibility of Subcommittee A05.18 on Editorial and Terminology.

Current edition approved April 10, 2003. Published June 2003. Originally approved in 1990. Last previous edition approved in 2002 as A 902 – 02.

<sup>2</sup> *Annual Book of ASTM Standards*, Vol 01.06.

<sup>3</sup> *Annual Book of ASTM Standards*, Vol 02.05.

<sup>4</sup> *Annual Book of ASTM Standards*, Vol 06.02.

**chemical treatment**, *n*—a passivating treatment normally applied to metallic coatings to retard the formation of corrosion products (storage stain) during shipment and storage.

DISCUSSION—The inhibiting characteristics of the treatment are limited and if a lot becomes wet in shipment or storage, the product should be used or dried immediately. Chemical treatment may be undesirable because of further processing, such as phosphatizing or painting. (1991)

**continuous coating**, *n*—of *metallic coated steel products*, the process of uninterrupted passage of long lengths of steel products, usually steel sheet or wire, through the various processing steps such as cleaning, annealing, and coating.

DISCUSSION—Continuous coating involves the use of equipment that is capable of joining long lengths of product without stoppage of the coating process. (1995)

**delamination**, *n*—as related to *metallic coated steel*, the separation of a coating (either full or partial thickness) from underlying layers; the separation can occur in small localized areas or large areas of surface.

DISCUSSION—*Flaking*, *peeling*, and *spalling* are colloquial terms sometimes used to describe the separation. (1997)

**differentially coated sheet**, *n*—metallic coated sheet with specified difference in weight (mass) of metallic coating between the two surfaces. (1991)

**electrolytic process**, *n*—the application of a metallic coating on a steel product by passing an electric current through a chemical solution in which the product is immersed; the coating may be applied in a continuous process or a batch process. (1995)

**embrittlement**, *n*—the loss or partial loss of ductility in a steel, such that failure is characteristically by fracture without appreciable deformation. (1990)

**extra smooth sheet**, *n*—product produced by cold rolling (skin passing) the metallic coated sheet with a small reduction in thickness to smooth the surface and impart resistance to stretcher strain. (Syn. **skin passed sheet**)

DISCUSSION—Extra smooth is frequently specified when fluting or stretcher strains may be a hazard. Extra smooth may not be available in all coating types or weights (masses). (1991)

**fabricator**, *n*—as related to *corrugated metal pipe*, (1) the organization that produces the finished pipe, or (2) for structural plate pipe, the organization that processes flat sheets and other items needed for the field assembly of the finished products. (1990)

*flaking*—See **delamination**. (1994)

**galvanized coating**, *n*—a coating of virtually pure zinc on steel, applied by various methods or processes including hot-dip process and electrodeposition (electrolytic process).

DISCUSSION—For hot-dipped galvanized coatings, the molten bath is typically at least 99 % zinc; as applied to the steel, the coating typically contains intermetallic layers of zinc-iron alloys adjacent to the steel surface. Other methods of applying the zinc coating include metal spraying (metallizing), sherardizing, vacuum deposition, and mechanical deposition, but there is not general agreement that all produce a

“galvanized coating”. There is general agreement that the coating produced by application of zinc-rich paint is not a “galvanized coating”. (1999)

**galvannealed coating**, *n*—a coating on steel of zinc-based alloy, containing about 6 to 15 % iron, produced by hot-dip immersion in a high-zinc content coating bath, followed by heating the steel to induce diffusion alloying between the molten zinc coating and the steel. (1994)

**grain pattern**, *n*—Synonym for **spangle**. (1999)

**heat**, *n*—a specific lot of material representing a single melt of steel produced to a specified chemical analysis. (1991)

**heat analysis**, *n*—the chemical composition of a specific production lot of liquid steel. (2003)

DISCUSSION—The sample on which the analysis is performed is usually taken from the molten steel.

**hot-dip process**, *n*—the application of a metallic coating on a steel product by immersion of the product in a bath of the molten metal which forms the coating; the coating may be applied in a continuous process or a batch process. (1995)

**ladle analysis**, *n*—Deprecated term. Use preferred term **heat analysis**. (1997)

**lot**, *n*—a finite quantity of a given product, produced under conditions that are considered uniform for sampling purposes. (1995)

DISCUSSION—In the case of metallic-coated iron or steel products, the conditions which may be considered necessary for a single lot are similar units, coating at approximately the same time, in the same manner, in a single coating bath. Consideration must also be given to the uniformity of the iron or steel product to which the coating is applied, such as being from a single heat. For material sampled after shipment from the manufacturer’s or coater’s facility (where the heat or processing identification may have been lost), a lot may consist of all similar material in a given shipment.

**manufacturer**, *n*—as related to *corrugated metal pipe*, the organization that produces the metal sheet from which pipe is made. (1990)

**mechanical polishing**, *n*—of *metallic coatings*, the loosening and detachment of superficial, small particles of coating metal during processing or testing, due to mechanical abrasion. (1994)

**minimum thickness**, *n*—of *steel sheet*, an ordering designation which indicates that the applicable tolerance for thickness is all plus from the ordered thickness.

DISCUSSION—As an example, the thickness tolerance for sheet material ordered as 0.035 in. minimum is +0.008 in., –0.000 in., and the allowable range of thickness is 0.035 in. to 0.043 in. [or ordered as 1.32 mm minimum is +0.26 mm, –0.00 mm, and the allowable range of thickness is 1.32 mm to 1.58 mm]. The total thickness tolerance for sheet ordered to minimum thickness is usually twice the tabular tolerance for sheet ordered to nominal thickness. (1997)

**nominal thickness**, *n*—of *steel sheet*, an ordering designation which indicates that the applicable tolerance for thickness is both plus and minus from the ordered thickness.

DISCUSSION—As an example, the thickness tolerance for sheet material ordered as 0.035 in. nominal is +0.004 in., –0.004 in., and the allowable range of thickness is 0.031 in. to 0.039 in. [or ordered as 1.32

mm nominal is +0.13 mm, -0.13 mm, and the allowable range of thickness is 1.19 mm to 1.45 mm]. In some cases, the purchaser may specify the tolerances unequally, such as +0.006 in., -0.002 in. [or +0.20 mm, -0.06 mm]. The total tolerance is always the same, whether indicated equally or unequally, plus and minus. (2003)

**oiled**, *adj*—describing a coating applied to metallic coated steel sheet alone or in addition to chemical treatment for further protection against the onset of storage corrosion; the oil coating is intended as a corrosion inhibitor only and not as a rolling or drawing lubricant. (2001)

*peeling*—See **delamination**. (1994)

**phosphatized**, *adj*—pertains to chemical treatment, in a phosphate solution, of uncoated and metallic coated sheet to prepare the surface for painting without further treatment except normal cleaning. (Syn. **phosphated**, **phosphate coated**)

DISCUSSION—This is a surface treatment only and other characteristics of the metallic coating remain unchanged on phosphatized sheet. Cleaning procedures are described in Practice D 2092. (1993)

**powdering**, *n*—*as related to metallic coatings*, microcracking and fine particle separation of generally brittle coatings when the coating is severely stressed, resulting in a fine powder residue. (1994)

**producer**, *n*—*as related to corrugated metal pipe*, deprecated term. Use preferred term **manufacturer**. (1990)

**product analysis**, *n*—a chemical analysis of the semifinished or finished steel. (1993)

**purchaser**, *n*—*as related to corrugated metal pipe*, the person or agency that purchases the finished pipe. (1990)

**sample**, *n*—a portion of the material in a lot, selected according to a specific sampling plan, intended to represent the lot.

DISCUSSION—The sample may consist of one or more discrete units, or may be one or more portions selected from one or more large units (such as from a coil of wire or steel sheet). (1994)

**seam**, *n*—*in wire*, a longitudinal discontinuity that extends radially into the wire from its surface.

DISCUSSION—The discontinuity may appear as a crack. The discontinuity can develop during solidification, rolling, or the wire drawing operation as a result of dynamic strain aging. A seam originating in wire drawing is also known as a split. (1992)

**skin passed sheet**, *n*—Synonym for **extra smooth sheet**. (1991)

*spalling*—See **delamination**. (1997)

**spangle**, *n*—*in hot-dip coatings*, the crystalline structure that develops on a metallic-coated surface when the molten coating metal solidifies, especially on steel sheet and articles coated after fabrication. (Syn. **grain pattern**) (1999)

**specimen**, *n*—a portion of a sample on which a specific test is performed. (Syn. **test specimen**) (1994)

**stabilized steel**, *n*—a steel which has been treated with one or more carbide- or nitride-forming elements such as titanium, vanadium, or columbium, to control the level of interstitial solute elements (carbon or nitrogen) in the steel. (2001)

DISCUSSION—Stabilized steel has improved formability as compared to steel that has not been stabilized. Also, stabilized steels are non-aging

*strand*—See **wire strand**. (1995)

**steel sheet designation**, *n*—a title given to a steel sheet product, associated with unique requirements for chemical composition and with mandatory or nonmandatory (typical) mechanical properties; the specific titles include *commercial steel*, *drawing steel*, *deep drawing steel*, *extra deep drawing steel*, *forming steel*, *high strength-low alloy steel*, *high temperature steel*, and *structural steel*.

DISCUSSION—These designations are abbreviated as *CS*, *DS*, *DDS*, *EDDS*, *FS*, *HSLAS*, *HTS* and *SS*, respectively. Designations *HSLAS* and *SS* have mandatory mechanical property requirements, and specifications for the other designations contain nonmandatory tabulations of typical mechanical properties. (1997)

**temper**, *n*—*as related to metallic-coated steel wire*, stiffness or resistance to bending, typically described by reference to tensile strength.

DISCUSSION—Temper is usually described by terms such as *soft*, *medium*, and *hard*, with related tensile strengths as shown in a specification, such as Specification A 641/A 641M. (1990)

**terne coating**, *n*—a lead-based coating, most commonly applied to steel sheet; the coating typically contains from 3 to 20 % tin, and other minor (<1 %) alloying elements may be present. (1994)

**wire**, *n*—a single continuous length of metal, generally with a circular cross section, that is cold drawn from wire rod or bar.

DISCUSSION—Wire is distinguished from cold-drawn bar by being in the form of a coil or spool. (1994)

**wire rod**, *n*—a hot-rolled, single continuous length of metal, generally of circular cross section, hot wound or laid into irregular coils, considered a semifinished product, primarily intended for wire drawing. (1994)

**wire rope**, *n*—a number of wire strands laid helically about an axis. (1994)

**wire strand**, *n*—a number of wires laid helically about an axis; may or may not contain a center wire. (1995)

**Zn-5 Al-MM coated wire**, *n*—steel wire-coated with either: (1) predominately Zn-5 Al-MM alloy as manufactured by the single-dip method, or (2) a Zn-Al-Fe intermetallic inner layer and a Zn-5 Al-MM alloy outer layer as manufactured by the double dip method. (1998)

3.2 *Abbreviations:*

CS—commercial steel

DDS—deep drawing steel

DS—drawing steel

EDDS—extra deep drawing steel

FS—forming steel

HSLAS—high strength-low alloy steel

HTS—high temperature steel

SS—Structural steel

Zn-5Al-MM—zinc-5 % aluminum-mischmetal alloy

#### 4. Keywords

definitions; metallic-coated steel materials; steel products – metallic coated; terminology

## APPENDIXES

### (Nonmandatory Information)

#### X1. RECOMMENDED KEYWORDS FOR COMMITTEE A05 STANDARDS

X1.1 The following keywords are recommended for use as determined appropriate by the subcommittee responsible for the standard. Other keywords may be used as necessary.

##### X1.1.1 *General for All Standards:*

aluminum coatings  
 coatings—aluminum  
 coatings—55 % aluminum-zinc alloy  
 coatings—metallic  
 coatings—zinc  
 coatings—zinc-5 % aluminum alloy  
 coatings—zinc-5 % aluminum-mischmetal  
 galvanized coatings [see *zinc coatings*]  
 steel products—metallic coated  
 zinc coatings  
 zinc-5 % aluminum alloy coatings

##### X1.1.2 *Related to Testing:*

coating thickness  
 coating weight [mass]

##### X1.1.3 *Related to Steel Sheet:*

aluminum coatings—steel sheet  
 coatings—composite  
 coatings—polymer  
 coatings—terne metal  
 coatings—zinc-5 % aluminum-mischmetal  
 coatings—zinc-5 % aluminum-magnesium  
 electrodeposited coatings  
 metallic coated steel sheet  
 polymer coated steel sheet  
 polymer coatings  
 steel sheet—aluminum coated  
 steel sheet—55 % aluminum-zinc alloy coated  
 steel sheet—polymer coated  
 steel sheet—terne coated  
 steel sheet—zinc coated (electrolytic process)

steel sheet—zinc coated (hot dip process)  
 steel sheet—zinc-5 % aluminum-mischmetal coated  
 steel sheet—zinc-5 % aluminum-magnesium coated  
 zinc coatings—steel sheet

##### X1.1.4 *Related to Steel Wire:*

aluminum coatings—steel wire products  
 copper clad steel wire  
 fencing material  
 fences/fencing—chain link  
 fences/fencing—farm/field  
 metallic coated steel wire  
 steel wire—aluminum coated  
 steel wire—copper clad  
 steel wire—zinc coated  
 steel wire—zinc-5 % aluminum-mischmetal coated  
 steel wire rope  
 steel wire strand

zinc coatings—steel wire products

##### X1.1.5 *Related to Steel Fabricated Products:*

coatings—zinc  
 steel hardware—zinc coated  
 steel products—metallic coated  
 zinc coatings—steel products

##### X1.1.6 *Related to Steel Pipe:*

corrugated steel sewer/drain pipe  
 culvert pipe  
 drainage pipe  
 polymer coated steel pipe  
 polymer coatings  
 sewer and drainage pipe  
 steel pipe—corrugated  
 steel pipe—sewers/drainage systems  
 storm sewer/drainage pipe  
 structural design

#### X2. TERMINOLOGY SPECIFIC TO INDIVIDUAL COMMITTEE A05 STANDARDS

X2.1 The following terms are defined in individual standards under the jurisdiction of Committee A05, and are applicable only to the specific document (or documents) in which the term is defined. Definitions are not necessarily the same when a term is listed in two or more documents.

##### X2.2 **Referenced Documents**

###### X2.2.1 *ASTM Standards:*

A 123/A 123M Specification for Zinc Hot-Dip Galvanized Coatings on Iron and Steel Products  
 A 143 Practice for Safeguarding Against Embrittlement of Hot-Dip Galvanized Structural Steel Products and Procedure for Detecting Embrittlement

A 308 Specification for Steel Sheet, Terne Lead-Tin Alloy Coated by the Hot-Dip Process

A 390 Specification for Zinc-Coated Galvanized Steel Poultry Fence Fabric Hexagonal and Straight Line

A 475 Specification for Zinc-Coated Steel Wire Strand

A 591/A 591M Specification for Steel Sheet, Electrolytic Zinc-Coated, for Light Coating Weight Mass Applications

A 653/A 653M Specification for Steel Sheet, Zinc-Coated Galvanized or Zinc-Iron Alloy-Coated Galvannealed by the Hot-Dip Process

A 740 Specification for Hardware Cloth (Woven or Welded Galvanized Steel Wire Fabric)

A 742/A 742M Specification for Steel Sheet, Metallic Coated and Polymer Precoated for Corrugated Steel Pipe

A 754/A 754M Test Method for Coating Weight Mass of Metallic Coatings on Steel by X-Ray Fluorescence

A 755/A 755M Specification for Steel Sheet, Metallic Coated by the Hot-Dip Process and Prepainted by the Coil-Coating Process for Exterior Exposed Building Products

A 760/A 760M Specification for Corrugated Steel Pipe, Metallic-Coated for Sewers and Drains

A 761/A 761M Specification for Corrugated Steel Structural Plate, Zinc-Coated, for Field-Bolted Pipe, Pipe-Arches, and Arches

A 762/A 762M Specification for Corrugated Steel Pipe, Polymer Precoated for Sewers and Drains

A 796/A 796M Practice for Structural Design of Corrugated Steel Pipe, Pipe-Arches, and Arches for Storm and Sanitary Sewers and Other Buried Applications

A 807/A 807M Practice for Installing Corrugated Steel Structural Plate Pipe for Sewers and Other Applications

A 809 Specification for Aluminum-Coated (Aluminized) Carbon Steel Wire

A 818 Specification for Coppered Carbon Steel Wire

A 824 Specification for Metallic-Coated Steel Marcellled Tension Wire for Use With Chain Link Fence

A 849 Specification for Post-Applied Coatings, Pavings, and Linings for Corrugated Steel Sewer and Drainage Pipe

A 855/A 855M Specification for Zinc-5 % Aluminum-Mischmetal Alloy-Coated Steel Wire Strand

A 875/A 875M Specification for Steel Sheet, Zinc-5 Aluminum Alloy-Coated by the Hot-Dip Process

A 885/A 885M Specification for Steel Sheet, Zinc and Aramid Fiber Composite Coated for Corrugated Steel Sewer, Culvert, and Underdrain Pipe

A 929/A 929M Specification for Steel Sheet, Metallic-Coated by the Hot-Dip Process for Corrugated Steel Pipe

A 930 Practice for Life-Cycle Cost Analysis of Corrugated Metal Pipe Used for Culverts, Storm Sewers, and Other Buried Conduits

A 964/A 964M Specification for Corrugated Steel Box Culverts

A 974 Specification for Welded Wire Fabric Gabions and Gabion Mattresses (Metallic Coated or Polyvinyl Chloride (PVC) Coated)

A 975 Specification for Double-Twisted Hexagonal Mesh Gabions and Revet Mattresses (Metallic Coated Steel Wire or Metallic Coated Steel Wire with Polyvinyl Chloride (PVC) Coating)

A 978/A 978M Specification for Composite Ribbed Steel Pipe, Precoated and Polyethylene Lined for Gravity Flow Sanitary Sewers, Storm Sewers, and Other Special Applications

A 979/A 979M Specification for Concrete Pavements and Linings Installed in Corrugated Steel Structures in the Field

X2.3 Terms marked with a double asterisk (\*\*) in X2.4 are also defined in 3.1 of Terminology A 902. The definition in the other document(s) listed is not necessarily the same as the definition in Terminology A 902.

X2.4 Terms:

**acrylic**—A 755

**aluminum-coated (aluminized) wire**—A 809

**annealed coppered wire**—A 818

**annealed-in-process wire**—A 818

**arch**—A 761/A 761M, A 798/A 798M, A 807/A 807M

**average coating thickness**—A 123/A 123M

**averaging time**—A 754

**bedding**—A 796/A 796M, A 798/A 798M, A 807/A 807M

**black**—A 123/A 123M

**bottom side**—A 755

**box culvert**—A 761/A 761M, A 964/A 964M

**carbon steel\*\***—A 809, A 818

**chalking**—A 755

**chick fence fabric**—A 390

**coating thickness grade**—A 123/A 123M

**coil coating**—A 755

**common costs**—A 930

**composite**—A 978/A 978M

**composite coating**—A 885/A 885M

**contractor**—A 979/A 979M

**conversion coating**—A 755

**coppered steel wire**—A 818

**crown**—A 964/A 964M

**deltoid shape**—A 978/A 978M

**differentially coated\*\***—A 653/A 653M

**discount rate**—A 930

**double-twisted wire mesh**—A 975

**drainage project**—A 930

**edge wire**—A 975

**electrolytic nickel plate**—A 308

**embrittlement\*\***—A 143

**engineer**—A 979/A 979M

**epoxy**—A 755

**extruded liner**—A 978/A 978M

**fabricator\*\***—A 742/A 742M, A 760/A 760M, A 761/A 761M, A 762/A 762M, A 849/A 849M, A 885/A 885M, A 929/A 929M, A 979/A 979M

**fade**—A 755

**fastener**—A 975

**flat plate**—A 761/A 761M

**fluorocarbon**—A 755

**future costs**—A 930

**gabion**—A 974, A 975

**gabion mattress**—A 974

**gloss**—A 755

**hard drawn wire**—A 818

**hardware cloth**—A 740

**haunch**—A 796/A 796M, A 798/A 798M, A 807/A 807M, A 964/A 964M

**high strength-low alloy steel, Type A sheet**—A 653/A 653M

**high strength-low alloy steel, Type B sheet**—A 653/A 653M

**inflation**—A 930

**initial cost**—A 930

**invert**—A 796/A 796M, A 798/A 798M, A 807/A 807M

**lacing wire**—A 974, A 975

**lining**—A 849, A 979/A 979M

**maintenance cost**—A 930

- manufacturer\*\***—A 742/A 742M, A 760/A 760M, A 761/A 761M, A 762/A 762M, A 849/A 849M, A 885/A 885M, A 929/A 929M, A 979/A 979M
- marcelling**—A 824
- material category**—A 123/A 123M
- material service life**—A 930
- mesh size**—A 740
- mil**—A 755
- minimized coating structure**—A 760/A 760M, A 762/A 762M, A 875/A 875M, A 929/A 929M
- minimized spangle**—A 653/A 653M
- multi-specimen article**—A 123/A 123M
- netting**—A 390
- nonwoven fabric**—A 885/A 885M
- paint**—A 755
- pavement**—A 979/A 979M
- paving**—A 849
- pipe**—A 761/A 761M, A 796/A 796M, A 798/A 798M, A 807/A 807M
- pipe, horizontal ellipse**—A 761/A 761M
- pipe, vertically elongated**—A 761/A 761M
- pipe-arch**—A 761/A 761M, A 796/A 796M, A 798/A 798M, A 807/A 807M
- plastisol**—A 755
- polyester**—A 755
- polyurethane**—A 755
- post coating**—A 849
- poultry-and-garden fence fabric**—A 390
- primer**—A 755
- project design life**—A 930
- purchaser\*\***—A 742/A 742M, A 760/A 760M, A 761/A 761M, A 762/A 762M, A 849/A 849M, A 885/A 885M, A 929/A 929M, A 979/A 979M
- regular coating structure**—A 760/A 760M, A 762/A 762M, A 875/A 875M, A 929/A 929M
- regular spangle**—A 653/A 653M, A 792/A 792M
- rehabilitation cost**—A 930
- replacement cost**—A 930
- response time**—A 754
- revet mattress**—A 975
- rise**—A 964/A 964M
- roll former**—A 755
- sample\*\***—A 123/A 123M
- selvedge wire**—A 975
- shell**—A 964/A 964M
- silicone polyester**—A 755
- single-specimen article**—A 123/A 123M
- span**—A 964/A 964M
- spangle-free**—A 653/A 653M
- special shape**—A 761/A 761M
- specimen\*\***—A 123/A 123M
- specimen coating thickness**—A 123/A 123M
- spiral binder**—A 974
- standards**—A 754
- stiffener**—A 974, A 975
- stiffeners**—A 964/A 964M
- strand\*\***—A 475, A 855/A 855M
- structural plate**—A 761/A 761M
- substrate**—A 754
- surface treatment**—A 591/A 591M
- temper\*\***—A 809
- terminal value**—A 930
- terne metal**—A 308
- terne-coated sheet**—A 308
- test article**—A 123/A 123M
- time constant**—A 754
- top side**—A 755
- underpass**—A 807/A 807M
- unit weight**—A 964/A 964M
- vehicular underpass**—A 761/A 761M
- wash coat**—A 755
- welded wire fabric**—A 974
- x-ray fluorescence**—A 754
- zinc-iron alloy**—A 653/A 653M

## SUMMARY OF CHANGES

This section identifies the location of selected changes to this terminology. For the convenience of the user, Committee A05 has highlighted those changes that may impact the use of this terminology. This section may also include descriptions of the changes or reasons for the changes, or both.

A 902 - 03:

(1) Revised the *Discussion* for the definition nominal thickness.

(2) Revised the definition of heat analysis.

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# Standard Specification for Steel Sheet, Coated by the Electrolytic Process for Applications Requiring Designation of the Coating Mass on Each Surface (General Requirements)<sup>1</sup>

This standard is issued under the fixed designation A 917; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

## 1. Scope

1.1 This specification covers hot-rolled and cold-rolled steel sheet coated by the electrolytic process. Coatings can be comprised of pure metals or metal alloys. For specific coatings, refer to Specifications A 879 and A 918.

1.2 The product shall be coated on one or both surfaces with equal or differential coating masses on the two surfaces. Sheet-coated with equal coating masses on each surface has similar levels of corrosion protection on each surface. Often, however, a higher level of corrosion protection is required on one surface than is required on the other. In these situations, one surface shall be specified with a heavier coating mass than the other. Either surface, when specified to be painted, will provide additional corrosion protection as compared to an unpainted surface.

1.3 This coating process has essentially no effect on the base metal mechanical properties, and use is permitted on any grade of hot-rolled or cold-rolled steel sheet. The coated sheet is available as Commercial Steel (CS), Drawing Steel (DS), Deep Drawing Steel (DDS), Extra-Deep Drawing Steel (EDDS), Structural Steel (SS) High-Strength Low-Alloy Steel (HSLAS), or High-Strength Low-Alloy Steel with Improved Formability (HSLAS-F).

1.4 The values stated in SI units are to be regarded as the standard.

## 2. Referenced Documents

### 2.1 ASTM Standards:

- A 90/A 90M Test Method for Weight [Mass] of Coatings on Iron and Steel Articles with Zinc or Zinc-Alloy Coatings<sup>2</sup>
- A 366/A 366M Specification for Commercial Steel (CS) Sheet, Carbon, (0.15 Maximum Percent) Cold-Rolled<sup>3</sup>
- A 370 Test Methods and Definitions for Mechanical Testing of Steel Products<sup>3</sup>
- A 568/A 568M Specification for Steel, Sheet, Carbon, and

- High-Strength, Low-Alloy, Hot-Rolled, and Cold-Rolled, General Requirements for<sup>3</sup>
- A 569/A 569M Specification for Steel, Carbon (0.15 Maximum, Percent), Hot-Rolled Sheet and Strip Commercial<sup>3</sup>
- A 570/A 570M Specification for Steel, Sheet and Strip, Carbon, Hot-Rolled, Structural Steel<sup>3</sup>
- A 591/A 591M Specification for Steel Sheet, Electrolytic Zinc-Coated, for Light Coating Mass Applications<sup>2</sup>
- A 607 Specification for Steel, Sheet and Strip, High-Strength, Low-Alloy, Columbium or Vanadium, or Both, Hot-Rolled and Cold-Rolled<sup>3</sup>
- A 611 Specification for Structural Steel (SS), Sheet, Carbon, Cold-Rolled<sup>3</sup>
- A 620/A 620M Specification for Drawing Steel (DS), Sheet, Carbon, Cold-Rolled<sup>3</sup>
- A 621/A 621M Specification for Forming Steel (FS), Sheet and Strip, Carbon, Hot-Rolled<sup>4</sup>
- A 622/A 622M Specification for Drawing Steel (DS), Sheet and Strip, Carbon, Hot-Rolled<sup>3</sup>
- A 715 Specification for Steel Sheet and Strip, High-Strength, Low-Alloy, Hot-Rolled, and Steel Sheet, Cold-Rolled, High-Strength, Low-Alloy, with Improved Formability<sup>3</sup>
- A 754/A 754M Test Method for Coating Weight [Mass] by X-Ray Fluorescence<sup>2</sup>
- A 879 Specification for Steel Sheet, Zinc-Coated by the Electrolytic Process for Applications Requiring Designation of the Coating Mass on Each Surface<sup>2</sup>
- A 902 Terminology Relating to Metallic-Coated Steel Products<sup>2</sup>
- A 918 Specification for Steel Sheet, Zinc-Nickel Alloy Coated by the Electrolytic Process for Applications Requiring Designation of the Coating Mass on Each Surface<sup>2</sup>
- A 963/A 963M Specification for Deep Drawing Steel (DDS), Sheet, Carbon, Cold-Rolled<sup>3</sup>
- A 969/A 969M Specification for Extra-Deep Drawing Steel (EDDS), Sheet, Carbon, Cold-Rolled<sup>3</sup>
- B 504 Test Method for Measurement of Thickness of Metallic Coatings by the Coulometric Method<sup>5</sup>

<sup>1</sup> This specification is under the jurisdiction of ASTM Committee A05 on Metallic Coated Iron and Steel Products and is the direct responsibility of Subcommittee A05.11 on Sheet Specifications.

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<sup>2</sup> *Annual Book of ASTM Standards*, Vol 01.06.

<sup>3</sup> *Annual Book of ASTM Standards*, Vol 01.03.

<sup>4</sup> Discontinued; See *1996 Annual Book of ASTM Standards*, Vol 01.03.

<sup>5</sup> *Annual Book of ASTM Standards*, Vol 02.05.

**3. Terminology**

3.1 *Definitions*—For definitions of terms and abbreviations used in this specification, see Terminology A 902.

**4. Ordering Information**

4.1 Ordering information for all products is shown in the individual product specifications.

**5. Coating Designation (Mass and Type)**

5.1 The following seven-character format shall be used to identify the coating mass required:

5.1.1 *First and Second Characters*—Minimum coating mass of the surface with the less critical surface quality requirements;

5.1.2 *Third Character*—A letter, as designated in the appropriate product specification, to denote the kind of coating; G for pure zinc and N for zinc-nickel alloy;

5.1.3 *Fourth and Fifth Characters*—Minimum coating mass of the surface with the more critical surface quality requirements;

5.1.4 *Sixth Character*—A letter, as designated in the appropriate product specification, to denote the kind of coating; G for pure zinc and N for zinc-nickel alloy;

5.1.5 *Seventh Character*—Either E or U, designating an exposed or unexposed application, respectively.

Example:	60	G	20	G	E
	↓	↓	↓	↓	↓
See Section:	5.1.1	5.1.2	5.1.3	5.1.4	5.1.5

NOTE 1—The terms “exposed” and “unexposed” describe the intended application as either hidden or exposed to view and is an indicator of the degree of freedom from surface imperfections that affect the cosmetic characteristics of the coated surface.

**6. Chemical Requirements**

6.1 The heat analysis of the steel shall conform to the requirements of the specification for the steel ordered or as specified by negotiations.

**7. Base Metal Requirements**

7.1 The steel shall conform to all of the requirements of the appropriate specification listed as follows for the steel ordered. Where reference is made to a combined standard (such as Specification A 569/A 569M), conformance shall be to the metric portion, using SI units of measurement as standard.

7.1.1 *Hot Rolled:*

7.1.1.1 *Commercial Steel (CS)*—Specification A 569/A 569M.

7.1.1.2 *Drawing Steel (DS)*—Specification A 622/A 622M.

7.1.1.3 *Structural Steel (SS)*—Specification A 570/A 570M.

7.1.1.4 *High-Strength Low-Alloy Steel (HSLAS)*—Specification A 607.

7.1.1.5 *High-Strength Low-Alloy Steel with Improved Formability (HSLAS-F)*—Specification A 715.

7.1.2 *Cold Rolled:*

7.1.2.1 *Commercial Steel (CS)*—Specification A 366/A 366M.

7.1.2.2 *Drawing Steel (DS)*—Specification A 620/A 620M.

7.1.2.3 *Deep Drawing Steel (DDS)*—Specification A 963/A 963M.

7.1.2.4 *Extra-Deep Drawing Steel (EDDS)*—Specification A 969/A 969M.

7.1.2.5 *Structural Steel (SS)*—Specification A 611.

7.1.2.6 *High-Strength Low-Alloy Steel (HSLAS)*—Specification A 607.

7.1.2.7 *High-Strength Low-Alloy Steel with Improved Formability (HSLAS-F)*—Specification A 715.

7.2 *Base Metal Specimens:*

7.2.1 Test specimens shall be prepared from finished material and tested in accordance with Test Methods and Definitions A 370.

7.2.2 In determining the base metal mechanical properties, base metal thickness shall be measured after stripping the coating from the ends of the specimen contacting the grips of the tension testing machine before testing.

7.2.3 When the percent elongation in the tension test is less than the specified minimum and any part of the fracture is outside the middle half of the gage length as scribed before the test, the test shall be discarded and a retest shall be permitted.

7.3 *Retests for Base Metal Mechanical Properties*—If one test fails for base metal mechanical requirements, retesting shall conform to the provisions of the applicable base metal specification.

7.4 The base metal requirements of this section apply to Specification A 591/A 591M.

**8. Coating Mass Requirements**

8.1 *Coating Mass:*

8.1.1 Coating mass shall conform to the requirements prescribed in the individual coating specification.

8.1.2 The mass of the coating is the single spot value on each surface of the sheet expressed in grams per square metre.

8.2 *Coating Mass Tests:*

8.2.1 *Test Method A 90/A 90M*—The weigh-strip-weigh method is a destructive test that determines coating mass by measuring the difference in weight between a coated and a stripped (uncoated) sample. If one surface is protected suitably during the initial stripping, coating mass can be determined for each surface independently. Conversion of the coating to coating thickness is only possible if the density of the coating is known precisely.

8.2.2 *Test Method A 754/A 754M*—Measurement by X-ray fluorescence is a nondestructive test that determines coating mass by converting X-ray fluorescence measurements to coating mass values. This test method is readily adaptable to the continuous monitoring of coating mass during the electroplating process. Thus, modern electroplating facilities are frequently equipped with X-ray fluorescence gages that provide feedback to control the coating mass. These devices are used as a basis for determining suitability for shipment provided that they have been calibrated properly.

8.2.3 *Test Method B 504*—Measurement of the coating mass by the coulometric method is a destructive test that determines coating mass or thickness, or both, electrochemically. This test method is rapid and versatile for lighter coating mass applications.

8.2.4 The referee method to be used shall be as agreed upon between the producer and the consumer. In the absence of such agreement, Test Method A 90/A 90M, the weigh-strip-weigh

method, shall be used as the referee method.

8.3 *Sampling for Coated Mass Test:*

8.3.1 One test specimen shall be taken from the lift of cut lengths or coils such that no portion of the specimen is closer than 25 mm to the edge of the as-received sheet.

8.3.2 The coating mass of this specimen shall conform to both the minimum and maximum values shown in the applicable coating specification for the coating mass specified. If either of these values is not met, the material represented shall be subject to retest in accordance with the procedures given in 9.4.

8.4 *Retest for Coating Mass Values:*

8.4.1 When it is desired to retest to determine compliance to the coating mass values, two test specimens shall be selected at random from the same lift of cut lengths or coil, such that no portion of either sample is closer than 25 mm from the as-received edges.

8.4.2 When tested, each of the two retest specimens shall conform to both the minimum and maximum values shown in the specification for the coating mass specified.

9. **Coating Bend Test Requirements**

9.1 For all steel designations other than structural steel, high-strength low-alloy steel and high-strength low-alloy steel with improved formability, the coated sheet shall be capable of being bent flat through 180° in any direction without flaking of the coating on the outside of bend only.

9.2 Coated cold-rolled structural steel sheet in Grades 25, 30, 33 Types 1 and 2, and 40 Types 1 and 2, and coated hot-rolled structural steel sheet in Grades 30, 33, 36 Types 1 and 2, 40, 45, 50, and 55 shall be capable of being bent through 180° in any direction without flaking of the coating on the outside of the bend only. The coating bend test inside diameter shall have a relationship to the thickness of the specimen as prescribed in Table 1. There is no coating bend test applicable to cold-rolled structural steel Grade 80.

9.3 Coated cold-rolled and hot-rolled high-strength low-alloy steel, and high-strength low-alloy steel with improved

formability sheet shall be capable of being bent through 180° in any direction without flaking of the coating on the outside of the bend only. The coating bend test inside diameter shall have a relationship to the thickness of the specimen as prescribed in Table 2.

9.4 Flaking of the coating within 6 mm of the edge of the bend specimen shall not be cause for rejection.

9.5 Coating bend test specimens shall be cut 50 to 100 mm wide. The specimen shall be cut not less than 50 mm from the edge of the test sheet.

9.6 Electrolytic coatings are usually tightly adherent, even when used for difficult forming operations. However, powdering is possible if the material is severely formed or coined during forming.

9.7 *Retests for Coating Bend Tests:*

9.7.1 If the specimen fails the coating bend test, two retests shall be taken on random samples from the same lot of any specific item.

9.7.2 Both retests must conform to the requirements of this specification.

10. **Certification**

10.1 When specified in the purchase order or contract, the purchaser shall be furnished with certification that samples representing each lot have been either tested or inspected as directed in this specification and the requirements have been met. When specified in the purchase order or contract, a report of the test results shall be furnished. The report shall include the purchase order number, the ASTM designation number, and the heat or lot number correlating the test results with the material represented.

11. **Keywords**

11.1 coatings, metallic; coatings, zinc; electrodeposited coatings; steel products; steel sheet; steel sheet-zinc coated; zinc coated (electrolytic process); zinc-coated iron/steel articles; zinc coatings

TABLE 1 Coating Bend Test for Structural Steel

Ratio of the Bend Diameter to the Thickness of the Specimen <sup>A</sup>						
Cold-Rolled Sheet, Grade <sup>B</sup>						
25	30	33 Types 1 and 2		40 Types 1 and 2		
1½	2	2½		3		
Hot-Rolled Sheet, Grade						
30	33	36 Types 1 and 2		40	45	50 55
1	1½	1½		2	2½	3 3

<sup>A</sup>These ratios are applicable for all coating designations.

<sup>B</sup>Grade 80 is not subject to any bend test requirement; therefore, there is no coating bend requirement for this grade.

TABLE 2 Coating Bend Test for High-Strength Low-Alloy Steel and High-Strength Low-Alloy Steel with Improved Formability

Ratio of the Bend Test Diameter to the thickness of the Specimen <sup>A</sup>					
High-Strength Low-Alloy Steel Sheet, Grade, Classes 1 and 2					
45	50	55	60	65	70
1½	2	2	2½	2½	3
High-Strength Low-Alloy Steel with Improved Formability Sheet, Grade					
	50	60	70	80	
	2	2½	3	3	

<sup>A</sup>Ratios are applicable for all coating designations.

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# Standard Specification for Steel Sheet, Zinc-Nickel Alloy Coated by the Electrolytic Process for Applications Requiring Designation of the Coating Mass on Each Surface<sup>1</sup>

This standard is issued under the fixed designation A 918; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

## 1. Scope

1.1 This specification covers zinc-nickel alloy coatings applied by the electrolytic process to hot-rolled and cold-rolled steel sheet. The coating has a smooth, spangle-free surface. The zinc-nickel-coated sheet covered in this specification is produced in a range of coating masses to provide coatings that are compatible with the anticipated service life required. The coating mass varies, from very thin coatings that are usually painted to provide good service, to relatively heavy masses that provide good corrosion resistance in the bare (unpainted) condition. The composition range is from 9 to 16 % nickel, by weight, with the balance being zinc.

1.2 The product shall be coated on one or both surfaces with equal or differential coating masses on the two surfaces. Sheet coated with equal coating masses on each surface has similar levels of corrosion protection on each surface. Often, however, a higher level of corrosion protection is required on one surface than is required on the other. In these situations, one surface shall be specified with a heavier coating mass than the other. Either surface, when specified to be painted, will provide additional corrosion protection as compared to an unpainted surface.

1.3 This coating process has essentially no effect on the base metal mechanical properties, and use is permitted on any grade of hot- or cold-rolled steel sheet. The coated sheet is available as Commercial Steel (CS), Drawing Steel (DS), Deep Drawing Steel (DDS), Extra-Deep Drawing Steel (EDDS), Structural Steel (SS), or High-Strength Low-Alloy Steel (HSLAS), or High-Strength Low-Alloy Steel with Improved Formability (HSLAS-F).

1.4 The values stated in SI units are to be regarded as the standard.

## 2. Referenced Documents

### 2.1 ASTM Standards:

A 754/A 754M Test Method for Coating Weight [Mass] by

X-Ray Fluorescence<sup>2</sup>

A 917 Specification for Steel Sheet, Coated by the Electrolytic Process for Applications Requiring Designation of the Coating Mass on Each Surface (General Requirements)<sup>2</sup>

E 1659 Test Methods for Chemical Analysis of Zinc-Nickel Alloy Electrolytically Coated on Steel Sheet<sup>3</sup>

## 3. Classification

3.1 Coatings shall be designated as in Specification A 917. The letter N shall be used to designate zinc-nickel coatings.

## 4. Ordering Information

4.1 Orders for products to this specification shall include the following information, as necessary to adequately describe the desired product:

4.1.1 Name of product (electrolytic zinc-nickel alloy-coated steel sheet).

4.1.2 ASTM designation and year of issue.

4.1.3 Base metal type (hot rolled or cold rolled).

4.1.4 Base metal designation {Commercial Steel (CS), Drawing Steel (DS), Deep Drawing Steel (DDS), Extra-Deep Drawing Steel (EDDS), High-Strength Low-Alloy Steel (HSLAS), or High-Strength Low-Alloy with Improved Formability (HSLAS-F)}.

4.1.5 Formability type, strength, grade, or class, or combination thereof, as required for structural or high-strength low-alloy steels.

4.1.6 Coating designation (see 3.1).

4.1.7 Surface treatments required (see Note 1).

NOTE 1—Steel sheet is available without surface treatment (dry) or with surface treatments designated as chemical treatment, oiled, or phosphatized. Unless otherwise specified sheet is furnished oiled.

4.1.8 Dimensions (show thickness (minimum or nominal), width, and length, if cut lengths).

4.1.9 Coil size (must include inside diameter, outside diameter, and maximum coil weight).

4.1.10 Application (part name and description).

4.1.11 Special requirements, if applicable.

<sup>1</sup> This specification is under the jurisdiction of ASTM Committee A05 on Metallic Coated Iron and Steel Products and is the direct responsibility of Subcommittee A05.11 on Sheet Specifications.

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<sup>2</sup> Annual Book of ASTM Standards, Vol 01.06.

<sup>3</sup> Annual Book of ASTM Standards, Vol 03.06.

4.1.12 Certification, if required, heat analysis and mechanical property report.

**5. Coating Mass**

5.1 Coating mass shall conform to the requirements for coating designation (mass and type) as given in Specification A 917 and in Table 1 for the specific coating designation. The mass of the coating is the single spot value on each surface of the sheet in grams per square metre.

5.2 *Coating Mass Tests:*

5.2.1 Test Methods E 1659 describes the weigh-strip-weigh method is a destructive test that determines coating mass by measuring the difference in weight between a coated and a stripped (uncoated) sample. If one surface is protected suitably during the initial stripping, coating mass can be determined for each surface independently. Conversion of the coating mass to coating thickness is possible only if the density of the coating is known precisely.

5.2.2 Coating thickness measurements by X-ray fluorescence (see Test Method A 754/A 754M) is a nondestructive test

**TABLE 1 Coating Masses for Steel Sheet, Zinc-Nickel Alloy-Coated by the Electrolytic Process<sup>A</sup>**

Coating Designation <sup>B</sup>	Surface, g/m <sup>2</sup>	
	Minimum	Maximum
00N	no coating	no coating
20N	20	40
30N	30	50
40N	40	60
50N	50	70

<sup>A</sup>The product shall be coated on at least one surface; therefore, the combination 00/00 shall not be specified.

<sup>B</sup>See Specification A 917.

method that determines coating mass by converting X-ray fluorescence measurements to coating mass values. This test method is readily adaptable to the continuous monitoring of coating mass during coating. Thus, modern electroplating facilities are frequently equipped with X-ray fluorescence gages that provide feedback to control the coating mass. These devices are used as a basis for determining the suitability for shipment provided that they have been calibrated properly in accordance with Test Method A 754/A 754M.

5.2.3 Sampling and retests for coating mass determinations shall be as given in Specification A 917.

5.2.4 The referee test methods for measurement of the coating mass are Test Methods E 1659.

**6. Coating Composition**

6.1 *Coating Composition Tests:*

6.1.1 The test for chemical determination of the coating composition by atomic absorption spectroscopy is a destructive test that requires stripping of the coating from a specimen. If one surface is protected suitably during the stripping, coating compositions can be determined for each surface independently.

6.1.2 Sampling and retests for coating composition determinations shall be as given in Specification A 917.

6.1.3 The referee test methods for determination of the coating composition are Test Methods E 1659.

**7. Keywords**

7.1 electrolytic coating; steel sheet-zinc nickel alloy coated; zinc-nickel alloy coated; zinc-nickel alloy coated steel sheet

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# Standard Specification for General Requirements for Steel Sheet, Metallic-Coated by the Hot-Dip Process<sup>1</sup>

This standard is issued under the fixed designation A 924/A 924M; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

## 1. Scope\*

1.1 This specification covers the general requirements that, unless otherwise specified in the product specification, apply to steel sheet in coils and cut lengths, metallic-coated on continuous lines by the hot-dip process. The product is intended for applications requiring corrosion resistance. The product specifications contain requirements for specific strength levels, heat resistance, paintability, or formability, or a combination thereof.

1.2 Subject to individual product specification provisions, steel sheet is available as Commercial Steel (CS) Types A, B, and C, Forming Steel (FS), Drawing Steel (DS), Deep Drawing Steel (DDS), Extra Deep Drawing Steel (EDDS), High Temperature Steel (HTS), Structural Steel (SS), and High Strength Low Alloy Steel (HSLAS). Steel sheet is produced with the following metallic coatings. Specific information on each of the following is contained in the individual product specification:

- 1.2.1 Zinc or zinc-iron alloy coated,
- 1.2.2 Zinc-5 % aluminum alloy coated,
- 1.2.3 55 % aluminum–zinc alloy coated,
- 1.2.4 Aluminum–coated, and
- 1.2.5 Terne (lead-tin alloy) coated.

1.3 Products covered by this general requirements specification are described in the following product standards: Specifications A 308; A 463/A 463M; A 653/A 653M; A 755/A 755M; A 792/A 792M; A 875/A 875M; and A 929/A 929M.

1.4 Metallic-coated steel sheet is produced to various coating designations, as shown in the individual product specifications. Except for differentially coated sheet, the coating is always expressed as the total coating of both surfaces.

1.5 In case of any conflict in requirements, the requirements of the individual product specifications shall prevail over those of this general specification.

1.6 The purchaser is permitted to specify additional requirements that do not negate any of the provisions of this general

specification or of the individual product specifications. Such additional requirements, the acceptance of which are subject to negotiation with the supplier, shall be included in the order information.

1.7 For purposes of determining conformance with this specification and the various product specifications referenced in 1.3, values shall be rounded to the nearest unit in the right-hand place of figures used in expressing the limiting values (except to the nearest 5 MPa for SI strength values) in accordance with the rounding method of Practice E 29.

1.8 Metallic-coated steel sheet covered by this specification is produced to thickness requirements expressed to 0.001 in. [0.01 mm] for both coils and cut lengths. The thickness is the total of the base steel and the coating.

1.9 The values stated in inch-pound units or SI units are to be regarded separately as standard. Within the text, the SI units are shown in brackets. The values stated in each system are not exact equivalents; therefore, each system must be used independently of the other.

1.10 This specification and some of the applicable product specifications are expressed in both inch-pound and SI units. However, unless the order specifies the applicable “M” specification designation (SI units), the product shall be furnished to inch-pound units.

1.11 The text of this specification references notes and footnotes that provide explanatory material. These notes and footnotes (excluding those in tables and figures) shall not be considered as requirements of the specification.

## 2. Referenced Documents

### 2.1 ASTM Standards:<sup>2</sup>

- A 90/A 90M Test Method for Weight [Mass] of Coating on Iron and Steel Articles with Zinc or Zinc-Alloy Coatings
- A 308 Specification for Steel Sheet, Terne (Lead-Tin Alloy) Coated by the Hot-Dip Process
- A 309 Test Method for Weight and Composition of Coating on Terne Sheet by the Triple-Spot Test

<sup>1</sup> This specification is under the jurisdiction of ASTM Committee A05 on Metallic-Coated Iron and Steel Products and is the direct responsibility of Subcommittee A05.11 on Sheet Specifications.

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<sup>2</sup> For referenced ASTM standards, visit the ASTM website, [www.astm.org](http://www.astm.org), or contact ASTM Customer Service at [service@astm.org](mailto:service@astm.org). For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

\*A Summary of Changes section appears at the end of this standard.

- A 361/A 361M Specification for Steel Sheet, Zinc-Coated (Galvanized) by the Hot-Dip Process for Roofing and Siding<sup>3</sup>
- A 370 Test Methods and Definitions for Mechanical Testing of Steel Products
- A 428/A 428M Test Method for Weight of Coating on Aluminum-Coated Iron or Steel Articles
- A 463/A 463M Specification for Steel Sheet, Aluminum-Coated, by the Hot-Dip Process
- A 653/A 653M Specification for Steel Sheet, Zinc-Coated, (Galvanized) or Zinc-Iron Alloy-Coated (Galvannealed) by the Hot-Dip Process
- A 700 Practices for Packaging, Marking, and Loading Methods for Steel Products for Domestic Shipment
- A 751 Test Methods, Practices, and Terminology for Chemical Analysis of Steel Products
- A 754/ A 754M Test Method for Coating Weight by X-Ray Fluorescence
- A 755/A 755M Specification for Steel Sheet, Metallic Coated by the Hot-Dip Process and Prepainted by the Coil-Coating Process for Exterior Exposed Building Products
- A 792/A 792M Specification for Steel Sheet, 55 % Aluminum-Zinc Alloy-Coated by the Hot-Dip Process
- A 875/A 875M Specification for Steel Sheet, Zinc-5 % Aluminum Alloy-Coated by the Hot-Dip Process
- A 902 Terminology Relating to Metallic-Coated Steel Products
- A 929/A 929M Specification for Steel Sheet, Metallic-Coated by the Hot-Dip Process for Corrugated Steel Pipe
- A 1030/A 1030M Practice for Measuring Flatness Characteristics of Coated Sheet Products
- E 29 Practice for Using Significant Digits in Test Data to Determine Conformance with Specifications
- E 376 Practice for Measuring Coating Thickness by Magnetic-Field or Eddy-Current (Electromagnetic) Test Methods
- 2.2 *Military Standards:*
- MIL-STD-129 Marking for Shipment and Storage<sup>4</sup>
- MIL-STD-163 Steel Mill Products Preparation for Shipment and Storage<sup>4</sup>
- 2.3 *Federal Standard:*
- Fed. Std. No. 123 Marking for Shipment (Civil Agencies)<sup>4</sup>

### 3. Terminology

3.1 *Definitions*—For definitions of items used in this specification, refer to Terminology A 902.

### 4. Ordering Information

4.1 Ordering information for all products are shown in the individual product specifications.

### 5. Chemical Composition

#### 5.1 Base Steel:

**TABLE 1 Product Analysis Tolerances**

Element	Limited or Maximum of Specified Element, %	Tolerance	
		Under Minimum Limit	Over Maximum Limit
Carbon	To 0.15, incl	0.02	0.03
	Over 0.15 to 0.40, incl	0.03	0.04
	Over 0.40 to 0.80, incl	0.03	0.05
Manganese	To 0.60, incl	0.03	0.03
	Over 0.60 to 1.15, incl	0.04	0.04
	Over 1.15 to 1.65, incl	0.05	0.05
Phosphorus	...	...	0.01
Sulfur	...	...	0.01
Silicon	To 0.30, incl	0.02	0.03
	Over 0.30 to 0.60	0.05	0.05
Copper	...	0.02	...
Titanium	To 0.10, incl	0.01 <sup>A</sup>	0.01
Vanadium	To 0.10, incl	0.01 <sup>A</sup>	0.01
	Over 0.10 to 0.25, incl	0.02	0.02
Columbium	Minimum only specified	0.01	...
	To 0.10, incl	0.01 <sup>A</sup>	0.01

<sup>A</sup>If the minimum of the range is 0.01 %, the under tolerance is 0.005 %.

5.1.1 Chemical composition requirements of the base steel are shown in the individual product specifications.

5.1.2 An analysis of each heat shall be made by the manufacturer to determine the percentage of carbon, manganese, phosphorus, sulfur, and any other elements specified or restricted by the individual product specification.

5.1.3 When desired, product analysis shall be made by the purchaser on finished product. The product analysis so determined shall meet the tolerances shown in Table 1.

5.1.3.1 Capped or rimmed steels are not technologically suited to product analysis due to the nonuniform character of their chemical composition, and therefore, the tolerances in Table 1 do not apply. Product analysis is appropriate on these steels only when misapplication is apparent.

5.1.3.2 Product analysis for phosphorus or sulfur is not technologically appropriate because of segregation of these elements in non-killed steels. Product analysis is appropriate only when misapplication is apparent.

5.1.3.3 Samples for product analysis shall be drillings through areas stripped free of coating. At least three pieces shall be selected, but if the product of more than one mill lift or coil is involved, at least six pieces shall be selected.

5.1.3.4 When supplying High-Strength Low-Alloy Steel (HSLA), some producers use one or more microalloying elements as strengthening agents or use alloy additions to effect inclusion control, or both. The producer shall be consulted for the specific chemical composition applied. If any alloying addition is known to be of concern to the user, the producer shall be notified of this concern.

5.1.4 *Method of Analysis*—The determination of chemical composition is permitted to be made by any test method, except in case of dispute, where the referee test methods listed in the section on test methods of Test Methods A 751 shall be used.

#### 5.2 Coating:

5.2.1 *Coating Analysis*—The nominal composition of the coating is described in the individual product specification.

5.2.2 *Method of Analysis*—The determination of chemical composition shall be made in accordance with acceptable chemical, spectrochemical, or other test methods.

<sup>3</sup> Withdrawn.

<sup>4</sup> Available from Standardization Documents Order Desk, Bldg. 4 Section D, 700 Robbins Ave., Philadelphia, PA 19111-5094, Attn: NPODS.



## 6. Tests for Mechanical Properties

6.1 Test specimens shall be prepared from finished metallic-coated product.

6.2 *Mechanical Properties-Base Metal*—When base metal mechanical properties are specified, tests shall be conducted in accordance with Test Methods A 370. Requirements for all mechanical properties are included in the individual product specifications.

6.2.1 *Tension Tests*—Specimens for base-metal tension tests shall be taken longitudinally, approximately midway between the center and edge of the product as rolled, and shall conform to the requirements for the sheet-type test specimen in the figure for rectangular tension test specimens of Test Methods A 370.

6.2.1.1 The determination of the yield strength and tensile strength values shall be based on the as-produced base-metal thickness that is obtained after stripping the coating from the ends of the specimen contacting the grips of the tension testing machine. The thickness measurement shall be made before testing on an end of the specimen that has been stripped free of coating.

## 7. Tests for Coating Properties

### 7.1 Coating Weight [Mass]:

7.1.1 Coating weight [mass] shall conform to the requirements prescribed in the individual product specifications (see 1.3).

7.1.2 The coating weight [mass] of equally coated product is the total amount on both sides of the sheet, expressed in ounces per square foot [grams per square metre] of sheet.

7.1.3 For differentially coated product, the coating weight [mass] on each surface is nominally one half of the stated coating designation.

7.2 *Coating Weight [Mass] Tests*—One of the following test methods shall be used:

#### 7.2.1 Weigh-Strip-Weigh Method:

7.2.1.1 The weigh-strip-weigh method, described in Test Methods A 90/A 90M, A 309, and A 428/A 428M, is a destructive test that determines coating weight [mass] by measuring the difference in weight [mass] between a coated and a stripped (uncoated) sample. If one surface is protected suitably during the initial stripping, coating weight [mass] can be determined for each surface independently.

7.2.1.2 Test specimens for product over 18 in. [450 mm] in width shall be taken from a representative sample piece approximately 1 ft [300 mm] in length by the associated width. Three test specimens shall be taken from the sample, one from the middle of the width and one from each edge. The edge samples shall not be taken closer than 2 in. [50 mm] from each edge. The test specimen shall have a minimum area of 5 in.<sup>2</sup> [3200 mm<sup>2</sup>].

7.2.1.3 For product 18 in. [450 mm] in width and narrower, only one test specimen is required. Specimens shall be at least 2 in. [50 mm] from the edge, when possible. For product narrower than 2.25 in. [60 mm] the test specimen shall be chosen to give a minimum area of 5 in.<sup>2</sup> [3200 mm<sup>2</sup>].

7.2.1.4 The triple-spot coating weight [mass] shall be the average of the determinations of the three tests done in accordance with the procedures in 7.2.1.2.

7.2.1.5 The minimum single-spot coating weight [mass] shall be that test result that is the lightest coating weight [mass], or in those cases where only one test is needed, it shall be that single test result.

7.2.1.6 The frequency of sampling shall be sufficient to adequately characterize the lot of material being tested.

#### 7.2.2 X-Ray Fluorescence Method:

7.2.2.1 The X-ray fluorescence method is a nondestructive test that determines coating weight [mass] by converting X-ray fluorescence measurements to coating weight [mass] values. X-ray fluorescence gages can be used as off-line laboratory instruments or as a means of continuous on-line testing for conformance to coating weight [mass] requirements, or both.

7.2.2.2 *Off-Line Testing*—X-ray fluorescence gages can be used as off-line laboratory instruments to test for coating weight [mass] provided that they have been calibrated in accordance with Test Method A 754/A 754M and use the sample test locations as described in 7.2.1.2 or 7.2.1.3.

7.2.2.3 *On-Line Testing*—When X-ray fluorescence gages are used for on-line testing, they shall be operated in accordance with Test Method A 754/A 754M. A minimum of five random full-width traverses shall be used to characterize each coil tested.

(a) The triple-spot coating weight [mass] of a coil shall be determined using the following procedure: from the individual edge, center, edge readings provided by the minimum five full width traverses, compute the average of one edge, the average of the center, and the average of the other edge. These three results shall then be averaged to obtain the triple-spot average of the coil.

(b) The minimum single-spot coating weight [mass] shall be the lightest coating weight [mass] obtained from the individual edge, center, edge measurements provided by the minimum five full width traverses (lightest of at least fifteen readings—five from one edge, five from the center, and five from the other edge).

7.3 *Coating Bend Test*—Refer to the individual product specification.

7.3.1 Coating bend test specimens shall be 2 to 4 in. [50 to 100 mm] wide. The specimen shall be cut not less than 2 in. [50 mm] from the edges of the test sheet.

## 8. Dimensions and Permissible Variations

8.1 The permissible variations for dimensions shall comply with the applicable limits in Tables 2-14.

### 8.2 Flatness Tolerances:

8.2.1 Flatness tolerances for sheet are contained in Table 10 and in Table 11 for sheet specified to restricted flatness.

8.2.2 Measurement techniques for flatness characteristics are described in Practice A 1030/A 1030M.

8.2.3 Two alternative methods for flatness determination are the use of I-Units and % Steepness. A description of these two alternative methods is contained in Practice A 1030/A 1030M.

8.2.3.1 The use of I-Units or % Steepness as a flatness standard is subject to negotiation between the purchaser and the producer.

**TABLE 2 Thickness Tolerances for Hot-Dip Metallic-Coated Sheet— $\frac{3}{8}$ -in. [10-mm] Minimum Edge Distance**

NOTE 1—The coated sheet thickness includes the base metal and coating and is measured at any point across the width of the coated sheet not less than  $\frac{3}{8}$  in. [10 mm] from a side edge.

NOTE 2—Regardless of whether total thickness tolerance is specified equally or unequally, over and under, the total tolerance shall be equal to twice the tabular tolerances.

NOTE 3—Micrometers used for measurement of thickness shall be constructed with anvils and spindles having minimum diameters of 0.188 in. [4.80 mm]. The tip of the anvil shall be flat or rounded with a minimum radius of curvature of 0.10 in. [2.55 mm] and the tip of the spindle shall be flat. Micrometers with conical tips shall not be used for thickness measurements of sheet steels.

Inch-Pound Units							
Specified Width, in.		Thickness Tolerances, Plus and Minus, in., for Specified Thickness, in. <sup>A</sup>					
Over	Through	Through 0.023	Over 0.023 Through 0.043	Over 0.043 Through 0.061	Over 0.061 Through 0.075	Over 0.075 Through 0.101	Over 0.101 Through 0.187
...	32	0.003	0.004	0.005	0.006	0.007	0.008
32	40	0.003	0.004	0.005	0.006	0.008	0.008
40	60	0.003	0.004	0.005	0.006	0.008	0.009
60	72	...	0.004	0.005	0.006	0.009	0.009

SI Units							
Specified Width, mm		Thickness Tolerances, Plus and Minus, mm, for Specified Thickness, mm <sup>B</sup>					
Over	Through	Through 0.4	Over 0.4 Through 1.0	Over 1.0 Through 1.5	Over 1.5 Through 2.0	Over 2.0 Through 2.5	Over 2.5 Through 5.0
...	1500	0.08	0.10	0.13	0.15	0.20	0.23
1500	...	...	0.10	0.13	0.15	0.23	0.23

<sup>A</sup>Thickness is measured at any point across the width not less than  $\frac{3}{8}$  in. from a side edge.

<sup>B</sup>Thickness is measured at any point across the width not less than 10 mm from a side edge.

**TABLE 3 Thickness Tolerances for Hot-Dip Metallic-Coated Sheet—1-in. [25-mm] Minimum Edge Distance**

NOTE 1—The coated sheet thickness includes the base metal and coating and is measured at any point across the width of the coated sheet not less than 1 in. [25 mm] from a side edge.

NOTE 2—Regardless of whether total thickness tolerance is specified equally or unequally, over and under, the total tolerance shall be equal to twice the tabular tolerances.

NOTE 3—Micrometers used for measurement of thickness shall be constructed with anvils and spindles having minimum diameters of 0.188 in. [4.80 mm]. The tip of the anvil shall be flat or rounded with a minimum radius of curvature of 0.10 in. [2.55 mm] and the tip of the spindle shall be flat. Micrometers with conical tips shall not be used for thickness measurements of sheet steels.

Inch-Pound Units				
Specified Widths, in.	Thickness Tolerance, Plus and Minus, in., for Specified Thickness, in.			
	0.061 and thinner	Over 0.061 to 0.075, inclusive	Over 0.075 to 0.101, inclusive	Over 0.101 to 0.187, inclusive
To 40, inclusive	0.002	0.003	0.006	0.006
Over 40 to 60, inclusive	0.002	0.003	0.006	0.007
Over 60 to 72, inclusive	0.002	0.003	0.007	0.007

SI Units				
Specified Widths, mm	Thickness Tolerance, Plus and Minus, mm, for Specified Thickness, mm			
	1.5 and thinner	Over 1.5 to 2.0, inclusive	Over 2.0 to 2.5, inclusive	Over 2.5 to 5.0, inclusive
To 1500, inclusive	0.05	0.08	0.15	0.18
Over 1500	0.05	0.08	0.18	0.18

8.2.3.2 Measurement techniques for I-Units and % Steepness and rejection limits are subject to negotiation between the purchaser and producer.

**TABLE 4 Width Tolerances for Hot-Dip Metallic-Coated Sheet, Coils, and Cut Lengths, Not Resquared**

Inch-Pound Units		
Specified Width, in.		Tolerance Over Specified Width, No Tolerance Under, in.
Over	Through	
12	30	$\frac{1}{8}$
30	48	$\frac{3}{16}$
48	60	$\frac{1}{4}$
60	72	$\frac{5}{16}$

SI Units		
Specified Width, mm		Tolerance Over Specified Width, No Tolerance Under, mm
Over	Through	
300	600	3
600	1200	5
1200	1500	6
1500	1800	8

## 9. Number of Tests and Retests

9.1 *Number of Tests*—The frequency of tests by the producer shall be adequate to ensure conformance of the lot. The producer and user shall agree to a frequency other than that normally used by the producer.

### 9.2 *Number of Retests:*

9.2.1 Retests may be permitted if test method variability, as described in 9.2.2, is believed to be a cause of the out-of-specification test result. Retests are also permitted under the criteria described in 9.2.3.

9.2.2 Test method variability is considered to be a factor if test results on an original test specimen are within 2 ksi [15 MPa] of the required tensile strength, within 1 ksi [5 MPa] of the required yield strength, within 2 % of the required elongation, or within 0.05 oz/ft<sup>2</sup> [15 g/m<sup>2</sup>] of the specified coating

**TABLE 5 Length Tolerances for Hot-Dip Metallic-Coated Sheet, Cut Lengths, Not Resquared**

Inch-Pound Units		
Specified Length, in.		Tolerance Over Specified Length, No Tolerance Under, in.
Over	Through	
12	30	1/8
30	60	1/4
60	96	1/2
96	120	3/4
120	156	1
156	192	1 1/4
192	240	1 1/2
240	...	1 3/4
SI Units		
Specified Length, mm		Tolerance Over Specified Length, No Tolerance Under, mm
Over	Through	
300	1500	6
1500	3000	20
3000	6000	35
6000	...	45

**TABLE 6 Camber Tolerances for Hot-Dip Metallic-Coated Sheet**

NOTE 1—Camber is the greatest deviation of a side edge from a straight line, the measurement being taken on the concave side with a straightedge.  
 NOTE 2—The camber tolerances for sheet in cut lengths, not resquared, are as shown in this table.

Inch-Pound Units		
For Coils Over 12 in. in Width		
Cut Length, ft		Camber Tolerance, <sup>A</sup> in.
Over	Through	
...	4	1/8
4	6	3/16
6	8	1/4
8	10	5/16
10	12	3/8
12	14	1/2
14	16	5/8
16	18	3/4
18	20	7/8
20	30	1 1/4
30	40	1 1/2
SI Units		
For Coils Over 300 mm in Width		
Cut Length, mm		Camber Tolerance, <sup>B</sup> mm
Over	Through	
...	1200	4
1200	1800	5
1800	2400	6
2400	3000	8
3000	3700	10
3700	4300	13
4300	4900	16
4900	5500	19
5500	6000	22
6000	9000	32
9000	12 200	38

<sup>A</sup>The camber tolerance for sheet in coils is 1 in. in any 20 ft, except as shown in Table 14.  
<sup>B</sup>The camber tolerance for sheet in coils is 25 mm in any 6000 mm, except as shown in Table 14.

weight. If such is the case, two additional tests shall be taken at random. If the results on both of these retest specimens meet

**TABLE 7 Diameter Tolerances for Hot-Dip Metallic-Coated Sheet, Sheared Circles**

Inch-Pound Units				
Specified Thickness, in.	Tolerance Over Specified Diameter, No Tolerance Under, in.			
	Diameters			
Over	Through	Under 30	30 through 48	Over 48
...	0.61	1/16	1/8	3/16
0.061	0.101	3/32	5/32	7/32
0.101	...	1/8	3/16	1/4
SI Units				
Specified Thickness, mm	Tolerance Over Specified Diameter, No Tolerance Under, mm			
	Diameters			
Over	Through	Through 600	Over 600 Through 1200	Over 1200
...	1.5	1.5	3.0	5.0
1.5	2.5	2.5	4.0	5.5
2.5	...	3.0	5.0	6.5

**TABLE 8 Out-of-Square Tolerances for Hot-Dip Metallic-Coated Sheet Cut Lengths, Not Resquared**

NOTE 1—Out-of-square is the greatest deviation of an end edge from a straight line at right angles to a side and touching one corner. It is also obtained by measuring the difference between the diagonals of the cut length. The out-of-square deviation is one half of that difference.

Inch-Pound Units	
For Coils Over 12 in. in Width	
The tolerance for cut lengths of all thicknesses and all sizes is 1/16 in. in each 6 in. of width or fraction thereof.	
SI Units	
For Coils Over 300 mm in Width	
The tolerances for cut lengths of all thicknesses and all sizes is 1.0 mm in each 100 mm of width or fraction thereof.	

**TABLE 9 Resquared Tolerances for Hot-Dip Metallic-Coated Sheet**

NOTE 1—When cut lengths are specified resquared, the width and length are not less than the dimensions specified. The individual tolerance for over-width, over-length, camber, or out-of-square shall not exceed the stated values.

Inch-Pound Units	
For Cut-lengths Over 12 in. in Width	
Shall not exceed 1/16 in. for cut lengths up to and including 48 in. in width and up to and including 120 in. in length. For cut lengths wider or longer the applicable tolerance is 1/8 in.	
SI Units	
For Cut-lengths Over 300 mm in Width	
Shall not exceed 1.6 mm for cut lengths up to and including 1200 mm in width and up to and including 3000 mm in length. For cut lengths wider or longer, the applicable tolerance is 3.2 mm.	

the specified requirements, the lot shall be accepted. For chemical analysis not in conformance, retesting shall be done by the methods contained in the section on test methods of Test Methods, Practices, and Terminology A 751.

9.2.3 If the original test results do not conform to the specification for either base-metal properties or coating and are outside the criteria described in 9.2.2, the product represented by the out-of-specification test results must be discarded and a new test shall be taken from the remaining lot adjacent to the product associated with the out-of-specification test result. The retest must conform to the requirements of this specification.

**TABLE 10 Flatness Tolerances for Hot-Dip Metallic-Coated Sheet, Cut Lengths**

NOTE 1—This table does not apply to structural steel (SS) and High-Strength Low-Alloy Steel (HSLAS).

NOTE 2—This table also applies to sheet cut to length from coils by the consumer when adequate flattening measures are performed

Inch-Pound Units			
Specified Thickness, in.	Specified Width, in.		Flatness Tolerance, <sup>A</sup> in.
	Over	Through	
Through 0.048	12	36	3/8
	36	60	5/8
	60	72	7/8
Over 0.048	12	36	1/4
	36	60	3/8
	60	72	5/8

SI Units			
Specified Thickness, mm	Specified Width, mm		Flatness Tolerance, <sup>A</sup> mm
	Over	Through	
Through 1.0	300	900	10
	900	1500	15
	1500	...	20
Over 1.0	300	900	8
	900	1500	10
	1500	1800	15
	1800	...	20

<sup>A</sup>Maximum deviation from a horizontal flat surface.

**TABLE 11 Flatness Tolerances Specified to Restricted Flatness for Hot-Dip Metallic-Coated Sheet, Cut Lengths**

Inch-Pound Units			
Specified Thickness, in.	Specified Width, in.	Specified Length, in.	Flatness Tolerance, <sup>A</sup> in.
Over 0.019 through 0.032	over 12 through 36	through 120, inclusive	1/4
		wider or longer	3/8
Over 0.032	over 12 through 48	through 120, inclusive	1/8
		wider or longer	1/4

SI Units			
Specified Thickness, mm	Specified Width, mm	Specified Length, mm	Flatness Tolerance, <sup>A</sup> mm
0.35 through 0.8	through 900	through 3000	8
		wider or longer	10
Over 0.8	through 1200	through 3000	5
		wider or longer	8

<sup>A</sup>Maximum deviation from a horizontal flat surface.

## 10. Inspection

10.1 The producer shall afford the purchaser's inspector reasonable access to facilities to ensure that the product is being produced in compliance with this specification. Unless otherwise specified, all inspection and tests, except product analysis, shall be made at the producer's facilities prior to shipment. Such inspection or sampling shall be made concurrently with the producer's regular inspection and test operations unless it causes interference with normal operations or is otherwise specified.

10.2 *Responsibility for Inspection*—Unless otherwise specified in the contract or purchase order, the producer is responsible for the performance of all inspection requirements as

**TABLE 12 Width Tolerances—Narrow Widths for Hot-Dip Metallic-Coated Sheet, Coil and Cut Lengths, Not Resquared**

NOTE 1—This table applies to widths produced by slitting from wider sheet.

NOTE 2—The specified width range captions noted as follows are also applied when sheet is specified to width tolerance all over, nothing under. In such cases, the stated tolerances are doubled.

NOTE 3—Tolerances based upon practice found to be generally followed by producers.

Inch-Pound Units				
Specified Thickness, in.	Tolerances Over and Under Specified Width, in.			
	Over	Through	From 2 Through 6	Over 6 Through 9
0.014	0.068	0.008	0.016	0.032
0.068	0.083	0.012	0.016	0.032
0.083	0.110	0.016	0.032	0.032
0.110	0.187	0.032	0.032	0.032

SI Units		
Specified Width, mm	Width Tolerance, Over and Under, mm	
	Over	Through
50	100	0.3
100	200	0.4
200	300	0.8

**TABLE 13 Length Tolerances—Narrow Widths for Hot-Dip Metallic-Coated Sheet, Cut Lengths, Not Resquared**

NOTE 1—This table applies to widths of 2 to 12 in. [50 to 300 mm] incl. that have been produced by slitting from wider sheet.

Inch-Pound Units		
Specified Length, in.	Tolerance Over Specified Length, No Tolerance Under, in.	
	Over	Through
from 24	60	1/2
60	120	3/4
120	240	1

SI Units		
Specified Length, mm	Tolerance Over Specified Length, No Tolerance Under, mm	
	Over	Through
600	1500	15
1500	3000	20
3000	6000	25

**TABLE 14 Camber Tolerances—Narrow Widths for Hot-Dip Metallic-Coated Sheet, in Coils**

NOTE 1—This table applies to widths of 2 to 12 in. [50 to 300 mm] incl. that have been produced by slitting from wider sheet.

Inch-Pound Units
The camber tolerance is 1/4 in. in any 8 ft.

SI Units
The camber tolerance is 5.0 mm in any 2000 mm.

specified herein. Except as otherwise specified in the contract or order, the producer's facilities, or any other facilities suitable for the performance of the inspection requirements, shall be used. The purchaser reserves the right to perform any

of the inspections set forth in this specification to ensure supplies and services conform to the prescribed requirements.

## **11. Rejection and Rehearing**

11.1 Unless otherwise specified, any rejection shall be reported to the producer within a reasonable time after receipt of product by the purchaser.

11.2 Product that is reported to be unacceptable subsequent to the shipment to the purchaser's plant, shall be set aside, adequately protected, and correctly identified. The producer shall be notified as soon as possible to permit a timely investigation.

11.3 Samples that are representative of the rejected product shall be made available to the producer. In the event that the producer is dissatisfied with the rejection, a rehearing shall be requested.

## **12. Certification**

12.1 When required by the purchase order, a certificate of compliance or a test report, or both, shall be furnished to the purchaser.

12.1.1 The certificate of compliance shall include a certification that the product has been manufactured and tested in accordance with the requirements of the product specification, and that the test results conform to the requirements of that specification.

12.1.2 The test report shall show the heat analysis and the results of all tests required by the product specification and the order.

12.1.3 These documents shall provide information necessary to identify the product represented; for example, the manufacturer's name or brand, ASTM specification, coating designation, grade (when required), ordered thickness, width, length (if cut length), and unit identification (heat number, coil number, etc.).

12.1.4 A signature is not required. However, the certification documents shall clearly identify the organization submitting the information. Notwithstanding the absence of a signa-

ture, the organization submitting the documents is responsible for the accuracy of the information.

12.2 The furnishing of a certificate of compliance or test report, or both, shall not restrict the right of the purchaser to sample and test the product furnished.

## **13. Packaging and Package Marking**

13.1 It is common practice to use the methods of packaging as listed in the latest revision of Practices A 700, but the purchaser is permitted to specify other packaging methods.

13.2 As a minimum requirement, the product shall be identified by having the manufacturer's name or brand, ASTM specification, coating designation, grade, size, unit weight, purchaser's order number, and unit identification (that is, ticket number, coil number, etc.) legibly shown on a tag attached to each coil or shipping unit.

13.3 Most producers are able to ink stamp metallic-coated sheet with their logo and the pertinent ASTM specification when ordered in either coil or cut lengths. Since many of the metallic-coated products are stamped with a permanent ink (not water soluble), the purchaser shall be very specific when placing an order as to the requirements on sheet marking.

13.4 The purchase order shall include the specific loading instructions.

13.5 When specified in the contract or order, and for direct shipments to the U.S. Federal government, when Level A is specified, preservation, packaging, and packing shall be in accordance with the Level A requirements of MIL-STD-163. Marking for shipment shall be in accordance with Fed. Std. No. 123 for civil agencies and MIL-STD-129 for military agencies.

## **14. Keywords**

14.1 aluminum-coated iron/steel; aluminum-zinc alloy-coated steel, 55 %; coating; coatings—aluminum; coatings—55 % aluminum-zinc; coatings—hot dip; coatings—metallic; coatings—terne metal; coatings—zinc (hot-dip); coatings—zinc-5 % aluminum; corrosion; hot-dip; metallic-coated; sheet; steel; steel products—hot-dip coatings; steel sheet—aluminum-coated; steel sheet—terne coated; steel sheet—zinc-coated (galvanized); zinc-coated iron/steel

## **APPENDIX**

### **(Nonmandatory Information)**

#### **X1. PRODUCT INFORMATION**

X1.1 Metallic coated sheets are used to provide corrosion protection to steel. The various types of coatings have different characteristics and the consumer should consult the individual producers for applicability and product data.

X1.2 Metallic-coated sheet of rimmed- or capped-type steels is subject to the phenomenon commonly known as aging when stored over a period of time. This may result in such surface disturbances as fluting and stretcher strains when fabricated. To minimize fluting, effective roller leveling must

be performed immediately before fabrication, or Deep Drawing Steel (DDS), which ages at a slower rate, should be specified. To minimize stretcher straining, extra-smooth steel sheet is required and it must be effectively roller-leveled immediately prior to fabrication, otherwise extra-smooth DDS must be specified.

X1.3 Metallic-coated sheet in coils is subject to coil breaks when coiled to a smaller inside diameter than is compatible to the thickness of the sheet. Other factors also effect this

tendency for coil breaks.

X1.4 The production of coils does not afford the same opportunity for inspection and sorting as does the production of cut lengths. Consequently, appropriate processing and quality control procedures are required by the purchaser to obtain optimum utilization of the product.

X1.5 *Coating Thickness Measurements with Magnetic*

*Gages*—A reasonable estimate of weight [mass] of coating may be obtained by converting coating thickness measurements made with magnetic gages. An accuracy of  $\pm 15\%$  in determining the thickness may be realized by following the recommended practice for magnetic instruments described in Practice E 376. This test may be used as a basis for acceptance, but rejection shall be governed by the weight [mass] of coating tests described in Section 7.

## SUMMARY OF CHANGES

Committee A05 has identified the location of selected changes to this standard since the last issue (A 924/A 924M - 99) that may impact the use of this standard.

*A 924/A 924M - 04:*

- (1) Added reference to Practice A 1030/A 1030M in 2.1.
- (2) Added new 8.2.2 to refer to Practice A 1030/A 1030M.

- (3) Renumbered subsequent subsections, and changed reference in 8.2.3 from Appendix X2 to Practice A 1030/A1030M.
- (4) Deleted Appendix X2 in its entirety.

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# Standard Specification for Zinc-5 % Aluminum-Mischmetal Alloy-Coated Steel Overhead Ground Wire Strand<sup>1</sup>

This standard is issued under the fixed designation A 925; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon ( $\epsilon$ ) indicates an editorial change since the last revision or reapproval.

## 1. Scope\*

1.1 This specification covers high-strength, extra-high-strength, and utilities grades of concentric lay steel wire strand composed of three wires or seven wires with Class A, Class B, or Class C zinc-5 % aluminum-mischmetal (Zn-5 Al-MM) alloy coatings specifically intended for use as overhead ground wires or static wires for electric power transmission lines.

1.2 The values stated in inch-pound units are to be regarded as the standard. The values given in brackets are for information only.

## 2. Referenced Documents

### 2.1 *ASTM Standards:*<sup>2</sup>

A 90/A 90M Test Method for Weight [Mass] of Coating on Iron and Steel Articles with Zinc or Zinc-Alloy Coatings  
A 902 Terminology Relating to Metallic-Coated Steel Products

B 750 Specification for Zinc-5 % Aluminum-Mischmetal Alloy (UNS Z 38510) in Ingot Form for Hot-Dip Coatings  
E 27 Method for Spectrographic Analysis of Zinc and Zinc Alloys by the Solution-Residue Technique  
E 47 Test Method for Chemical Analysis of Zinc Die-Casting Alloys

### 2.2 *Other Standard:*<sup>3</sup>

GF-1 Standard Practice for Determination of Cerium and Lanthanum Compositions in Galfan Alloy (5-Al-0.04 % La-0.04 % Ce-Bal SHG Zn)

## 3. Terminology

3.1 Definitions—For definitions of terms used in this specification refer to Terminology A 902.

<sup>1</sup> This specification is under the jurisdiction of ASTM Committee A05 on Metallic-Coated Iron and Steel Products and is the direct responsibility of Subcommittee A05.12 on Wire Specifications.

Current edition approved October 1, 2003. Published December 2003. Originally approved in 1994. Last previous edition approved in 1998 as A 925 - 98.

<sup>2</sup> For referenced ASTM standards, visit the ASTM website, [www.astm.org](http://www.astm.org), or contact ASTM Customer Service at [service@astm.org](mailto:service@astm.org). For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

<sup>3</sup> Available from International Lead Zinc Research Organization, 292 Madison Ave., New York, NY 10017.

## 4. Ordering Information

4.1 Orders for strand purchased under this specification shall include the following information:

4.1.1 Quantity of each size,

4.1.2 Size and grade of strand (Table 1),

4.1.3 Class of Zn-5 Al-MM alloy coating (Section 11 and Table 2), and

4.1.4 ASTM designation and year of issue.

## 5. Materials and Manufacture

5.1 *Base Metal*—The base metal shall be steel made by any commercially accepted steel making process and of such quality and purity that, when drawn to the size of wire specified and coated with Zn-5 Al-MM alloy, the finished strand and the individual wires shall be of uniform quality and have the properties and characteristics as prescribed in this specification.

5.2 *Coating Bath Analysis*—The bath metal used in continuous hot-dip Zn-5 Al-MM alloy coating shall meet the chemical composition limits specified in Specification B 750.

5.2.1 For a two-step coating operation where the first coating is zinc (hot-dip galvanized or electrogalvanized) the final bath may have an aluminum content of up to 7.2 %, to prevent depletion of the aluminum content of the bath.

5.2.2 *Method of Analysis*—The determination of chemical composition shall be made in accordance with suitable chemical (see Test Method E 47), spectrochemical (see Method E 27), or other methods. In case of dispute, the results secured by Test Method E 47 shall be the basis of acceptance.

5.2.3 A standard practice of X-ray fluorescence spectrometry for determination of cerium and lanthanum in a Zn-5 Al-MM alloy has been established by the International Lead Zinc Research Organization (Standard Practice GF-1).

## 6. Stranding

6.1 The strand shall have a left lay with a uniform pitch of not more than 16 times the nominal diameter of the strand. A left lay is defined as a counter-clockwise twist away from the observer. Stranding shall be sufficiently close to ensure no significant reduction in diameter when stressed to 10 % of the minimum breaking strength.

\*A Summary of Changes section appears at the end of this standard.

**TABLE 1 Physical Properties of Zn-5 Al-MM Alloy-Coated Steel Overhead Ground Wire Strand**

Nominal Diameter of Strand, in. [mm]	Number of Wires in Strand	Nominal Diameter of Coated Wire in Strand, in. [mm]	Approximate Weight of Strand, lb/1000 ft [kg/km]	Minimum Breaking Strength of Strand, lbf [kN]		
				High-Strength Grade	Extra-High-Strength Grade	Utilities Grade
5/16 [7.94]	3	0.145 [3.68]	171 [255]	...	...	6500 [28.9]
5/16 [7.94]	7	0.104 [2.64]	205 [305]	8000 [35.6]	11 200 [49.8]	...
3/8 [9.52]	7	0.120 [3.05]	273 [407]	10 800 [48.0]	15 400 [68.4]	11 500 [51.2]
7/16 [11.11]	7	0.145 [3.68]	399 [595]	14 500 [64.5]	20 800 [92.5]	...
1/2 [12.7]	7	0.165 [4.19]	517 [770]	18 800 [83.6]	26 900 [119.6]	...

**TABLE 2 Minimum Weights of Coating**

Nominal Diameter of Coated Wire, in. [mm]	Minimum Weight of Coating of Uncoated Wire Surface, oz/ft <sup>2</sup> [g/m <sup>2</sup> ]		
	Class A	Class B	Class C
0.104 [2.64]	0.80 [245]	1.60 [490]	2.40 [730]
0.120 [3.05]	0.85 [260]	1.70 [520]	2.55 [780]
0.145 [3.68]	0.90 [275]	1.80 [550]	2.70 [825]
0.165 [4.19]	0.90 [275]	1.80 [550]	2.70 [825]

## 7. Preforming Strand

7.1 Preformed strand shall be supplied when so specified by the purchaser. Strand is preformed when the component wires are set to the helical form which they assume in the product by any means of process other than by merely laying them about the strand core.

## 8. Breaking Strength and Weight

8.1 The approximate weight per unit length of strand and the minimum breaking strength of the finished strand shall be as specified in Table 1.

8.2 A test in which the breaking strength is below the minimum specified and which may have been caused by the slipping of the specimen in the jaws of the testing machine, by breaking within the jaws, or within 1 in. [25.4 mm] of the jaws, or by the improper socketing of a specimen shall be disregarded and another sample from the same coil or reel shall be tested.

## 9. Elongation

9.1 The elongation of the strand in 24 in. [610 mm], determined in accordance with 9.2, shall be not less than 5 % for the high-strength and for the 5/16-in. [7.94-mm], three-wire utilities grades, and 4 % for the extra-highstrength and for the 3/8-in. [9.52-mm], seven-wire utilities grades.

9.2 The elongation shall be measured as the percentage increase in separation between the jaws of the testing machine from the position after application of the initial load, to the position at initial failure in the test specimen. The separation of the jaws of the testing machine shall be approximately 2 ft [0.61 m] when under an initial load equal to 10 % of the required minimum breaking strength of the strand. The elongation values shall be recorded only for specimens that break over 1 in. [25.4 mm] from jaws of the testing machine.

## 10. Ductility of Steel

10.1 The individual wires of the completed strand shall not fracture when wrapped at a rate not exceeding 15 turns per

minute in a close helix of at least two turns around a cylindrical mandrel equal to three times the nominal diameter of the wire under test.

## 11. Weight of Coating

11.1 The weight of Zn-5 Al-MM alloy coating shall not be less than that specified in Table 2.

11.2 *Weight of Coating Test*—The Zn-5 Al-MM alloy coating shall be tested for weight by a stripping test in accordance with Test Method A 90/A 90M.

## 12. Adherence of Coating

12.1 The Zn-5 Al-MM alloy coating shall adhere to the wire without delaminating and without being removable by rubbing with the bare fingers after the individual wires have been wrapped at a rate not exceeding 15 turns per minute, in a close helix of at least two turns around a cylindrical mandrel equal to three times the nominal diameter of the wire under test. Loosening or detachment during the adhesion tests of superficial, small particles of Zn-5 Al-MM alloy formed by mechanical polishing of the surface of Zn-5 Al-MM alloy-coated wire shall not be considered cause for rejection.

## 13. Joints and Splices

13.1 There shall be no joints of any kind made in the finished wire entering into the construction of the strand.

13.2 Electric-welded butt joints made prior to the start of cold drawing of the wire are permitted; however, no electric-welded butt joints of the wire shall be made during the cold drawing application.

13.3 There shall be no strand joints or strand splices in any length of the completed strand.

## 14. Permissible Variations in Wire Size

14.1 The diameter of the Zn-5 Al-MM alloy-coated wire forming the strand shall conform to the nominal diameter shown in Table 2 within a tolerance of  $\pm 0.004$  in. [0.102 mm] for wire sizes 0.104 in. [2.642 mm] and 0.120 in. [3.048 mm] and  $\pm 0.005$  in. [0.127 mm] for wire sizes 0.145 in. [3.683 mm] and 0.165 in. [4.191 mm].

## 15. Workmanship, Finish, and Appearance

15.1 The Zn-5 Al-MM alloy-coated wire shall be uniform in diameter and shall be free from splints, scales, inequalities, flaws, and other imperfections not consistent with good commercial practice. The coating shall be continuous and reasonably uniform.



## 16. Sampling

16.1 The number of samples to be taken shall be determined by lot size as follows:

Lot Size	Number of Samples
1 to 3 reels	1 from each reel
4 to 30 reels	3 min
31 reels or greater	4 min

16.2 Each sample taken shall be subjected to all tests prescribed in Sections 6, 8, and 9.

16.3 In addition to the strand testing in 16.2, the individual wires from the strand samples shall be tested for compliance with Sections 10, 11, 12, and 14. Select all three wires in three-wire strand, and four of the wires in seven-wire strand. Individual wire samples selected for compliance to Section 14 shall be discarded if any distortion of the wire occurred during the stranding operation.

16.4 Instead of testing the wires from the completed strand in accordance with 16.3, the producer may elect to establish compliance with Sections 10, 11, 12, and 14 of this specification by tests made on the wires prior to stranding, unless otherwise stipulated by the purchaser. However, if the producer makes this election, the purchaser shall still reserve the right to test wires from the completed strand for compliance.

## 17. Inspection

17.1 The manufacturer shall afford the inspector representing the purchaser all reasonable facilities to satisfy him that the material is being furnished in accordance with this specification. All tests and inspection shall be made on the finished strand at the place of manufacture prior to shipment and shall be so conducted as not to interfere unnecessarily with the operation of the works.

## 18. Rejection

18.1 In case there is a reasonable doubt in the first trial as to the failure of the wire or strand to meet any requirement of this specification, two additional tests shall be made on samples of

wire or strand from the same coil or reel, and if failure occurs in either of these tests, the strand shall be rejected.

## 19. Packaging and Package Marking

19.1 The completed strand shall be furnished on reels sufficiently sturdy to withstand normal service incident to shipping, hauling, and field erection.

19.2 The completed strand shall be furnished in random lengths. At least 95 % of the lengths shall be within the minimum and maximum limits shown in Table 3. Not more than 5 % of a total length ordered may be furnished in lengths that are below the minimum limits shown in Table 3 but which are not less than 1500 ft [457 m] long. Each reel shall be clearly marked to show the length of the strand contained thereon.

19.3 Each reel shall have a strong tag securely fastened to it showing the name of the material “ground wire strand,” the length, size, grade of the strand, class of coating, ASTM specification number (A 925), and the name or mark of the manufacturer.

## 20. Keywords

20.1 coated overhead strand; zinc 5 % aluminum-mischmetal alloy-coated overhead strand

**TABLE 3 Range of Strand Lengths per Reel for at Least 95 % of the Completed Strand**

Nominal Diameter of Strand, in. [mm]	Number of Wires in Strand	Length of Strand Per Reel for at Least 95 % of the Order, ft [m]	
		Min	Max
5/16 [7.94]	3	4700 [1430]	7900 [2410]
5/16 [7.94]	7	4800 [1460]	7700 [2350] <sup>A</sup>
3/8 [9.52]	7	3600 [1100]	5800 [1770] <sup>A</sup>
7/16 [11.11]	7	4700 [1430]	7900 [2410]
1/2 [12.7]	7	3600 [1100]	6100 [1860]

<sup>A</sup>Purchasers may procure maximum lengths up to 12 000 ft [3660 m] for 5/16-in. [7.94-mm] diameter strand and up to 9400 ft [2860 m] for 3/8-in. [9.52-mm] diameter strand.

## SUMMARY OF CHANGES

Committee A05 has identified the location of selected changes to this standard since the last issue (A 925 - 98) that may impact the use of this standard.

A 925 - 03:

- (1) Renumbered sections to meet Form and Style requirements.
- (2) Deleted “Size of Strand” section
- (3) Changed “base metal” in 5.1 to “any commercially accepted steel making process.”

- (4) Rewrote Section 8. (Breaking Strength and Weight)
- (5) Made editorial changes in paragraphs 11.1-11.2, 12.1, and Sections 13 and 18.
- (6) Changed kg/m to kg/km in Table 1.
- (7) Added Summary of Changes section.

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## A 925 – 03

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# Standard Test Method for Comparing the Abrasion Resistance of Coating Materials for Corrugated Metal Pipe<sup>1</sup>

This standard is issued under the fixed designation A 926; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon ( $\epsilon$ ) indicates an editorial change since the last revision or reapproval.

## 1. Scope\*

1.1 This test method covers a procedure for comparing materials used for coating, paving and lining corrugated metal pipe by use of a bed load abrasion testing machine. The procedure attempts to simulate the effect of stone, gravel and sand carried by a stream through corrugated metal pipe.

1.2 The values stated in inch-pound units are to be regarded as standard. The SI units given in brackets are for information only.

1.3 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

## 2. Referenced Documents

### 2.1 ASTM Standards:

- A 742/A 742M Specification for Steel Sheet, Metallic-Coated and Polymer Precoated for Corrugated Steel Pipe
- A 849 Specification for Post-Applied Coatings, Pavings, and Linings for Corrugated Steel Sewer and Drainage Pipe
- A 929/A 929M Specification for Steel Sheet, Metallic-Coated by the Hot-Dip Process for Corrugated Steel Pipe
- C 131 Test Method for Resistance to Degradation of Small-Size Coarse Aggregate by Abrasion and Impact in the Los Angeles Machine
- C 136 Test Method for Sieve Analysis of Fine and Coarse Aggregates

## 3. Summary of Test Method

3.1 Curved steel panels, coated with the matter to be evaluated, are mounted on the inside surface of a cylindrical drum. A charge of fine aggregate coarse aggregates and water are added and the drum is sealed. Then the drum is rotated to cause an abrasive flow over the materials being tested. After the prescribed number of revolutions, the panels are removed

from the drum, inspected and weighed for loss; or Alternative 2 counting grid method is used.

## 4. Significance and Use

4.1 This test method provides a means of determining an abrasion rate (weight and calculated average thickness loss) when comparing materials, coatings, pavings, or linings under test conditions that will be subjected to abrasive bed loads. The importance of this information is recognized when dealing with culverts, storm and sanitary sewer applications, although the last two generally do not have the same degree of abrasion due to the flatter slopes and less bed loads than culverts. Specifically, the invert of these types of pipe, regardless of the material used, can be exposed to flows containing abrasive bed loads or solid particulates that cause wearing of the pipe wall.

4.2 By subjecting materials to wear in the bed load abrasion machine with a controlled bed load charge made up of fine aggregate and coarse aggregate over a specified period, a comparison of the resistance between materials can be established.

4.3 This test method does not simulate the effect of abrasive material striking the upstream face of corrugations, as would be typical for coating materials which do not completely fill the corrugations.

**NOTE 1—Caution:** This test method uses specific quantitative values to encourage repetitive results and does not consider varying bed load characteristics, ratio of water to bed load, velocity, time or actual field conditions, and the effect of exposed edges on laminates. The user must use extreme care in comparing one test result to another because of these and other variables.

## 5. Apparatus

5.1 *Bed Load Abrasion Machine*, equipped with a counter and conforming in all essential characteristics to the design shown in Fig. 1. The machine shall consist of a hollow steel cylinder, closed at both ends, having an outside diameter of  $24 \pm 0.2$  in. [ $610 \pm 5$  mm]. One closed end of the cylinder shall have four bolted plexiglass windows one of which is elongated to provide placement of the specimens. A shaft mounted horizontal and through the cylinder shall have a drive pulley at

<sup>1</sup> This test method is under the jurisdiction of ASTM Committee A05 on Metallic Coated Iron and Steel Products and is the direct responsibility of Subcommittee A05.17 on Corrugated Steel Pipe Specifications.

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\*A Summary of Changes section appears at the end of this standard.

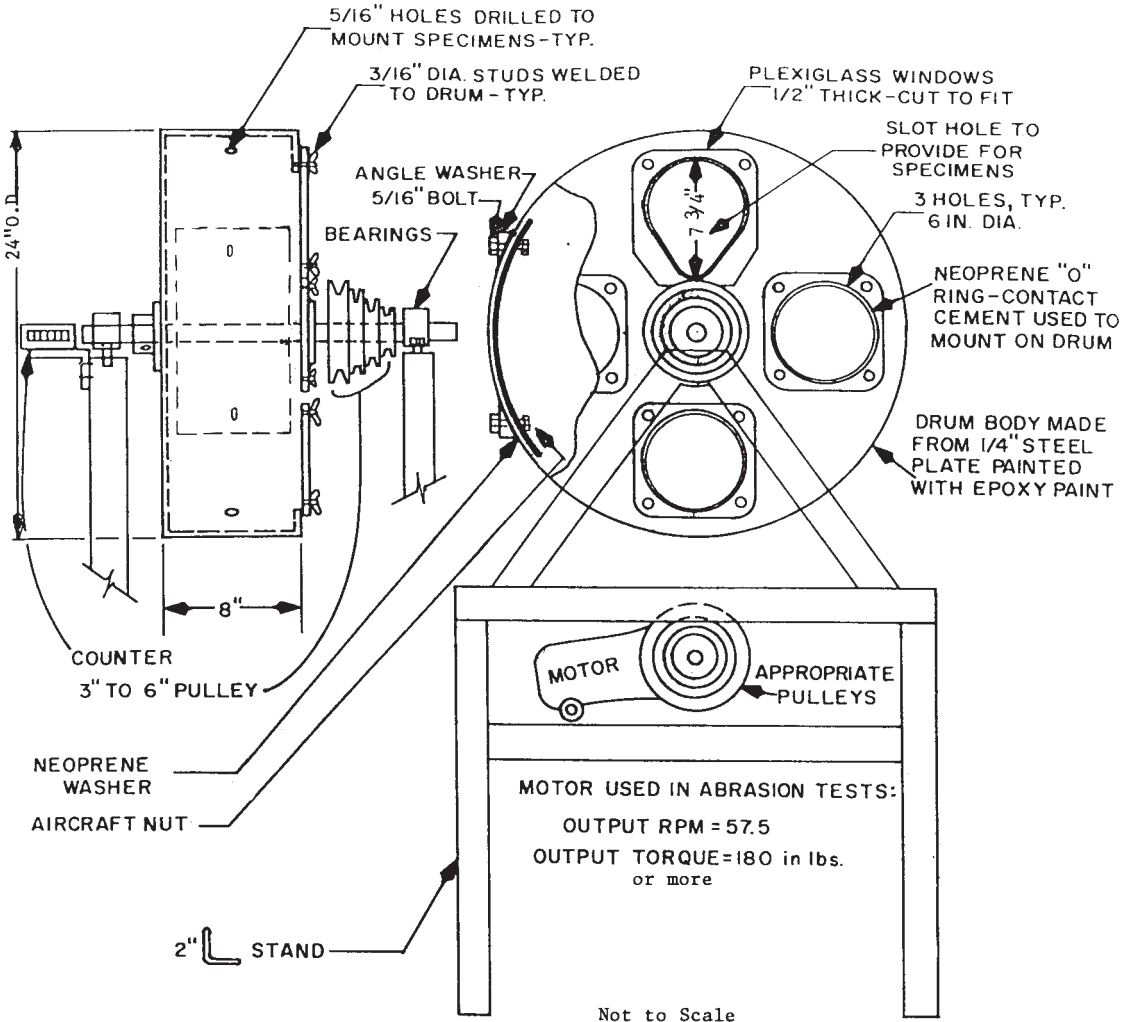


FIG. 1 Bed Load Abrasion Testing Machine

one end and be supported by bearings connected to a frame allowing the cylinder to turn freely and be in alignment with a drive motor below.

5.2 The machine shall consistently rotate at  $50 \pm 5$  r/min when specimens are mounted and drum is fully charged.

## 6. Test Specimens

6.1 *Panels*—Test specimens shall consist of zinc-coated steel sheet with or without a nonmetallic protective coating to be evaluated. The steel sheet shall conform to Specification A 929/A 929M with a specified thickness of 0.064 in. [1.63 mm]. All panels are curved as shown in Fig. 2, with the test surface concave. A plain zinc-coated panel serves as a control specimen.

6.1.1 Panels to serve as a substrate for coating materials to be applied to fabricated pipe shall be curved prior to application of the coating material. The control panel and panels having factory applied nonmetallic coating (such as polymer precoated sheet, Specification A 742/A 742M) shall be in the as-received condition.

6.1.2 Fabricate the panels as shown in Fig. 2. Take care in fabricating panels with preapplied nonmetallic coatings to avoid damage to the coating. Curve the panels to a smooth,

uniform radius with no straight tangent portions at the ends. A device as described in Appendix X1 shall be used.

6.2 *Coating*—Coat the panels as recommended by the manufacturer of the coating material. The thickness of the coating shall be equal to, or greater than, the minimum thickness proposed or required to be used on pipe (usually on the crest of corrugations).

6.3 *Mounting*—Mount the coated test panels in the drum using  $\frac{5}{16}$  in. (or M8) steel bolts. Other sizes of bolts may be used provided appropriate adjustments are made in the mounting hole slot. Use washers under the bolt head (or nut) to protect the coating from damage when tightening the bolt (or nut). Place a thin foam cushion (expanded neoprene, etc.) under the panels to provide a tight fit against the drum and to keep fines from eroding the backside of the panel. Shims shall be used as required under the test panels to maintain the same height between the surface of adjacent specimens and the drum when mounted.

6.4 *Panel Weight*—In order to evaluate the effect of the test, determine the panel weight using a balance accurate to 0.01 g.

6.4.1 Panel substrate prior to application of coating,

6.4.2 Panel with the coating before test, and

6.4.3 Panel with the coating after testing.

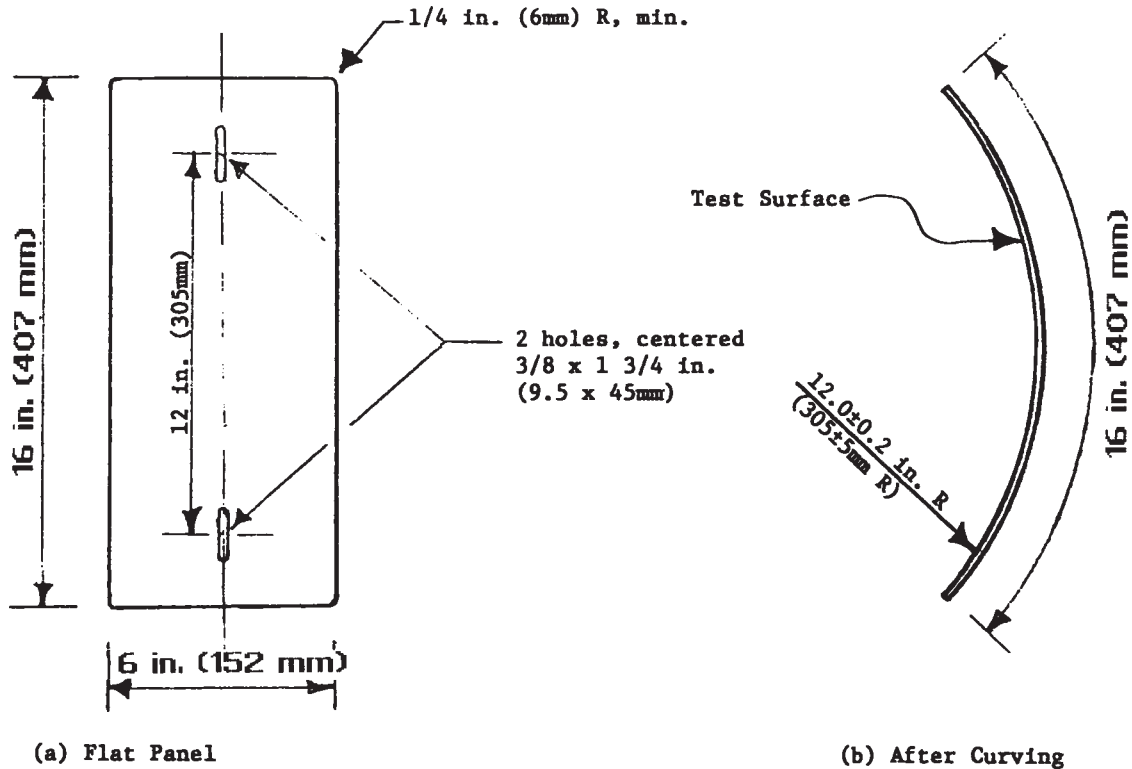


FIG. 2 Test Panel

6.4.4 Panels tested with factory applied coating do not permit determination of the weight as described in 6.4.1. Panels used as reference panels without non-metallic coating require weighing before and after test.

**7. Procedure**

7.1 Mount three test specimens with coating, paving, or lining and one control specimen made of a panel with no coating. Take care not to damage or alter test specimens after they have been coated and weighed.

7.2 *Charge*—The charge shall consist of 7 lb [3.2 kg] of aggregate and 35 lb [15.9 kg] of water having a pH of 7.0 ± 0.5. The aggregate shall be 3½ lb [1.6 kg] of ¾ in. [9.5 mm] to No. 4 coarse and 3½ lb [1.6 kg] of fine (wash sand) graded as in Table 1.

7.2.1 Sieve the aggregate according to the procedure in Test Method C 136 and recombine to obtain the grading in Table 1.

7.2.2 For comparison of coatings performed by one agency, the aggregate may be from any source able to supply a consistent product. The aggregate shall be a crushed rock

having a loss in the Los Angeles test (see Test Method C 131) not greater than 20 %.

7.2.3 For comparison of coatings performed by different agencies, use either a reference aggregate (see Note 2) or establish by comparison tests that the aggregate used by each agency provides comparable results.

NOTE 2—The following source has been used as a reference by some agencies: Bear River Aggregate, available from R. J. Miles Co., Corner of Railroad and Oak, Colfax, CA.

7.3 *Alternative 1*—Perform the test in two segments with measurements being made at the conclusion of both. The first stopping shall be at 500,000 revolutions, approximately 6.95 days or 166 h and 50 min and the second stopping shall be at 1,000,000 revolutions, approximately 13.89 days or 333 h and 20 min concluding the test. Inspection shall be done with caution so as not to damage the samples or disturb the charge.

7.3.1 During testing maintain the ambient temperature at 68 to 86°F [20 to 30°C].

7.3.2 Upon completion of the test, wash, dry, weigh, photograph, and log each sample.

7.3.3 Make comparison between the weight of the coated, paved, or lined test specimen before the test and after.

7.4 *Alternative 2*—Perform the test as Alternative 1 except the charge shall be replaced with new material every 250 000 revolutions and the test will continue until at least one specimen has exceeded the limits of 7.4.1.

7.4.1 An acrylic counting grid using 1 in. [25 mm] squares (6 in. [152 mm] by 16 in. [407 mm] panel or 6 grid squares by 16 grid squares totaling 96 grid squares) shall be used to

Coarse Aggregate		Fine Aggregate (Wash Sand)	
Sieve Size	Percent Passing	Sieve Size	Percent Passing
½ in. [12.5 mm]	100	No. 4 (4.75 mm)	100
¾ in. [9.5 mm]	100	No. 8 (2.36 mm)	91
No. 4 [4.75 mm]	14	No. 16 (1.18 mm)	71
No. 8 [2.36 mm]	0	No. 30 (600 µm)	42
		No. 50 (300 µm)	11
		No. 100 (150 µm)	2
		No. 200 (75 µm)	1

measure performance. The number of grid squares showing exposed metal shall not exceed 10 grid squares of the total grid squares.

NOTE 3—Certain coatings may coat the aggregate and affect the test results.

## 8. Report

8.1 Prepare a report for each set of samples run, and report the following essential information:

8.1.1 Color photographs of the sample taken before and after the test,

8.1.2 A complete identification of all four samples (User option is to include an IR fingerprint of the coating material).

8.1.3 A complete description of the location of any visible surface flaws,

8.1.4 The weight of each sample substrate after preparation (holes, etc.),

8.1.5 The weight of samples after coating has been applied,

8.1.6 The weight of samples after the specified number of revolutions have been completed,

8.1.7 The number of revolutions,

8.1.8 Duration, days, hours and minutes of test,

8.1.9 Notation of any deviation in test procedure from that set forth in preceding paragraphs, that is, RPM at which test was conducted, and

8.1.10 When using Alternative 2 document the wear pattern and number of grid squares affected for each test specimen at each charge change until at least one specimen has exceeded the limits of 7.4.1.

8.1.11 Comments.

## 9. Precision and Bias

9.1 *Precision*—The precision of this test method has not been determined.

9.2 *Bias*—No statement is being made about the bias of this test method since there is no accepted reference material suitable for determining the bias of this procedure.

## 10. Keywords

10.1 abrasion resistance of pipe coatings; coatings—abrasion; corrugated metal pipe; resistance of coating materials to abrasion; steel pipe coatings

## APPENDIX

(Nonmandatory Information)

### X1. PANEL CURVING DIE

X1.1 Curving the uncoated, paved or lined zinc-coated culvert sheet shall be accomplished by using the two part wooden die shown in Fig. X1.1 and a hydraulic press. The radius of the die shall be  $7 \pm 0.2$  in. [ $175 \pm 5$  mm] to allow

for springback. If materials to be curved do not meet the requirements of Section 6 the die radius must be altered to allow for a differing degree of springback to achieve the final specimen radius of curvature required.

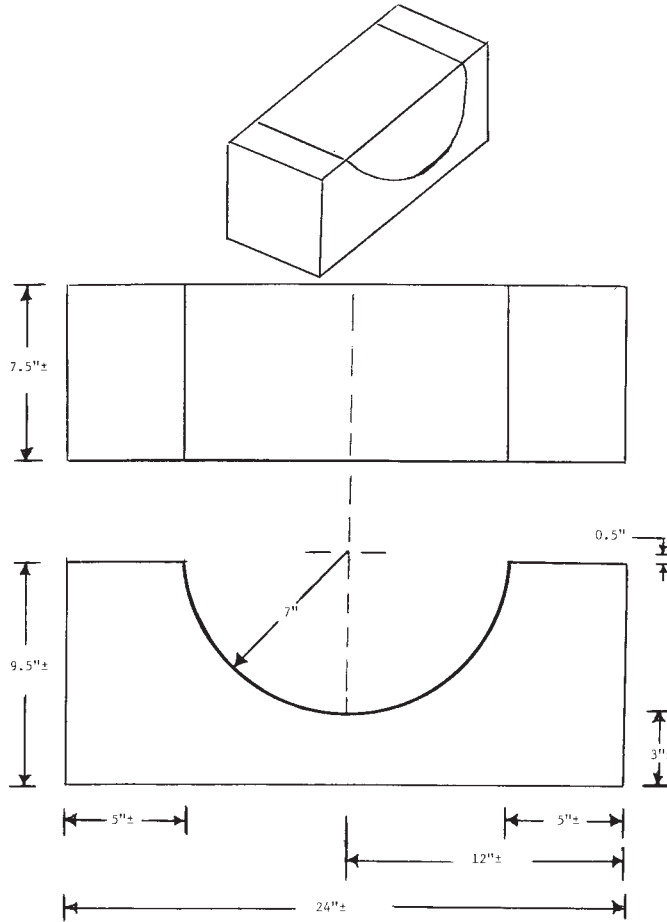


FIG. X1.1 Wooden Two Part Die

### SUMMARY OF CHANGES

Committee A05 has identified the location of selected changes to this standard since the last issue (A 926 - 97) that may impact the use of this standard.

A 926 - 03:

(1) Replaced reference to Specification A 444/A 444M with its replacement: Specification A 929/A 929.

(2) Replaced “may” with “shall” in several instances.

(3) Added text to Summary of Test Method for clarity.

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# Standard Specification for Steel Sheet, Metallic-Coated by the Hot-Dip Process for Corrugated Steel Pipe<sup>1</sup>

This standard is issued under the fixed designation A 929/A 929M; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon ( $\epsilon$ ) indicates an editorial change since the last revision or reapproval.

## 1. Scope

1.1 This specification covers steel sheet used in the manufacture of corrugated steel pipe for storm sewers, culverts, drains, and similar uses. The sheet is metallic coated by the hot-dip process. Material for this use is furnished in coils, flat in cut lengths, and corrugated in cut lengths. Many metallic coated materials are covered in this material specification. Users must determine which product best serves their needs. Five different metallic coatings are included:

1.1.1 Zinc-coated (galvanized),

1.1.2 Zinc-5 % aluminum-Mischmetal (Zn-5Al-MM) alloy coated,

1.1.3 55 % aluminum-zinc (55Al-Zn) alloy coated,

1.1.4 Aluminum-coated Type 2 (aluminized Type 2), and

1.1.5 Aluminum-coated Type 1 (aluminized Type 1).

1.2 Zinc-coated sheet is available in two coating weights [masses]. Other metallic coatings are available in one coating weight [mass] only.

1.3 The values stated in either inch-pound units or SI units are to be regarded separately as the standard. Within the text, the SI units are shown in brackets. The values stated in each system are not equivalents; therefore, each system must be used independently of the other. Combining values from the two systems may result in nonconformance with the specification.

## 2. Referenced Documents

### 2.1 ASTM Standards:

A 90/A 90M Test Method for Weight [Mass] of Coating on Iron and Steel Articles with Zinc or Zinc-Alloy Coatings<sup>2</sup>

A 428/A 428M Test Method for Weight [Mass] of Coating on Aluminum-Coated Iron or Steel Articles<sup>2</sup>

A 902 Terminology Relating to Metallic Coated Steel Products<sup>2</sup>

A 924/A 924M Specification for General Requirements for Steel Sheet, Metallic-Coated by the Hot-Dip Process<sup>2</sup>

<sup>1</sup> This specification is under the jurisdiction of ASTM Committee A05 on Metallic Coated Iron and Steel Products and is the direct responsibility of Subcommittee A05.11 on Sheet Specifications.

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<sup>2</sup> Annual Book of ASTM Standards, Vol 01.06.

B 750 Specification for Zinc-5 % Aluminum-Mischmetal Alloy (UNS Z38510) in Ingot Form for Hot-Dip Coatings<sup>3</sup>  
E 29 Practice for Using Significant Digits in Test Data to Determine Conformance with Specifications<sup>4</sup>

## 3. Terminology

3.1 *Definitions:* For definitions of terms used in this specification, refer to Terminology A 902. The following definitions are as stated in that terminology:

3.1.1 *fabricator, n— as related to corrugated metal pipe, (1) the organization that produces the finished pipe; or (2) for structural plate pipe, the organization that processes flat sheets and other items necessary for the field assembly of finished products.*

3.1.2 *manufacturer, n— as related to corrugated metal pipe, the organization that produces the metal sheet from which pipe is made.*

3.1.3 *purchaser, n—as related to corrugated metal pipe, the person or agency that purchases the finished pipe.*

3.1.4 *Discussion—*With regard to this specification for sheet for corrugated steel pipe, the fabricator may also be considered as the purchaser of the sheet, where that term is used in this specification. Such interpretation would not restrict the purchaser of the finished pipe from enforcing any provisions of this specification.

### 3.2 Definitions of Terms Specific to This Standard:

3.2.1 *minimized coating structure, n—*a coating characterized by a finer metallurgical coating structure obtained by a treatment designed to restrict the formation of the normal coarse grain structure formed during solidification of the Zn-5Al-MM coating.

3.2.2 *regular coating structure, n—*the normal coating structure resulting from unrestricted grain growth during normal solidification of the Zn-5Al-MM coating.

### 3.3 Abbreviations:

3.3.1 Al T2—aluminum-coated Type 2

3.3.2 Al T1—aluminum-coated Type 1

3.3.3 55Al-Zn—55 % aluminum-zinc alloy

3.3.4 Zn—zinc

<sup>3</sup> Annual Book of ASTM Standards, Vol 02.04.

<sup>4</sup> Annual Book of ASTM Standards, Vol 14.02.



3.3.5 Zn-5Al-MM—zinc-5 % aluminum-Mischmetal alloy

**4. Classification**

4.1 The Zn-5Al-MM coating is available in two coating classes, as follows:

- 4.1.1 *Class A*—Minimized coating structure, and
- 4.1.2 *Class B*—Regular coating structure.

**5. Ordering Information**

5.1 All sheet, both flat and formed, covered by this specification shall be ordered only to the specified thicknesses in the table on coated steel sheet thickness requirements.

5.2 All material furnished to this specification shall be chemically treated unless otherwise specified in the purchase order.

5.3 Orders for material to this specification shall include the following information, as necessary, to describe the desired product adequately:

- 5.3.1 Name of material (steel sheet for corrugated pipe):
- 5.3.2 ASTM designation and year of issue, as A 929-\_\_\_\_\_ for inch-pound units, or A 929M-\_\_\_\_\_ for SI units;
- 5.3.3 Type of metallic coating (zinc, zinc-5 % aluminum-Mischmetal alloy, 55 % aluminum-zinc alloy, aluminum-coated Type 2, or aluminum-coated Type 1) (Note 1);
  - 5.3.3.1 For zinc-coated sheet, the coating weight [mass] (see Table 3). If the coating weight [mass] is not stated, sheet having 2.00 oz/ft<sup>2</sup> [610 g/m<sup>2</sup>] nominal coating shall be furnished.
  - 5.3.3.2 For Zn-5Al-MM coating the class (coating structure) (see 4.1).
- 5.3.4 *Quantity and Dimensions*:
  - 5.3.4.1 *Cut Lengths*— Show the number of sheets; thickness; width, either flat or overall corrugated; length; pitch; and depth of corrugations, if corrugated;
  - 5.3.4.2 *Coiled Sheet*— Show the total weight [mass]; thickness; width; coil requirements (maximum outside diameter, acceptable inside diameter, and maximum weight [mass] of individual coils).
- 5.4 Certification, if required (see 12.1); and
- 5.5 Special requirements.

NOTE 1—Abbreviations may be used to describe the coating type (see 3.3).

NOTE 2—A typical ordering description (inch-pound units) is as follows: steel sheet for corrugated pipe in accordance with ASTM A 929-\_\_\_\_\_, zinc coated, 5000 sheets, 0.064 by 25½ by 60 in. with 2¾ by ½ in. corrugations, certified.

NOTE 3—A typical ordering description [SI units] is as follows: steel sheet for corrugated pipe in accordance with ASTM A 929M-\_\_\_\_\_, aluminum coated, Type 2, 45 000 kg, 2.77 by 700 mm by coil, 1500 mm max outside diameter, 600 mm, inside diameter, 7000 kg max, certified.

**6. Chemical Composition**

6.1 *Base Metal Analysis*—The base metal cast or product

**TABLE 1 Chemical Composition**

	Cast Analysis	Product Analysis
Sulfur, max, %	0.05	0.06
Sum of carbon, manganese, phosphorus, sulfur, and silicon, max, %	0.70	0.74

**TABLE 2 Mechanical Requirements (Properties of Flat Sheet Prior to Fabrication)<sup>A</sup>**

Tensile strength, min, <sup>B</sup> ksi [MPa]	45.0 [310]
Yield strength, min, <sup>B</sup> ksi [MPa]	33.0 [230]
Elongation in 2 in. [50 mm], <sup>C</sup> min, %	20

<sup>A</sup> To determine conformance with this specification, round each value for tensile strength and yield strength to the nearest 0.1 ksi [1 MPa] and each value for elongation to the nearest 1 %, both in accordance with the rounding method of Practice E 29.

<sup>B</sup> Yield point and tensile strength are based on the thickness of the base metal. If tests are made after coating, determine the base metal thickness after stripping the coating from the ends of the specimen contacting the grips of the tension testing machine prior to tensile testing.

<sup>C</sup> The elongation requirement does not apply to material tested after corrugating.

analyses shall conform to the chemical requirements of Table 1.

**6.2 Coating Bath Composition:**

6.2.1 *Zinc Coating*— The coating bath metal shall contain not less than 99 % zinc.

6.2.2 *Zinc-5 % Aluminum-Mischmetal Alloy Coating*—The ingot used for the coating bath shall conform to Specification B 750.

6.2.3 *55 % Aluminum-Zinc Alloy Coating*—The coating bath metal composition shall be 52 to 58 % aluminum, 2.0 % silicon maximum, and balance zinc.

6.2.4 *Aluminum Coating Type 2*—The coating bath metal composition shall be as follows (all percentages are maximum): Iron, 3.0 %; silicon, 0.35 %; magnesium, 0.50 %; other, each, 0.05 %; other, total, 0.20 %; balance, aluminum.

6.2.5 *Aluminum Coating Type 1*—The coating bath metal composition shall be 5 to 11 % silicon, the balance aluminum.

**7. Mechanical Properties**

7.1 The metallic-coated sheet shall conform to the mechanical requirements listed in Table 2.

7.2 Two tension tests shall be made on random samples of finished material from each cast or heat. One test is sufficient when the finished material from said cast or heat is less than 50 tons [45 Mg]. One tension test shall be made from both the thickest and thinnest material rolled, regardless of the weight represented, when material rolled from one cast or heat differs 0.050 in. [1.25 mm] or more in thickness. The samples shall be prepared and tested in accordance with the method specified in Specification A 924 [A 924M].

**8. Coating Requirements**

8.1 The metallic coating weight [mass] shall conform to the requirements listed in Table 3 for the type of metallic coating specified.

8.2 Adhesion of the coating shall be such that no peeling or flaking occurs while the coated sheet is being corrugated and formed into pipe.

**9. Dimensions and Tolerances**

9.1 *Thickness*—Sheet thickness shall conform to the dimensions prescribed in Table 4. The thickness of the sheet includes both the base steel and the coating.

9.2 *Length*—Permissible variations in the length of cut-length sheets, both flat and corrugated, shall be in accordance with Specification A 924 [A 924M].

**TABLE 3 Coating Weight [Mass] Requirements**

Type	Coating Weight [Mass], Total Both Sides		Equivalent Coating Thickness, Total Both Sides <sup>A</sup>	
	Triple Spot, Average, min oz/ft <sup>2</sup> [g/m <sup>2</sup> ]	Single Spot, min oz/ft <sup>2</sup> [g/m <sup>2</sup> ]	Triple Spot Average, min in. [μm]	Single Spot, min in. [μm]
Zn	2.00 [610]	1.80 [550]	0.0034 [86]	0.0031 [78]
Zn	4.00 [1220]	3.60 [1100]	0.0068 [172]	0.0062 [156]
Zn-5Al-MM	2.10 [640]	1.80 [550]	0.0037 [93]	0.0032 [80]
55Al-Zn	0.70 [210]	0.60 [180]	0.0022 [56]	0.0019 [48]
Al Type 2 <sup>B</sup>	1.00 [305]	0.90 [275]	0.0037 [95]	0.0034 [86]
Al Type 1	1.00 [305]	0.90 [275]	0.0040 [101]	0.0036 [91]

<sup>A</sup> Coating thicknesses are approximate, for information only (see 10.5.1). Conversions are based on the following relationships: (1) Zn coating: 1 oz/ft<sup>2</sup> = 0.0017 in.; 1 g/m<sup>2</sup> = 0.1415 μm; (2) Zn-5Al-MM coating: 1 oz/ft<sup>2</sup> = 0.001754 in., 1 g/m<sup>2</sup> = 0.1460 μm; (3) 55Al-Zn coating: 1 oz/ft<sup>2</sup> = 0.0032 in.; 1 g/m<sup>2</sup> = 0.26636 μm; (4) Al T2 coating: 1 oz/ft<sup>2</sup> = 0.00374 in.; 1 g/m<sup>2</sup> = 0.31131 μm and (5) Al T1 coating: 1 oz/ft<sup>2</sup> = 0.00398 in.; 1 g/m<sup>2</sup> = 0.33128 μm.

<sup>B</sup> Aluminum coating Types 2 and 1 include both free and alloy layers.

**TABLE 4 Coated Steel Sheet Thickness Requirements**

NOTE—Thickness is measured not less than 3/8 in. [10 mm] from an edge. On corrugated sheet, thickness is measured on the tangents of corrugations.

Specified Thickness, in. [mm] <sup>A</sup>	Minimum Thickness, in. [mm] <sup>A</sup>
0.040 [1.02] <sup>B</sup>	0.036 [0.91]
0.052 [1.32]	0.046 [1.17]
0.064 [1.63]	0.057 [1.45]
0.079 [2.01]	0.072 [1.83]
0.109 [2.77]	0.101 [2.57]
0.138 [3.51]	0.129 [3.28]
0.168 [4.27] <sup>B</sup>	0.159 [4.04]

<sup>A</sup> For 4 oz/ft<sup>2</sup> [1220 g/m<sup>2</sup>] zinc coating, the specified thickness and the minimum thickness shall be increased by 0.003 in. [0.076 mm] to account for the greater coating thickness as compared to the 2 oz/ft<sup>2</sup> [610 g/m<sup>2</sup>] zinc coating thickness.

<sup>B</sup> Aluminum-coated sheet is not furnished in these thicknesses.

**9.3 Flat Sheet**—Permissible variations in the width and camber of flat materials shall be in accordance with Specification A 924 [A 924M]. The flatness tolerances are given in Table 5.

**9.4 Corrugated Sheet:**

**9.4.1 Corrugations**—Corrugations shall form smooth continuous curves and tangents. The dimensions of the corrugations shall be in accordance with Table 6.

**9.4.2 Covering Width and Lip Dimension**—The covering width of corrugated sheet shall be in accordance with Table 7. The covering width is the distance between the crests of the extreme corrugations. The lip dimension of corrugated sheet shall be in accordance with Table 8 and is measured along the radial curvature from the crest of the corrugation to the edge of the sheet. There is no established tolerance for overall width since the covering width and lip dimensions are the governing factors for the formed product.

**TABLE 5 Flatness Tolerances (Cut Lengths Only)**

NOTE—This table also applies to sheets cut to length from coils by the fabricator when adequate flattening measures are performed.

Specified Thickness, in. [mm]	Specified Width, in. [mm]	Flatness Tolerance (Maximum Deviation from a Horizontal Flat Surface), in. [mm]
0.064 [1.63] and thicker	to 60 [1500], incl	1/2 [13]
0.052 [1.32] and thinner	to 36 [900], incl	1/2 [13]
	over 36 [900] to 60 [1500], incl	3/4 [19]

**TABLE 6 Corrugation Size**

Nominal Size, in. [mm]	Maximum Pitch, <sup>A</sup> in. [mm]	Minimum Depth, <sup>B</sup> in. [mm]	Radius of Curvature, in. [mm]	
			nominal	minimum
2 1/2 by 1/2 [68 by 13]	2 7/8 [73]	0.48 [12]	1 1/16 [17]	0.5 [13]
3 by 1 [75 by 25]	3 1/4 [83]	0.95 [24]	3/16 [14]	0.5 [13]
5 by 1 [125 by 25]	5 5/16 [135]	0.95 [24]	1 3/64 [40]	1.4 [36]

<sup>A</sup> Pitch is measured from crest of corrugations, at 90° to the direction of the corrugations.

<sup>B</sup> Depth is measured as the vertical distance from a straight edge resting on the corrugation crests to the bottom of the intervening valley.

**TABLE 7 Covering Width Tolerance for Corrugated Sheet**

Covering Width, in. [mm]	Tolerance, Over and Under, in. [mm]
To 24 [600], incl	1/4 [6]
Over 24 [600] to 36 [900], incl	3/8 [10]
Over 36 [900] to 48 [1200], incl	1/2 [13]

**TABLE 8 Corrugated Sheet Lip Dimensions**

Nominal Corrugation Size, in. [mm]	For Riveted Pipe Construction, <sup>A</sup> in. [mm]	For Spot-Welded Pipe Construction, min in. [mm]
2 1/2 by 1/2 [68 by 13]	3/4 [19]	7/16 [11]
3 by 1 [75 by 25]	7/8 [22]	1/2 [13]
5 by 1 [125 by 25]	7/8 [22]	1/2 [13]

<sup>A</sup> Tolerances, +3/16 in. [+5 mm], -0.

**10. Testing**

**10.1** The manufacturer shall make such tests and measurements as deemed necessary to ensure that the coated sheet produced complies with this specification.

**10.2** The purchaser may make tests and measurements, as determined to be necessary, to confirm conformance with this specification.

**10.3 Chemical Analyses of Steel**—Cast analysis (by the manufacturer) and product analysis (by the purchaser) shall be in accordance with Specification A 924 [A 924M].

**10.4 Mechanical Testing**—Mechanical property tests shall be conducted on the sheet prior to corrugating or other fabrication, when possible, and shall be in accordance with Specification A 924 [A 924M]. If the tests are made after corrugating, the specimens shall be taken on the tangents of corrugations and used for the determination of tensile and yield strengths only.

**10.5 Coating Weight [Mass]:**

**10.5.1** Sampling for coating weight [mass] determinations

shall be in accordance with Specification A 924 [A 924M]. The coating thickness may be determined by the procedures described in Specification A 924 [A 924M], but the weigh-strip-weigh procedures described in 10.5.2 shall apply in case of dispute.

10.5.2 Test for coating weight [mass] using the following procedures:

10.5.2.1 *Zinc Coatings*— Test Method A 90 [A 90M].

10.5.2.2 *Zn-5Al-MM Coatings*—Test Method A 90 [A 90M].

10.5.2.3 *55Al-Zn Coatings*— Test Method A 90 [A 90M] using the dilute hydrochloric acid method.

10.5.2.4 *Aluminum Coatings*—Test Method A 428 [A 428M].

## 11. Rejection and Rehearing

11.1 Material tested by the purchaser and found not conforming to this specification may be rejected, subject to the rejection and rehearing provisions of Specification A 924 [A 924M].

## 12. Certification

12.1 A manufacturer's certification shall be furnished to the purchaser when specified in the purchase order or contract. The certification shall be in accordance with the provisions of Specification A 924 [A 924M] and shall include reference to this product specification designation and the coating type.

12.2 The test results, including chemical composition, mechanical properties, coating type, and coating weight [mass] for each heat and coating lot, shall be maintained by the manufac-

turer for seven years without regard to whether a certification was furnished. The test results shall be made available to the fabricator and purchaser upon request.

## 13. Product Marking

13.1 Each 2 to 5 ft [0.5 to 1.5 m] of sheet in coils or cut lengths shall be identified by showing the following:

13.1.1 Name of manufacturer,

13.1.2 Brand name,

13.1.3 Specified thickness,

13.1.4 Coating type (Zn, Zn-5Al-MM, 55Al-Zn, Al T2, or Al T1), including class for Zn-5Al-MM sheet,

13.1.5 Specified coating weight [mass],

13.1.6 Identification symbols relating to a specific heat number and coating lot number, and

13.1.7 ASTM designation number.

13.2 The brand shall be removed, obliterated, or the sheet rebranded "nonspecification" on each 2 to 5 ft [0.5 to 1.5 m] of sheet in a coating lot or heat for which control tests, as prescribed herein, show nonconformance to this specification.

## 14. Keywords

14.1 coatings—aluminum; coatings—metallic; coatings—zinc; coatings—zinc-5 % aluminum-Mischmetal; coatings—55 % aluminum-zinc alloy; corrugated steel pipe; pipe—corrugated steel; steel sheet—aluminum coated; steel sheet—hot-dip coated; steel sheet—metallic coated; steel sheet—zinc coated; steel sheet—zinc-5 % aluminum-Mischmetal alloy coated; steel sheet—55 % aluminum-zinc alloy coated

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# Standard Practice for Life-Cycle Cost Analysis of Corrugated Metal Pipe Used for Culverts, Storm Sewers, and Other Buried Conduits<sup>1</sup>

This standard is issued under the fixed designation A 930; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon ( $\epsilon$ ) indicates an editorial change since the last revision or reapproval.

## 1. Scope\*

1.1 This practice covers a procedure for using life-cycle cost (LCC) analysis techniques to evaluate alternative drainage system designs using corrugated metal pipe that satisfies the same functional requirements.

1.2 The LCC technique measures the present value of all relevant costs of installing, operating, and maintaining alternative drainage systems, such as engineering, construction, maintenance, rehabilitation, or replacement, over a specified period of time. The practice also accommodates any remaining residual or salvage value.

1.3 Using the results of the LCC analysis, the decision maker can then identify the alternative(s) with the lowest estimated total cost based on the present value of all costs.

1.4 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

## 2. Referenced Documents

### 2.1 ASTM Standards:

E 917 Practice for Measuring Life-Cycle Costs of Buildings and Building Systems<sup>2</sup>

### 2.2 Other Documents:

TM-5-802-1 Economic Studies for Military Construction Design—Applications (12/86)

Circular No. A-94 Guidelines and Discount Rates for Benefit-Cost Analysis of Federal Programs<sup>3</sup>

## 3. Terminology

### 3.1 Definitions:

3.1.1 *common costs, n*—costs common to all alternatives in nature and amounts such as initial planning fees or future annual inspection costs.

3.1.2 *discount rate, n*—the investor's time value of money, expressed as a percent, used to convert the costs occurring at different times to equivalent costs at a common point in time.

3.1.3 *drainage project, n*—a project having a definable, functional drainage requirement that can be satisfied by two or more design or construction alternatives.

3.1.4 *future costs, n*—costs required to keep the system operating that are incurred after the project is placed in service, such as operation, maintenance, rehabilitation, or replacement costs.

3.1.5 *inflation, n*—the general trend or rising prices that result in reduction of the purchasing power of the dollar from year to year over time.

3.1.6 *initial cost, n*—the total of all costs, such as design costs, material purchase costs, and construction and installation costs, that are specific to each alternative and are incurred to bring each alternative to a point of functional readiness.

3.1.7 *maintenance cost, n*—the annual or periodic costs, such as inspection and cleaning, to keep a drainage structure functioning for the project design life but that do not extend the material service life.

3.1.8 *material service life, n*—the number of years of service that a particular material, system, or structure will provide before rehabilitation or replacement is necessary.

3.1.9 *project design life, n*—the planning horizon for the project, expressed as the number of years of useful life required of the drainage structure.

3.1.10 *rehabilitation cost, n*—the total of all costs incurred to extend the material service life of a specific alternative.

3.1.11 *replacement cost, n*—the total of all costs incurred to replace a material before the end of the project design life.

3.1.12 *terminal value, n*—the remaining value of the drainage structure in place at the end of the project design life.

## 4. Summary of Practice

4.1 This practice outlines a procedure for conducting an LCC analysis of two or more drainage pipe alternatives using corrugated metal pipe over a specified project design life. It

<sup>1</sup> This practice is under the jurisdiction of ASTM Committee A05 on Metallic Coated Iron and Steel Products and is the direct responsibility of Subcommittee A05.17 on Corrugated Steel Pipe Specifications. This practice was prepared in cooperation with Subcommittee B07.08.

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<sup>2</sup> *Annual Book of ASTM Standards*, Vol 04.11.

<sup>3</sup> Available from Office of Management and Budget, Washington, D.C.

\*A Summary of Changes section appears at the end of this standard.

identifies the project data and general assumptions necessary for the analysis and the method of computation.

## 5. Significance and Use

5.1 LCC analysis is an economic method for evaluating alternatives that are characterized by differing cash flows over the designated project design life. The method entails calculating the LCC of each alternate capable of satisfying the functional requirement of the project and comparing them to determine which has (have) the lowest estimated LCC over the project design life.

5.2 The LCC method is particularly suitable for determining whether the higher initial cost of an alternative is economically justified by reductions in future costs (for example, operating maintenance, rehabilitation, or replacement) when compared to an alternative with lower initial costs but higher future costs. If a design alternative has both a lower initial cost and lower future costs than other alternatives, an LCC analysis is not necessary to show that the former is the economically preferable choice.

## 6. Procedures

6.1 The procedure for performing an LCC analysis for drainage pipe applications is summarized in the following steps:

6.1.1 Identify the project objectives, alternatives, and constraints (6.2).

6.1.2 Establish the basic assumptions (6.3).

6.1.3 Compile data (6.4).

6.1.4 Compute the LCC for each alternative (6.5).

6.1.5 Evaluate the results (6.6).

6.2 *Project Objectives, Alternatives, and Constraints:*

6.2.1 Specify the design objective that is to be accomplished, identify alternative systems or designs that accomplish that objective, and identify any constraints that may limit the options to be considered.

6.2.2 An example is the design of a storm water drainage system for a residential development project. The system must satisfy mandated drainage system objectives such as specified rainfall intensities and storm water runoff limits. Available alternatives, such as different pipe materials and varying configurations of catch basins, ponds, or underground detention chambers, may have different initial costs as well as expected future costs. The system design may be constrained by structural and hydraulic limits such as minimum and maximum slopes and depth of burial, limits on surface flows on streets, etc.

6.3 *Basic Assumptions:*

6.3.1 Establish the uniform assumptions to be made in the LCC analysis of all alternatives. These assumptions include the selection of discount rate, treatment of inflation, general inflation rate, project design life, and desired comprehensiveness of the analysis.

6.3.2 *Discount Rate*—The discount rate selected should reflect the owner's time value of money. That is, the discount rate should reflect the interest rate that makes the owner indifferent about paying or receiving a dollar now or at some

future time. The discount rate is used to convert the costs occurring at different times to equivalent costs at a common point in time.

6.3.2.1 No single correct discount rate exists for all owners. Selection of the discount rate should be guided by the rate of return on alternative investment opportunities of comparable risk (that is, the opportunity costs of capital) or, in the case of some public organizations, on mandated or legislated requirements such as that contained in OMB Circular No. A-94.

6.3.2.2 The discount rate may include general price inflation over the study period. This discount rate is referred to as the nominal discount rate in this practice. The discount rate may also be expressed as the real earning power of money over and above general price inflation, referred to as the real discount rate.

6.3.2.3 A nominal discount rate ( $d_n$ ) and its corresponding real discount rate ( $d_r$ ) are related as follows:

$$d_r = \frac{1 + d_n}{1 + I} - 1 \text{ or } d_n = (1 + d_r)(1 + I) - 1 \quad (1)$$

where:

$I$  = rate of general price inflation.

6.3.2.4 The same discount rate should be used when evaluating each design alternative. Table 1 contains a procedure to follow when developing the discount rate. This procedure can be applied by those who wish to select their own values as well as those required to follow mandated or legislated requirements.

6.3.3 *Inflation*—This practice is designed to accommodate only a uniform rate of general inflation. The LCC can be calculated in constant dollar terms (not including general inflation) or current dollar terms (including general inflation). If the latter is used, a consistent projection of general price inflation must be used throughout the LCC analysis, including adjustment of the discount rate to incorporate the general

**TABLE 1 Discount Rate Procedure**

1.0	<i>General</i> —This procedure is intended to guide the user in developing a real discount rate, that is, the long-term rate of return over and above the general inflation rate. This procedure can be used by those required to use rates specified by mandate or legislated requirement, as well as those desiring to select their own values. This procedure does not recommend any specific rates; that selection is up to the user and should be made based on the considerations described in 6.3.2.1.
1.1	Is there a discounted rate that must be used by policy, mandate, or legislated requirements? (check one):
1.1.1	<input type="checkbox"/> Yes. If yes, the discount rate is ____ %
1.1.2	<input type="checkbox"/> No. Proceed to 2.
1.2	Does the discount rate in 1.1.1 include inflation? (check one):
1.2.1	<input type="checkbox"/> Yes. If yes, the inflation rate is ____ % (proceed to 2.1.4)
1.2.2	<input type="checkbox"/> No. The rate shown in 1.1.1 is the real discount rate (excludes general inflation) and can be used as $d_r$ in (Eq 3) and (4).
2.	If no discount rate is mandated, two approaches are possible:
2.1	Select a long-term percentage rate of return on invested money, over and above the general inflation rate. This value can be used as $d_r$ in (Eq 3) and (4).
2.2	Select a nominal discount rate (including general inflation): ____ % = ( $d_n$ ).
2.3	Select a long-term rate of general inflation: ____% = ( $I$ ).
2.4	Calculate the real discount rate ( $d_r$ ) for use in (Eq 3) and (Eq 4).

$$d_r = \frac{1 + d_n}{1 + I} - 1$$

inflation (6.3.2.2). The percentage change in the GNP deflator and producers price index are two broad indicators of general inflation.

6.3.3.1 If the user desires or is required to treat inflation on an incremental (differential) basis, or uniquely to each individual cost component (for example, energy costs), he or she should consult either TM-5-802-1 or Practice E 917, respectively.

6.3.4 *Project Design Life*—The project design life (3.1.9) should be established from mandated public policy, legislated requirements, or selection by the owner based on situation requirements. The same design life must be used for each alternative under comparison and for all cost categories under consideration. The potential for future obsolescence, that is, the potential that future changes may modify drainage system requirements, should be considered when selecting a project design life.

6.3.5 *Comprehensiveness*—The appropriate degree of precision and detail to use in an LCC analysis is dependent on the intended use of the analysis. A less comprehensive or detailed analysis may be sufficient for ranking many alternatives roughly, whereas a more comprehensive analysis may be necessary for selecting from among a few close alternatives. In any case, omitting significant factors from an LCC analysis diminishes the usefulness of the results.

6.3.6 *Sensitivity Analysis*—No analysis can be more precise than the accuracy of the data and assumptions used in the calculation. The LCC can be calculated for a range of assumptions when uncertainty exists regarding basic assumptions (for example, cost estimates, design life, discount rate, etc.). The results of these calculations will show the user the extent to which the results are sensitive to variations of the key assumptions.

6.4 *Compilation Data*—Compile the following data specific to each alternative under consideration:

6.4.1 *Initial Costs*—The estimated dollar amount of all costs required to bring the alternative system to a point of functional readiness.

6.4.2 *Material Service Life*—The number of years of service expected of the alternate under study. Material service life varies depending on the pipe material, environment, effluent, and application. Potential changes in environmental conditions that may affect the material service life should be considered. Job site tests, published reports, manufacturer product data, and local experience can be used to establish the service life for each material. If the material service life is shorter than the project design life (3.1.9), the analysis must include the future cost to extend the service life sufficiently through rehabilitation or replacement in order to at least equal the project design life.

6.4.3 *Future Costs*—Cost estimates should be made for all significant items that are estimated to be required to allow the drainage system to satisfy performance requirements over the project design life. Common costs (1.1) may be excluded without affecting the relative ranking of the alternatives under study. The cost estimates should be made in constant dollars (not including inflation) in the same time frame as the estimate of initial costs.

6.4.3.1 *Operating Cost*—An estimate of the annual cost for labor, power, and consumable materials and supplies required to operate a drainage system. Except for pumped systems, most drainage systems do not have significant annual operating costs.

6.4.3.2 *Maintenance Costs*—Cost estimates and the frequency of any inspection, cleaning, and minor repair necessary to keep the system operating at capacity during the project design life.

6.4.3.3 *Rehabilitation Costs*—The cost of major repairs to extend the material service life to equal or exceed the project design life. The years in which the rehabilitation are planned should be noted if more than one rehabilitation is anticipated.

6.4.3.4 *Replacement Cost*—The timing and cost estimate for complete replacement of any drainage system component. Care should be taken to determine whether the service life of the replaced material or component will at least equal the project design life. If not, rehabilitation or further replacement will be necessary.

6.4.3.5 *Terminal Value*—The value of the drainage system at the end of the project design life. The potential residual or salvage value of a drainage system is dependent on some of the factors considered when establishing the project design life. For example, if a storm sewer is being evaluated and a long (75 years) project design life is used, consideration should be given to the risk of future obsolescence. The higher the likelihood of functional obsolescence, the greater chance there may be no residual or salvage value. However, if it is expected that the material could be removed and either reused or sold, the net cash value (in constant dollars) represents the terminal value. It is not recommended that a residual value be used to reflect an economic value for any remaining material life in excess of the project design life. As an alternative, if it is felt that the functional requirements of the system under design are for an indefinite period, consideration should be given to increasing the project design life to an appropriately higher value, at which the residual value would not affect comparison of the various alternatives significantly.

6.5 *Computation of Life-Cycle Costs*—To compute the LCC for a drainage system, all relevant cost flows over the design life of the project are discounted back to the present and summed.

6.5.1 Find the present value (PV) of each cost category (for example, initial cost (IC), operating and maintenance (M), rehabilitation or repair (R), and terminal value (T)) using the appropriate discount formula in this section. Then sum these present values to find the PVLCC, for example:

$$PVLCC = PVIC + PVM + PVR - PVT \quad (2)$$

6.5.2 Initial costs are assumed in this practice to occur in the base year (year zero). No discounting is required.

6.5.3 Future costs expected to occur at a single point in time (for example, rehabilitation costs) can be discounted to present value by multiplying the estimated current cost of the item by the single present value factor as follows:

$$PVA_s = A_s \left( \frac{1}{1 + d_r} \right)^n \quad (3)$$

where:

- $A_s$  = single amount,
- $d_r$  = real discount rate (Table 1), and
- $n$  = number of years from year zero to the time of the future single amount expenditure.

NOTE 1—The factor developed in this equation is generally known as the present value factor and can be found in financial tables of discount rates.

6.5.4 Future costs expected to occur in approximately the same amount (in constant dollars) from year to year (for example, operating or maintenance costs) can be discounted to present value as shown below:

$$PVA_r = A_r \frac{(1 + d_r)^n - 1}{d_r(1 + d_r)^n} \quad (4)$$

where:

- $A_r$  = recurring annual amount,
- $d_r$  = real discount rate (Table 1), and
- $n$  = number of years.

NOTE 2—The factor developed in this equation is generally referred to

as the uniform present worth factor and can be found in financial tables of discount rates.

6.5.5 Example calculations are presented in Appendix X1.

6.6 *Comparison of Life-Cycle Costs:*

6.6.1 After calculating the LCC for each alternative, compare them to determine which alternative has the lowest LCC.

6.6.2 If the functional performance of the two alternatives is equal (or if performance differences are recognized in the computation), the alternative(s) with the lowest estimated LCC is economically preferred.

6.6.3 The effect of variations in key assumptions on LCCs can be developed by a sensitivity analysis. By varying the discount rate, material service life, and timing and magnitude of future costs, the decision maker can determine which factors have the greatest effect on the LCC of each alternative.

## 7. Keywords

7.1 cost analysis; discount rate; drainage systems; engineering economics; least cost; life-cycle cost; material service life; present value analysis; project design life

## APPENDIX

### (Nonmandatory Information)

#### X1. APPLICATION OF PRACTICE

X1.1 This example has been prepared to demonstrate the application of this practice.

X1.2 *Project Objectives*—A private developer has prepared plans for a storm drainage system to satisfy local code requirements. There are two alternatives, based on using different corrugated metal pipeline materials.

#### X1.3 *Basic Assumptions:*

Project design life	75 years
Discount rate (nominal)	10 %
Inflation rate	5 %
Common design costs	\$150 000

#### X1.4 *Alternatives:*

	Material A	Material B
Material service life	60 years	100 years
Initial cost—Bid price for materials, installation, and inspection	\$300 000	\$345 000
Future costs—Annual inspection and maintenance	\$6 000	\$5 000
Partial invert rehabilitation in year 60 (base year \$); life of rehabilitation is 25 years	\$75 000	none
Terminal value—In base year \$	none	\$30 000

#### X1.5 *Discount Rate Calculations (See Table 1):*

$$d_r = \frac{1 + d_n}{1 + I} - 1 \quad \text{or} \quad \frac{1 + 0.10}{1 + 0.05} - 1 = 0.048$$

where:

- $d_n$  = investor nominal discount rate, and
- $I$  = general inflation rate.

X1.6 *Life-Cycle Cost — Material A:*

X1.6.1 *Initial Cost*—\$300 000.

X1.6.2 *Annual Inspection and Maintenance:*

$$\begin{aligned} PVA_r &= \frac{A_r(1 + d_r)^n - 1}{d_r(1 + d_r)^n} \\ &= \$6000 \frac{(1 + 0.048)^{75} - 1}{0.048(1 + 0.048)^{75}} \\ &= \$6000 (20.215) \quad \$121\,290 \end{aligned}$$

X1.6.3 *Rehabilitation:*

$$\begin{aligned} PVA_s &= A_s \left( \frac{1}{1 + d_r} \right)^n \\ &= \$75\,000 \left( \frac{1}{1 + 0.048} \right)^{60} \\ &= \$75\,000 (0.060) \quad \$4500 \end{aligned}$$

X1.6.4 *Total Life-Cycle Cost—Material A:*

Present value of:	
Initial cost	\$300 000
Annual inspection and maintenance	121 290
Rehabilitation	4 500
Total life-cycle cost	\$425 790
Rounded to	\$426 000

**X1.7 Life Cycle Cost — Material B:**
**X1.7.1 Initial Cost—\$345 000.**
**X1.7.2 Future Cost — Annual Inspection:**

$$PVA_r = A_r \frac{(1 + d_r)^n - 1}{d_r(1 + d_r)^n}$$

$$= \$5000 (20.215) \quad \$101\ 075$$

**X1.7.3 Terminal Value:**

$$PVA_s = A_s \left( \frac{1}{1 + d_r} \right)^n$$

$$= -\$30\ 000 \left( \frac{1}{1 + 0.048} \right)^{75}$$

$$= -30\ 000 (0.030) \quad \$-900$$

**X1.7.4 Total Life-Cycle Cost—Material B:**

Present value of:	
Initial cost	\$345 000
Annual inspection and maintenance	101 075
Rehabilitation	<u>-900</u>
Total life-cycle cost	\$445 175
Rounded to	\$445 000

**X1.8 Life-Cycle Cost Comparison:**

	Material A	Material B
LCC	\$426 000	\$445 000
Rank	1	2

### SUMMARY OF CHANGES

Committee A05 has identified the location of selected changes to this standard since the last issue (A 930 - 99) that may impact the use of this standard.

**A 930 - 03:**
**(1) Corrected an error in Eq 4.**

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# Standard Specification for Corrugated Steel Box Culverts<sup>1</sup>

This standard is issued under the fixed designation A 964/A 964M; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reappraisal. A superscript epsilon ( $\epsilon$ ) indicates an editorial change since the last revision or reappraisal.

## 1. Scope

1.1 This specification covers material, geometric, and wall section properties of steel box culverts manufactured from corrugated plate or sheet, with or without attached stiffeners, for field assembly. Appropriate fasteners and optional materials such as steel invert plates and headwalls are also described. Applications for steel box culverts include conduits for gravity flow drainage of surface water such as culverts and storm drains, as well as for small bridges and grade separation structures such as pedestrian or vehicular underpasses, and utility tunnels.

1.2 This specification does not include requirements for foundations, backfill, or the relationship between earth cover or live loads and strength requirements. These important design considerations are described in the AASHTO LRFD Bridge Design Specifications, Customary U.S. Units (LRFD Bridge Design Specifications, SI Units).

1.3 This specification does not include requirements for the hydraulic design of these structures. Hydraulic design, placement of footings or inverts, and end treatments to resist scour are described in FHWA HDS No. 5.

1.4 Appendix X1 lists nominal dimensions of box culvert sizes commonly available. Also listed are cross-sectional area and hydraulic design parameters for these sizes.

1.5 Appendix X2 lists manufacturers' suggested design properties for the box culvert types described in this specification, and for the spacing classes and material thicknesses typically available.

1.6 The values stated in either inch-pound units or SI units are to be regarded separately as standard. Within the text, the SI units are shown in brackets. The values stated in each system are not exact equivalents; therefore, each system shall be used independently of the other. Combining values from the two systems may result in nonconformance with the specification.

<sup>1</sup> This specification is under the jurisdiction of ASTM Committee A05 on Metallic Coated Iron and Steel Products and is the direct responsibility of Subcommittee A05.17 on Corrugated Steel Pipe Specifications.

Current edition approved October 1, 2003. Published December 2003. Originally approved in 1996. Last previous edition approved in 2002 as A 964/A 964M - 02.

## 2. Referenced Documents

### 2.1 *ASTM Standards:*<sup>2</sup>

A 6/A 6M Specification for General Requirements for Rolled Structural Steel Bars, Plates, Shapes, and Sheet Piling

A 36/A 36M Specification for Carbon Structural Steel

A 123/A 123M Specification for Zinc (Hot-Dip Galvanized) Coatings on Iron and Steel Products

A 761/A 761M Specification for Corrugated Steel Structural Plate, Zinc-Coated, for Field-Bolted Pipe, Pipe-Arches, and Arches

A 796/A 796M Practice for Structural Design of Corrugated Steel Pipe, Pipe-Arches, and Arches for Storm and Sanitary Sewers and Other Buried Applications

A 902 Terminology Relating to Metallic Coated Steel Products

### 2.2 *AASHTO Standard:*

LRFD Bridge Design Specifications, Customary U.S. Units (LRFD Bridge Design Specifications, SI Units)<sup>3</sup>

### 2.3 *FHWA Standard:*

HDS No. 5, Hydraulic Design of Highway Culverts, Report No. FHWA-IP-85-15<sup>4</sup>

## 3. Terminology

### 3.1 *Definitions:*

3.1.1 For definitions of general terms related to metallic coated steel products refer to Terminology A 902.

### 3.2 *Definitions of Terms Specific to This Standard:*

3.2.1 *box culvert, n*—a generally rectangular conduit having a cross section symmetric about a vertical axis, with a long radius crown segment, short radius haunch segments, and straight side segments, with or without stiffeners, footing plates, or invert plates.

<sup>2</sup> For referenced ASTM standards, visit the ASTM website, [www.astm.org](http://www.astm.org), or contact ASTM Customer Service at [service@astm.org](mailto:service@astm.org). For Annual Book of ASTM Standards volume information, refer to the standard's Document Summary page on the ASTM website.

<sup>3</sup> Available from American Association of State Highway and Transportation Officials, 444 N. Capitol St. N.W., Suite 225, Washington, DC 20001.

<sup>4</sup> Available from the National Technical Information Service, Springfield, VA 22161.

3.2.2 *cross-corrugations, n*—shallow corrugations formed transverse to the main corrugations on the inside of deep corrugated haunch plates to facilitate curving (see Fig. 8).

3.2.3 *crown, n*—the long radius top arc segment of a box culvert cross section (see Fig. 1).

3.2.4 *haunch, n*—the short radius segments at the upper corners of a box culvert cross section, making the transition between the long radius crown segment and the straight side segments (see Fig. 1).

3.2.5 *shell, n*—the continuous, structural enclosure of the box culvert consisting of modular, field assembled and bolted, corrugated plate members forming the crown, haunch and side segments (see Fig. 1).

3.2.6 *stiffeners, n*—spaced, hot rolled or cold formed structural members, curved to the shape of the transverse cross section of box culverts and attached by field bolting to the corrugated plate shell (see Fig. 1).

3.2.7 *rise, n*—the clear inside vertical dimension from the bottom of the straight side segments of a box culvert to the crown, measured at the axis of symmetry (see Fig. 1).

3.2.8 *span, n*—the clear inside horizontal dimension of a box culvert, measured at the bottom of the straight side segments (see Fig. 1).

3.2.9 *unit weight, n*—the force resulting from gravitational attraction on a mass having a unit volume.

4. Classification

4.1 Steel box culverts are furnished in five types. Each type represents an alternate means of providing the required structural strength. The shell thickness and, where applicable, the

stiffener thickness and spacing class at the crown and haunch of the box culvert are permitted to differ, provided they satisfy the ordering information and the design properties (see 5.1 and 6.1). Furthermore, while the box culvert structure shall be supplied in a consistent type throughout its length, the shell thickness and, where applicable, the stiffener thickness and spacing class also are permitted to be varied along the length, in accordance with cover and loading requirements, as agreed upon between the purchaser and the fabricator.

4.1.1 *Type I Box Culvert*, consisting of a corrugated plate shell having 6 by 2 in. [152 by 51 mm] corrugations in combination with spaced, cold formed, corrugated plate stiffeners as detailed in Fig. 2. Stiffener spacing classes shall be as defined below and as illustrated in Fig. 3.

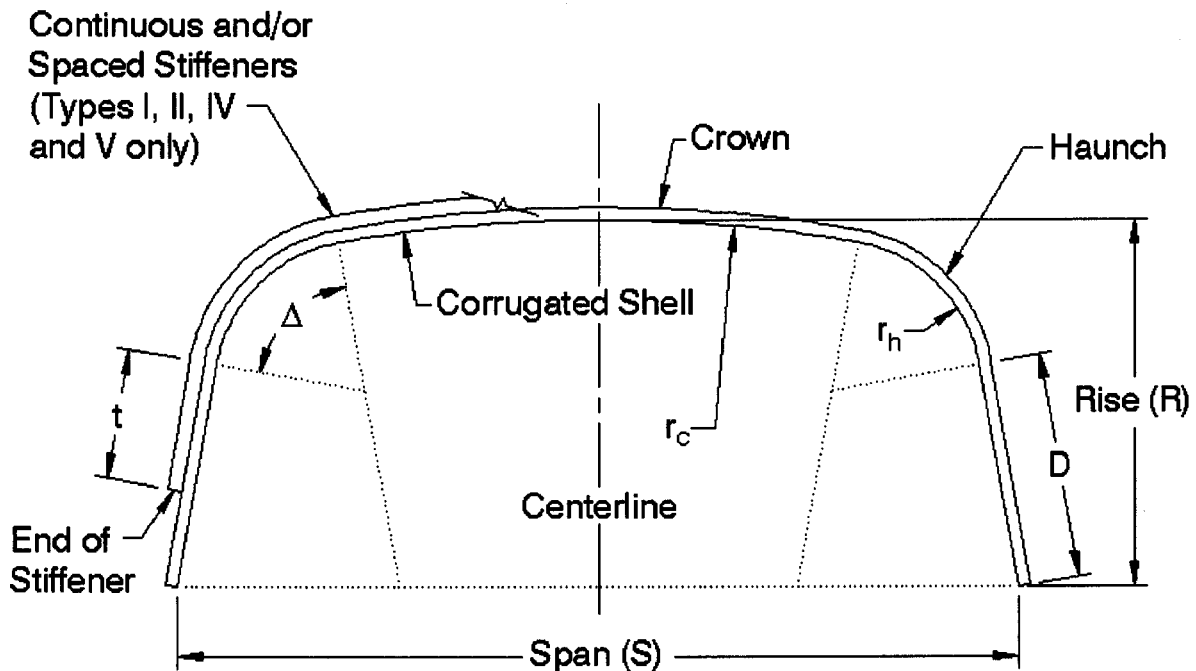
4.1.1.1 *Type I, Class A Spacing*, consisting of external stiffeners spaced at 24 in. [610 mm] center-to-center.

4.1.1.2 *Type I, Class B Spacing*, consisting of external stiffeners spaced at 12 in. [305 mm] center-to-center.

4.1.1.3 *Type I, Class C Spacing*, consisting of both external and internal stiffener groups, each spaced at 24 in. [610 mm] center-to-center, with the outer group offset 9 in. [229 mm] from the inner group.

4.1.2 *Type II Box Culvert*, consisting of a corrugated plate shell having 6 by 2 in. [152 by 51 mm] corrugations in combination with spaced, hot rolled, angle stiffeners as detailed in Fig. 4. Stiffener spacing classes shall be as defined below and as illustrated in Fig. 4.

4.1.2.1 *Type II, Class A Spacing*, consisting of external stiffeners spaced at 30 in. [762 mm] center-to-center.



NOTE - See Table 1 for explanation of notation.

FIG. 1 Box Culvert Geometry

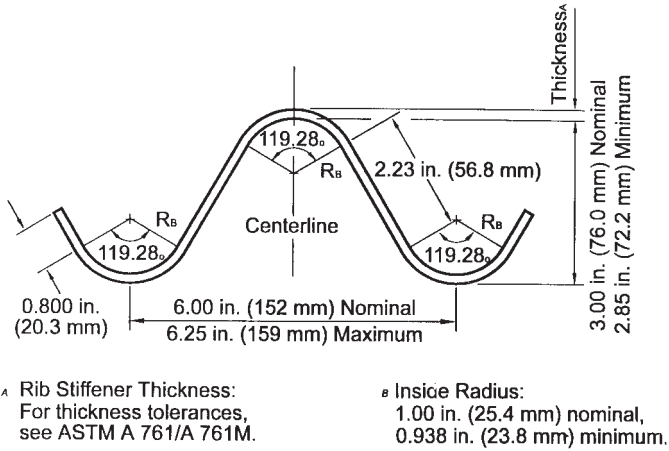
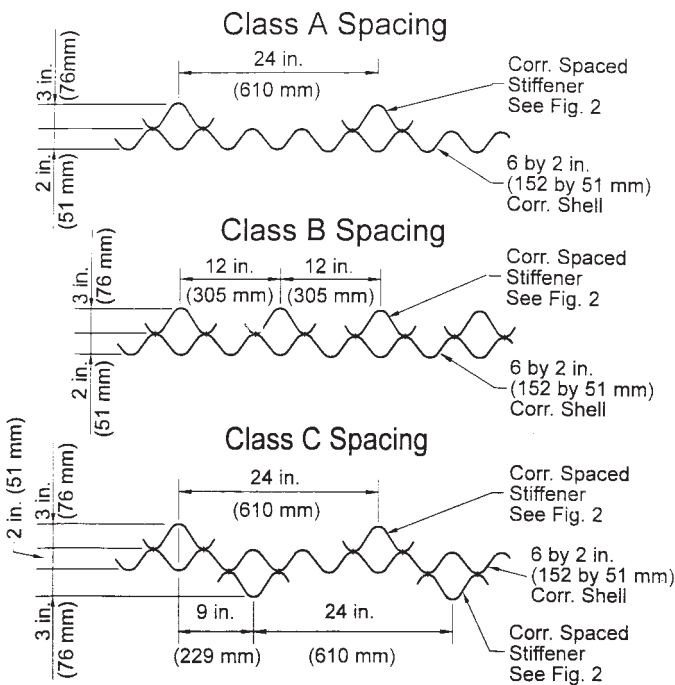


FIG. 2 Type I Rib Stiffener Geometry



NOTE—All dimensions are nominal.  
FIG. 3 Type I Rib Spacing Classes

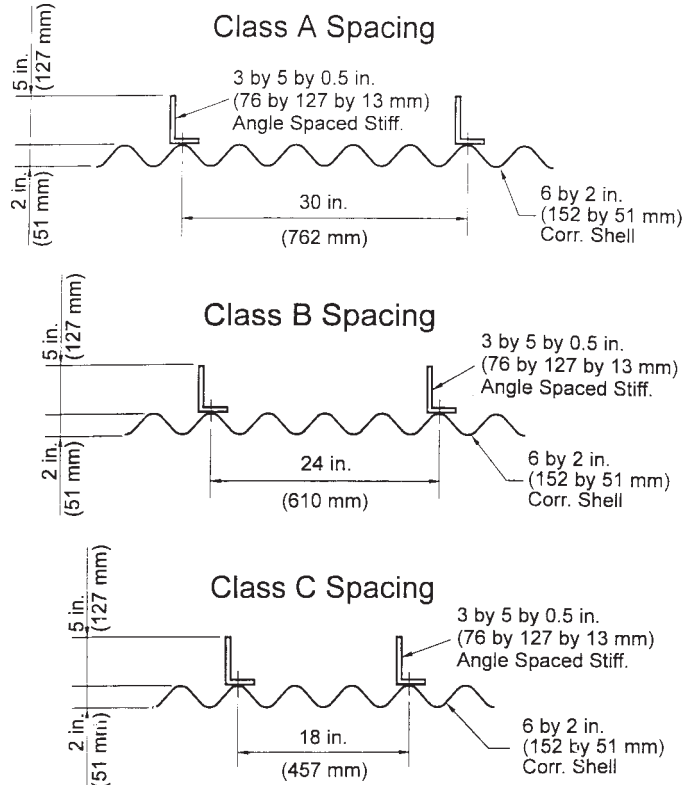
4.1.2.2 *Type II, Class B Spacing*, consisting of external stiffeners spaced at 24 in. [610 mm] center-to-center.

4.1.2.3 *Type II, Class C Spacing*, consisting of external stiffeners spaced at 18 in. [457 mm] center-to-center.

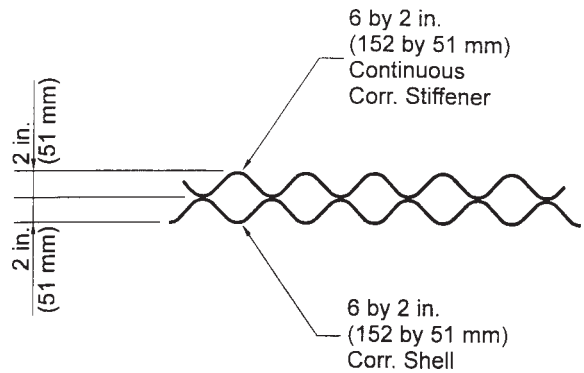
4.1.3 *Type III Box Culvert*, consisting of a 15 by 5.5 in. [381 by 140 mm] corrugated plate shell without stiffeners.

4.1.4 *Type IV Box Culvert*, consisting of a corrugated plate shell having 6 by 2 in. [152 by 51 mm] corrugations in combination with continuous corrugated plate stiffeners. The stiffener placement and cross section shall be as detailed in Fig. 5.

4.1.5 *Type V Box Culvert*, consisting of a corrugated plate shell having 15 by 5.5 in. [381 by 140 mm] corrugations in



NOTE—All dimensions are nominal.  
FIG. 4 Type II Rib Spacing Classes



NOTE—All dimensions are nominal.  
FIG. 5 Type IV Stiffener

combination with cold formed, corrugated plate stiffeners, continuous on the crown and, if required, spaced corrugated plate stiffeners on the haunches. The continuous crown stiffener placement and cross section shall be as detailed in Fig. 6. Where spaced haunch stiffeners are utilized, the stiffener spacing classes shall be as defined below and as illustrated in Fig. 7. Haunch stiffeners are not required to be continuous with the crown stiffeners around the periphery of the haunch and crown.

4.1.5.1 *Type V, Class A Spacing*, consisting of external haunch stiffeners spaced at 45 in. [1143 mm] center-to-center.

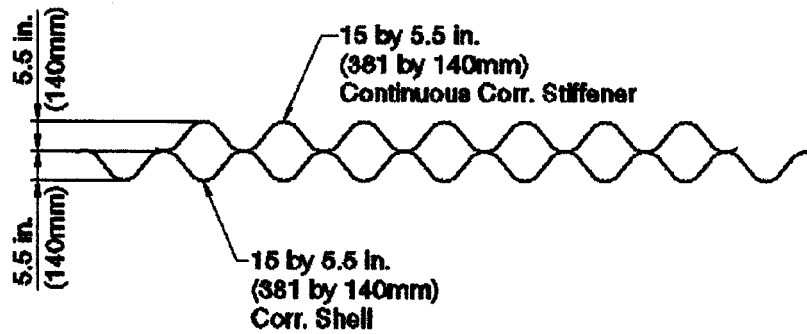


FIG. 6 Type V Continuous Crown Stiffener

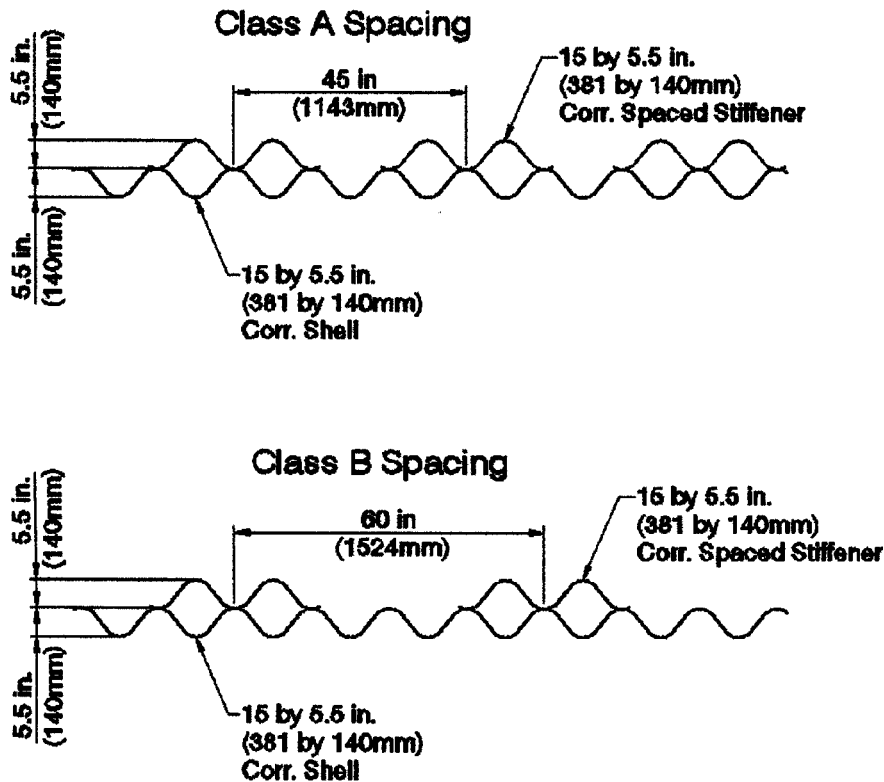


FIG. 7 Type V Spaced Haunch Stiffeners

4.1.5.2 *Type V, Class B Spacing*, consisting of external haunch stiffeners spaced at 60 in. [1524 mm] center-to-center.

## 5. Ordering Information

5.1 Orders for products specified herein shall include the following information required as necessary to adequately describe the desired product characteristics:

- 5.1.1 Name of product (corrugated steel box culvert),
- 5.1.2 ASTM designation and year of issue, as A 964- for inch-pound units or A 964M- for SI units,
- 5.1.3 Number of structures,
- 5.1.4 Nominal dimensions of each structure including the rise, span, length (measured along the bottom centerline), and the unobstructed cross sectional area required,

NOTE 1—The nominal length increment is 2 ft [0.61 m] for Types I, II

and IV box culverts and 2.5 ft [0.76 m] for Types III and V box culverts. Also, structure types with internal stiffeners reduce the available cross sectional area below nominal values. Therefore, the unobstructed cross sectional area required by the hydraulic design may be important in some cases.

5.1.5 The design ground surface profile documenting the location and magnitude of the minimum and maximum cover height over structure top centerline (measured from the inside crest of the corrugated plate to the finished surface of the traveled way),

NOTE 2—The design specifications limit cover height to a range of between 1.4 ft and 5.0 ft [0.43 m and 1.52 m]. Small deviations in the height of cover can make a significant difference in the design. It is recommended that the purchaser specify the ground surface profile to the nearest 0.1 ft [30 mm].

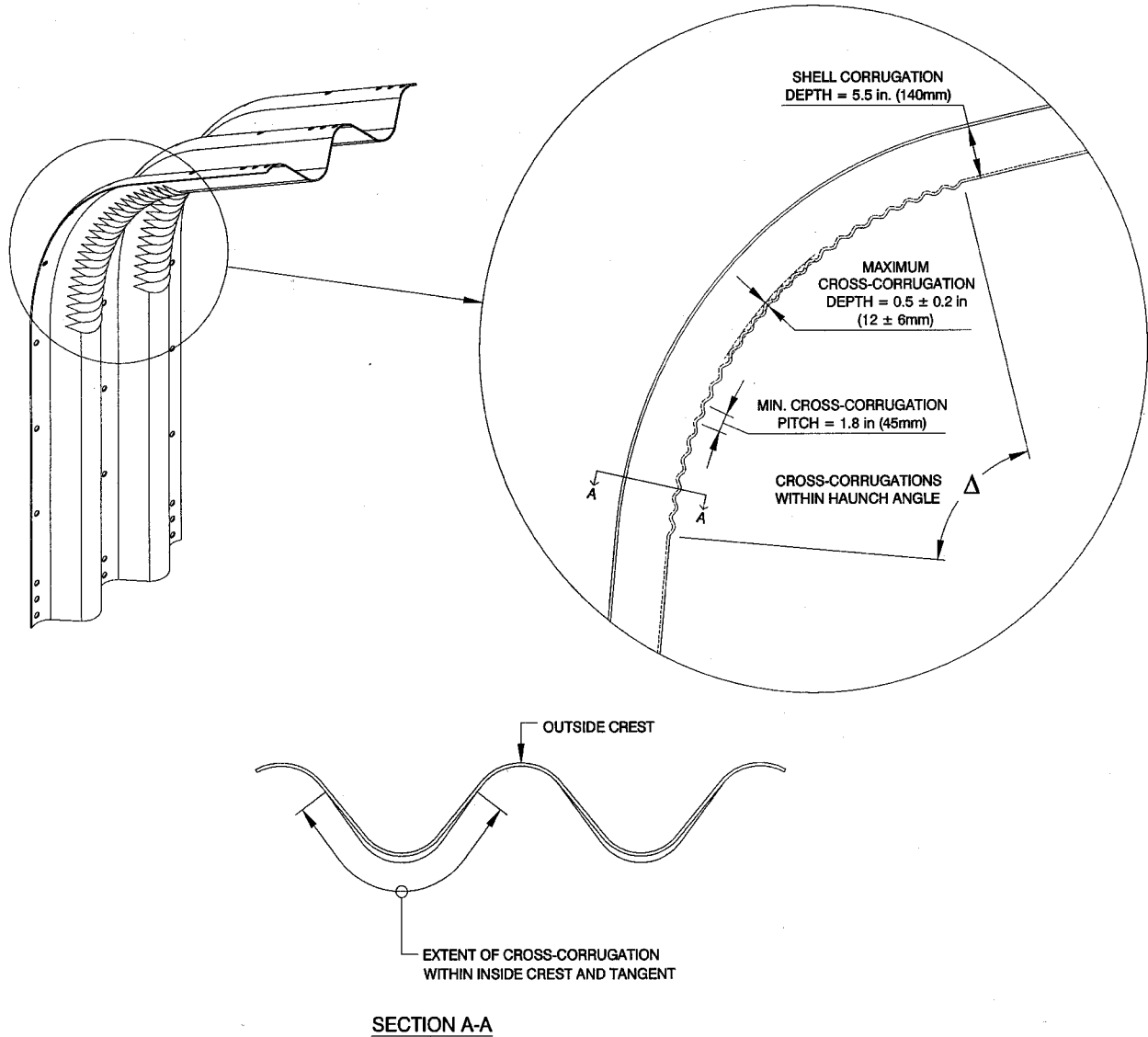


FIG. 8 Type V Cross-Corrugation Detail at Haunch

5.1.6 Dead load unit weight, if different than 120 lb/ft<sup>3</sup> [18.9 kN/m<sup>3</sup>],

5.1.7 Structure live load vehicle configuration, if different than AASHTO HS 20-44 (see AASHTO LRFD Bridge Design Specifications, Customary U.S. Units [LRFD Bridge Design Specifications, SI Units]),

5.1.8 Base channel, corrugated footing pads or full invert plates, if required. For box culverts not supported on concrete footings, allowable foundation bearing capacity, if different than 2 tons/ft<sup>2</sup> (192 kPa),

NOTE 3—Design procedures for corrugated footing pads or full invert plates are beyond the scope of this specification. However, general considerations for design of structural plate arch footings are given in A 796. Also, specific design criteria for similar applications are available in the AASHTO LRFD Bridge Design Specifications, Customary U.S. Units (LRFD Bridge Design Specifications, SI Units).

5.1.9 End treatment (bevel, skew, grade or slope corrections, corrugated steel headwalls, cut-off walls, or other special provision), if required,

NOTE 4—End conditions involving beveled or skewed cut ends may require a support wall or collar. The design procedures for these end treatments as well as vertical headwalls are beyond the scope of this specification.

5.1.10 Optionally, structure type (if not included in the order, structure type shall be the option of the fabricator),

NOTE 5—Some of the structure types specified herein may be proprietary and available from only one fabricator. Also, some fabricators may furnish more than one type. The most competitive alternative will generally be obtained by leaving type selection to the option of the fabricator. Note the revised plate material used in Type V boxes as specified in 7.1 and 7.6.

5.1.11 Other special requirements such as stubs, tap-ins, saddles, elbows, etc., if required, and

5.1.12 Material certification, if required (see 13.1).

NOTE 6—Typical ordering information may be described as: one corrugated steel box culvert, in accordance with ASTM A 964-, 7 ft, 3 in. rise by 20 ft, 8 in. span by 120 ft long, having a 1.4 ft minimum cover and a 3.0 ft maximum cover, with base channels for concrete footings; or two corrugated steel box culverts, in accordance with ASTM A 964M-, each being 1.88 m rise by 4.65 m span by 18.3 m long, each having 0.43 m minimum and maximum covers, assuming a dead load unit weight of 21.3 kN/m<sup>3</sup>, having full invert plates and having ends slope adjusted for 2-percent grade, including certification.

## 6. Design Properties

6.1 The required design properties shall be determined for the crown and haunch segments of the box culvert in accordance with the ordering information and the AASHTO LRFD Bridge Design Specifications, Customary U.S. Units (LRFD Bridge Design Specifications, SI Units) (see 1.6 and 2.2). The AASHTO specifications are applicable for the range of geometric limits given in Fig. 1 and Table 1.

## 7. Materials and Coatings

7.1 The corrugated plate material utilized for the shells of Type I, II, III and IV box culverts shall be fabricated from steel sheet or plate conforming to the chemical, mechanical, thickness, shape, and coating requirements of Specification A 761/A 761M. The corrugated plate material for Type V box culverts shall be fabricated from steel sheet or plate meeting the same requirements of A 761/A 761M except with a higher minimum flat plate yield strength of 40 ksi [275 MPa] and in accordance with the requirements of 7.11.

7.2 Stiffeners for Type I box culverts shall be 6 by 3 in. [152 by 76 mm] cold formed sections fabricated from steel sheet or plate conforming to the chemical, mechanical, thickness and coating requirements of Specification A 761/A 761M. They shall also meet the dimensions and tolerances of Fig. 2.

7.3 Stiffeners for Type II box culverts shall be 3 by 5 by 0.5 in. [76 by 127 by 13 mm] hot rolled steel angles conforming to the dimensional requirements of Specification A 6/A 6M and to the chemical and mechanical requirements of Specification A 36/A 36M. These members shall be hot dip galvanized after fabrication in accordance with the coating requirements of Specification A 123/A 123M.

7.4 Stiffeners for Type IV box culverts shall be a 6 by 2 in. [152 by 51 mm] corrugated structural member fabricated from

sheet or plate conforming to the chemical, mechanical, thickness, shapes and coating requirements of Specification A 761/A 761M.

7.5 Stiffeners for Type V box culverts shall be a 15 by 5.5 in. [381 by 140 mm] corrugated structural member fabricated from sheet or plate conforming to the chemical, mechanical, thickness, shapes and coating requirements of Specification A 761/A 761M except with a minimum flat plate yield strength of 40 ksi [275 MPa] and in accordance with the requirements of 7.11.

7.6 Base channels, when specified, shall be fabricated from flat steel plate conforming to the chemical, mechanical and coating requirements of Specification A 761/A 761M, having a nominal coated thickness of 0.188 in. [4.78 mm].

7.7 Corrugated steel footing and full invert members, when specified, shall conform to the same material and coating requirements as 7.1. Thickness shall be as required by the design (see Note 3).

7.8 Corrugated steel headwalls, when specified, shall conform to the same material and coating requirements as 7.1. Walers, tie-back rods, deadman anchors, and other members fabricated from steel shapes, plates and bars shall conform to the chemical and mechanical requirements of Specification A 36/A 36M, except that assembly fasteners shall meet the requirements of 7.10. These members shall be hot dip galvanized after fabrication in accordance with the coating requirements of Specification A 123/A 123M. Thickness, shape and dimensions of these members shall be as required by the design (see Note 4).

7.9 Steel cut-off walls, when specified, shall conform to the same material and coating requirements as 7.1 above, having a nominal coated thickness of not less than 0.111 in. [2.82 mm]. Cut-off walls are permitted to be either corrugated or flat.

7.10 Assembly fasteners. Bolts and nuts required to join corrugated members together, to join corrugated members to other structural shapes or to join structural shapes together shall conform to the requirements of Specification A 761/A 761M.

7.11 If agreed upon between the purchaser and the fabricator, steel sheet and plate having higher minimum yields are permitted to be substituted for Specification A 761/A 761M stock provided the elongation in 2 in. [50 mm] of the substituted steel is not less than 23 % before fabrication and the final fabricated product meets the required tolerances on shape and thickness specified in Specification A 761/A 761M.

## 8. Fabrication

8.1 The corrugated steel shell of the box culvert shall conform to the geometric dimensional limits specified in Table 1 and shall be subject to the permissible variations of 10.1, 10.2, and 10.3.

8.2 Corrugated steel shell plates of all box culvert types shall be fabricated in accordance with Specification A 761/A 761M. The longitudinal plate lap of the steel shell shall be adequate to develop the bending and axial forces carried by the shell at the location of the lap.

8.3 Corrugated stiffeners for Type I box culverts shall be formed with smooth, continuous curves and tangents in the

**TABLE 1 Geometric Limits of Box Culverts**

Elements <sup>A</sup>	Minimum	Maximum
Span ( <i>S</i> )	8.75 ft [2.67 m]	25.42 ft [7.75 m]
Rise ( <i>R</i> )	2.50 ft [0.76 m]	10.50 ft [3.20 m]
Radius of crown ( <i>r<sub>c</sub></i> )	...	24.79 ft [7.56 m]
Radius of haunch ( <i>r<sub>h</sub></i> )	2.50 ft [0.76 m]	...
Haunch angle ( $\Delta$ )	50°	70°
Length of leg ( <i>D</i> )	0.50 ft [0.15 m]	5.2 ft [1.59 m]
Length of rib on leg ( <i>t</i> )	<sup>B</sup> ...	...

<sup>A</sup>See Fig. 1 for illustration of geometric elements.

<sup>B</sup>Minimum 19 in. [483 mm] or length of leg (*D*) minus 3 in. [76 mm], whichever is less.

**TABLE 2 Permissible Variations<sup>A</sup> in Box Culvert Dimensions**

Rise <sup>B</sup>		Span <sup>B</sup>		Length		Area <sup>C</sup>
% Variation	Range-ft (m)	% Variation	Range-ft (m)	% Variation	% Variation	% Variation
±2 % of span	8.75 to 12.24 [2.67 to 3.72]	±7 % of span	30 to 49 [9.1 to 15.0]	±5 % of length	-2 % of area	
	12.25 to 20.41 [3.73 to 6.21]	±5 % of span	50 to 149 [15.1 to 45.5]	±3 % of length		
	20.42 to 25.42 [6.22 to 7.75]	±3 % of span	≥150 [≥45.6]	±1 % of length		

<sup>A</sup>The permissible variations listed provide for differences in shape between various manufacturers' standard products as well as normal manufacturing tolerances.

<sup>B</sup>In no case shall the permitted variations in rise and span result in a combination of cover height and loading requirements that fall outside the limits specified by the design (see 6.1).

<sup>C</sup>A limitation to the positive variation in area is not applicable.

cross section of the corrugation to the dimensional requirements shown in Fig. 2. Bolt hole spacing and edge distances shall be in accordance with Specification A 761/A 761M for the 6 by 2 in. [152 by 51 mm] corrugation. They shall be curved into annular rings conforming to the shape and dimensions of the structural plate shell. The bolt holes shall be punched so that all members having like dimensions and curvature are interchangeable. Sufficient bolt holes shall be provided in the corrugated shell to match the arrangement, number and spacing of bolt holes in the corrugated stiffeners. The layout of the corrugated stiffeners relative to the corrugated shell shall be in accordance with 4.1.1 for the thickness and spacing class required by the design.

8.4 Hot rolled angle stiffeners for Type II box culverts shall be curved into annular rings conforming to the shape and dimensions of the structural plate shell. The bolt holes shall be punched so that all members having like dimensions and curvature are interchangeable. Sufficient bolt holes shall be provided in the corrugated shell to match the arrangement, number and spacing of bolt holes in the angle stiffeners. The layout of the angle stiffeners relative to the corrugated shell shall be in accordance with 4.1.2 for the thickness and spacing class required by the design.

8.5 Corrugated stiffeners for Type IV box culverts shall be a 6 by 2 in. [152 by 51 mm] corrugated structural member curved into annular rings conforming to the shape and dimensions of the structural plate shell. They shall be formed with smooth, continuous curves and tangents in the cross section of the corrugation. Bolt hole spacing and edge spacing shall be in accordance with Specification A 761/A 761M for the 6 by 2 in. [152 by 51 mm] corrugation. The bolt holes shall be punched so that all members having like dimensions and curvatures are interchangeable. Sufficient matching bolt holes shall be provided in the corrugated shell and stiffeners to meet the requirements of 8.8. The layout of the corrugated stiffeners relative to the corrugated shell shall be in accordance with 4.1.4 for the thickness and spacing class required by the design.

8.6 Corrugated stiffeners for Type V box culverts shall be 15 by 5.5 in. [381 by 140 mm] corrugated structural members curved into annular rings conforming to the shape and dimensions of the structural plate shell. They shall be formed with smooth, continuous curves and tangents in the cross section of the corrugation. Bolt hole spacing shall be in accordance with Specification A 761/A 761M for the 15 by 5.5 in. [381 by 140 mm] corrugation except that edge bolt hole spacing shall be duplicated along the middle corrugation. The bolt holes shall be punched so that all members having like dimensions and curvatures are interchangeable. Sufficient bolt holes shall be

provided in the corrugated shell to match the arrangement, number and spacing of bolt holes in the corrugated stiffeners. The layout of the corrugated stiffeners relative to the corrugated shell shall be in accordance with 4.1.5 for the thickness and spacing class required by the design.

8.7 Stiffeners that are designed to be continuous around the periphery of the crown and haunch, but that are not fabricated in one piece, shall be either overlapped or provided with splice connections at the intermediate ends. The design of the overlap or splice shall be adequate to develop the bending and axial forces carried by the stiffener at the location of the overlap or splice.

8.8 Stiffeners shall be provided with adequate bolted connectors to resist the beam shear that develops between the stiffener and the shell due to the moment requirements described in 6.1.

8.9 Corrugated footing and invert plates shall be fabricated in accordance with Specification A 761/A 761M.

8.10 Special members for headwalls, cut-off walls, base channels, etc. and special plates forming skewed ends, beveled ends, or curved alignment, when required, shall be accurately cut to fit the requirements of the ordering information. Cut edges of members shall not contain excessive notches, gouges, or burrs, and shall present a workmanlike finish.

## 9. Repair of Damaged Coating

9.1 Plates, stiffeners, or accessories on which the metallic coating has been burned by welding, or has been otherwise damaged in fabricating or handling, shall be repaired in accordance with Specification A 761/A 761M.

## 10. Dimensions, Mass, and Permissible Variations

10.1 Furnished box culvert dimensions shall not vary from the ordered sizes by more than the permissible amounts given in Table 2, except as noted in 10.2 and 10.3.

10.2 When agreed upon between the purchaser and the fabricator, the span dimension furnished is permitted to exceed that allowed by the permissible variations given in Table 2. However, the variation in cross sectional area furnished shall meet the requirements of Table 2, compared to that ordered. Also, the actual span shall be used in lieu of the ordered span for structural design (see 1.2 and 6.1).

10.3 When agreed upon between the purchaser and the fabricator, the variation in the rise dimension furnished is permitted to exceed Table 2. However, the variation in cross sectional area furnished shall meet the requirements of Table 2, compared to that ordered. Also, the resulting shape and height

of cover shall meet the structural and hydraulic design requirements for box culverts (see 1.2, 1.3, and 6.1).

### 11. Workmanship, Finish, and Appearance

11.1 Corrugated plate shells, stiffeners, accessories, and fasteners shall be of uniform quality consistent with good manufacturing, fabrication and inspection practices.

### 12. Sampling and Testing

12.1 Sampling and testing of corrugated plate material for chemical composition, mechanical properties, and coating weight shall be in accordance with Specification A 761/A 761M.

12.2 Sampling and testing of miscellaneous structural shapes and flat plates for chemical composition and mechanical properties shall be in accordance with Specification A 6/A 6M. Sampling and testing for coating weight of these members shall be in accordance with Specification A 123/A 123M.

### 13. Rejection and Rehearing

13.1 Material that fails to conform to the requirements of this specification shall be subject to rejection. Rejection shall be reported to the fabricator promptly and in writing. In case of dissatisfaction with the results of the test, the fabricator shall make claim for a rehearing.

### 14. Material Certification

14.1 When specified in the purchase order or contract, the purchaser shall be furnished a material certification that samples representing each lot have been either tested or inspected as directed in this specification and that the requirements have been met. When specified in the purchase order or contract, a report of the test results shall be furnished.

### 15. Product Marking

15.1 Each corrugated plate, excluding corrugated stiffeners, shall be identified in accordance with the requirements of Specification A 761/A 761M.

### 16. Assembly Drawings

16.1 The purchaser shall be furnished with assembly drawings showing the layout and location of all structural members supplied in accordance with the ordering information. Legible identification shall be placed on each special member to designate its proper position in the finished structure and shall be referenced on the assembly drawings.

### 17. Keywords

17.1 bridge; box culvert; corrugated structural plate; culvert; galvanized steel; grade separation; low cover structure; low profile structure; storm sewer

## APPENDIXES

### (Nonmandatory Information)

#### X1. DIMENSIONS AND HYDRAULIC PROPERTIES OF BOX CULVERT SIZES COMMONLY AVAILABLE

X1.1 See Table X1.1 for nominal dimensions of box culvert sizes commonly available.

**TABLE X1.1 Dimensions and Hydraulic Properties of Box Culvert Sizes Commonly Available**

Number	Rise, ft [m]	Span, ft [m]	Area, <sup>A</sup> ft <sup>2</sup> [m <sup>2</sup> ]	R, <sup>B</sup> ft [m]	WP, <sup>C</sup> ft [m]	AR <sup>2/3D</sup>	AD <sup>1/2E</sup>
1	2 ft 6 in. [0.762]	9 ft 2 in. [2.79]	18.4 [1.71]	0.920 [0.280]	20.0 [6.10]	17.4 [0.732]	29.1 [1.49]
2	2 ft 7 in. [0.787]	9 ft 8 in. [2.95]	20.2 [1.88]	0.910 [0.277]	22.2 [6.77]	19.0 [0.798]	32.5 [1.67]
3	2 ft 8 in. [0.813]	10 ft 6 in. [3.19]	22.6 [2.10]	0.950 [0.290]	23.8 [7.25]	21.8 [0.919]	36.9 [1.89]
4	2 ft 9 in. [0.838]	11 ft 1 in. [3.37]	24.8 [2.30]	1.02 [0.311]	24.3 [7.41]	25.1 [1.06]	41.1 [2.11]
5	2 ft 10 in. [0.864]	11 ft 10 in. [3.60]	27.8 [2.58]	1.04 [0.317]	26.7 [8.15]	28.5 [1.20]	46.8 [2.40]
6	2 ft 11 in. [0.889]	12 ft 9 in. [3.89]	30.6 [2.84]	1.08 [0.329]	28.3 [8.64]	32.2 [1.36]	52.3 [2.68]
7	3 ft 1 in. [0.940]	13 ft 2 in. [4.02]	33.5 [3.11]	1.13 [0.344]	29.6 [9.04]	36.3 [1.53]	58.8 [3.02]
8	3 ft 2 in. [0.965]	14 ft 1 in. [4.29]	36.6 [3.40]	1.17 [0.357]	31.3 [9.53]	40.6 [1.71]	65.1 [3.34]
9	3 ft 3 in. [0.991]	14 ft 6 in. [4.43]	39.0 [3.62]	1.23 [0.375]	31.7 [9.66]	44.8 [1.88]	70.3 [3.61]
10	3 ft 4 in. [1.02]	9 ft [2.76]	24.2 [2.25]	1.13 [0.344]	21.4 [6.53]	26.3 [1.10]	44.2 [2.27]
11	3 ft 4 in. [1.02]	10 ft 1 in. [3.07]	27.7 [2.57]	1.18 [0.360]	23.5 [7.15]	30.9 [1.30]	50.6 [2.59]
12	3 ft 5 in. [1.04]	10 ft 10 in. [3.30]	30.8 [2.86]	1.20 [0.366]	25.7 [7.82]	34.8 [1.46]	56.9 [2.92]
13	3 ft 5 in. [1.04]	15 ft 4 in. [4.68]	43.3 [4.02]	1.27 [0.387]	34.1 [10.4]	50.8 [2.14]	80.0 [4.11]
14	3 ft 6 in. [1.07]	11 ft 6 in. [3.51]	33.2 [3.08]	1.25 [0.381]	26.6 [8.10]	38.5 [1.62]	62.1 [3.19]
15	3 ft 6 in. [1.07]	16 ft [4.89]	46.2 [4.29]	1.30 [0.396]	35.5 [10.8]	55.0 [2.32]	86.4 [4.43]
16	3 ft 8 in. [1.12]	12 ft 2 in. [3.70]	37.2 [3.46]	1.30 [0.396]	28.6 [8.72]	44.3 [1.86]	71.2 [3.65]
17	3 ft 8 in. [1.12]	16 ft 8 in. [5.09]	50.7 [4.71]	1.36 [0.415]	37.3 [11.4]	62.2 [2.62]	97.1 [4.98]
18	3 ft 9 in. [1.14]	12 ft 10 in. [3.91]	39.7 [3.69]	1.35 [0.411]	29.4 [8.96]	48.5 [2.04]	76.9 [3.94]
19	3 ft 10 in. [1.17]	13 ft 6 in. [4.10]	44.0 [4.09]	1.42 [0.433]	31.0 [9.44]	55.6 [2.34]	86.1 [4.42]
20	3 ft 10 in. [1.17]	17 ft 6 in. [5.33]	54.0 [5.02]	1.42 [0.433]	38.0 [11.6]	68.2 [2.87]	106 [5.42]
21	4 ft [1.22]	14 ft 4 in. [4.36]	47.8 [4.44]	1.44 [0.439]	33.2 [10.1]	61.0 [2.56]	95.6 [4.90]
22	4 ft [1.22]	18 ft 2 in. [5.54]	58.8 [5.46]	1.47 [0.448]	40.0 [12.2]	76.0 [3.20]	118 [6.03]
23	4 ft 1 in. [1.24]	9 ft 6 in. [2.90]	31.1 [2.89]	1.32 [0.402]	23.6 [7.18]	37.4 [1.57]	62.8 [3.22]





TABLE X1.1 Continued

Number	Rise, ft [m]	Span, ft [m]	Area, <sup>A</sup> ft <sup>2</sup> [m <sup>2</sup> ]	R, <sup>B</sup> ft [m]	WP, <sup>C</sup> ft [m]	AR <sup>2/3D</sup>	AD <sup>1/2E</sup>
24	4 ft 1 in. [1.24]	14 ft 10 in. [4.52]	51.3 [4.77]	1.50 [0.457]	34.2 [10.4]	67.2 [2.83]	104 [5.32]
25	4 ft 2 in. [1.27]	10 ft 7 in. [3.22]	35.9 [3.34]	1.37 [0.418]	26.2 [7.99]	44.3 [1.86]	73.3 [3.76]
26	4 ft 2 in. [1.27]	15 ft 7 in. [4.74]	55.6 [5.17]	1.54 [0.469]	36.1 [11.0]	74.1 [3.12]	113 [5.82]
27	4 ft 2 in. [1.27]	18 ft 9 in. [5.72]	62.2 [5.78]	1.53 [0.466]	40.7 [12.4]	82.6 [3.47]	127 [6.51]
28	4 ft 3 in. [1.30]	11 ft 2 in. [3.42]	39.4 [3.66]	1.42 [0.433]	27.7 [8.46]	49.8 [2.09]	81.2 [4.17]
29	4 ft 3 in. [1.30]	19 ft 5 in. [5.92]	66.0 [6.13]	1.55 [0.472]	42.6 [13.0]	88.4 [3.72]	136 [6.98]
30	4 ft 4 in. [1.32]	11 ft 9 in. [3.59]	42.4 [3.94]	1.50 [0.457]	28.3 [8.62]	55.6 [2.34]	88.3 [4.53]
31	4 ft 4 in. [1.32]	16 ft 3 in. [4.96]	59.5 [5.53]	1.61 [0.491]	37.0 [11.3]	81.7 [3.44]	124 [6.35]
32	4 ft 5 in. [1.35]	12 ft 6 in. [3.80]	46.9 [4.36]	1.53 [0.466]	30.7 [9.34]	62.3 [2.62]	98.6 [5.06]
33	4 ft 6 in. [1.37]	13 ft 3 in. [4.03]	49.4 [4.59]	1.57 [0.479]	31.5 [9.59]	66.7 [2.81]	105 [5.37]
34	4 ft 6 in. [1.37]	16 ft 10 in. [5.13]	64.1 [5.95]	1.65 [0.503]	38.8 [11.8]	89.5 [3.77]	136 [6.97]
35	4 ft 6 in. [1.37]	20 ft [6.08]	70.8 [6.58]	1.64 [0.500]	43.2 [13.2]	98.5 [4.14]	150 [7.70]
36	4 ft 7 in. [1.40]	17 ft 9 in. [5.42]	67.2 [6.24]	1.68 [0.512]	40.0 [12.2]	95.0 [4.00]	144 [7.38]
37	4 ft 7 in. [1.40]	20 ft 8 in. [6.29]	74.7 [6.94]	1.66 [0.506]	45.0 [13.7]	105 [4.41]	160 [8.20]
38	4 ft 8 in. [1.42]	13 ft 9 in. [4.20]	54.8 [5.09]	1.66 [0.506]	33.0 [10.1]	76.8 [3.23]	118 [6.07]
39	4 ft 9 in. [1.45]	14 ft 7 in. [4.45]	59.1 [5.49]	1.69 [0.515]	35.0 [10.7]	83.9 [3.53]	129 [6.61]
40	4 ft 9 in. [1.45]	18 ft 4 in. [5.60]	73.1 [6.79]	1.74 [0.530]	42.0 [12.8]	106 [4.45]	159 [8.17]
41	4 ft 11 in. [1.50]	10 ft [3.04]	39.1 [3.63]	1.52 [0.463]	25.7 [7.84]	51.7 [2.17]	86.7 [4.45]
42	4 ft 11 in. [1.50]	11 ft [3.34]	44.2 [4.11]	1.57 [0.479]	28.2 [8.58]	59.7 [2.51]	98.0 [5.03]
43	4 ft 11 in. [1.50]	15 ft [4.57]	63.2 [5.87]	1.77 [0.539]	35.7 [10.9]	92.5 [3.89]	140 [7.19]
44	4 ft 11 in. [1.50]	19 ft 2 in. [5.83]	78.2 [7.26]	1.81 [0.552]	43.2 [13.2]	116 [4.89]	173 [8.89]
45	4 ft 11 in. [1.50]	21 ft 6 in. [6.57]	83.8 [7.79]	1.77 [0.539]	47.3 [14.4]	123 [5.16]	186 [9.53]
46	5 ft [1.52]	11 ft 8 in. [3.54]	48.2 [4.48]	1.66 [0.506]	29.0 [8.85]	67.6 [2.84]	108 [5.53]
47	5 ft [1.52]	15 ft 10 in. [4.82]	68.1 [6.33]	1.80 [0.549]	37.8 [11.5]	101 [4.24]	152 [7.81]
48	5 ft 1 in. [1.55]	12 ft 5 in. [3.79]	52.5 [4.88]	1.68 [0.512]	31.3 [9.52]	74.2 [3.12]	118 [6.07]
49	5 ft 1 in. [1.55]	19 ft 8 in. [5.98]	82.3 [7.65]	1.85 [0.564]	44.5 [13.6]	124 [5.22]	186 [9.52]
50	5 ft 2 in. [1.57]	12 ft 10 in. [3.91]	56.6 [5.26]	1.77 [0.539]	32.0 [9.75]	82.8 [3.48]	129 [6.60]
51	5 ft 2 in. [1.57]	16 ft 4 in. [4.98]	72.2 [6.71]	1.86 [0.567]	38.8 [11.8]	109 [4.59]	164 [8.42]
52	5 ft 3 in. [1.60]	17 ft 2 in. [5.22]	77.6 [7.21]	1.91 [0.582]	40.6 [12.4]	119 [5.03]	178 [9.12]
53	5 ft 3 in. [1.60]	20 ft 8 in. [6.30]	88.4 [8.21]	1.90 [0.579]	46.5 [14.2]	136 [5.71]	203 [10.4]
54	5 ft 4 in. [1.63]	13 ft 8 in. [4.17]	60.8 [5.65]	1.79 [0.546]	34.0 [10.4]	89.6 [3.77]	140 [7.20]
55	5 ft 4 in. [1.63]	22 ft 8 in. [6.90]	95.0 [8.83]	1.91 [0.582]	49.7 [15.2]	146 [6.15]	219 [11.25]
56	5 ft 5 in. [1.65]	14 ft [4.27]	65.6 [6.09]	1.89 [0.576]	34.7 [10.6]	100 [4.22]	153 [7.83]
57	5 ft 5 in. [1.65]	18 ft [5.49]	82.2 [7.64]	1.95 [0.594]	42.2 [12.8]	128 [5.40]	191 [9.81]
58	5 ft 5 in. [1.65]	21 ft 2 in. [6.44]	94.1 [8.74]	1.98 [0.604]	47.5 [14.5]	148 [6.24]	219 [11.2]
59	5 ft 7 in. [1.70]	11 ft [3.34]	47.9 [4.45]	1.65 [0.503]	29.0 [8.85]	66.9 [2.81]	113 [5.81]
60	5 ft 7 in. [1.70]	14 ft 10 in. [4.53]	70.7 [6.57]	1.92 [0.585]	36.8 [11.2]	109 [4.60]	167 [8.57]
61	5 ft 7 in. [1.70]	18 ft 4 in. [5.58]	87.9 [8.17]	2.02 [0.616]	43.5 [13.3]	140 [5.91]	208 [10.7]
62	5 ft 8 in. [1.73]	11 ft 5 in. [3.47]	52.6 [4.89]	1.77 [0.539]	29.7 [9.06]	77.0 [3.24]	125 [6.42]
63	5 ft 8 in. [1.73]	15 ft 5 in. [4.71]	75.1 [6.98]	2.00 [0.610]	37.6 [11.4]	119 [5.02]	179 [9.17]
64	5 ft 8 in. [1.73]	19 ft 3 in. [5.87]	93.3 [8.67]	2.07 [0.631]	45.1 [13.7]	152 [6.38]	222 [11.4]
65	5 ft 8 in. [1.73]	22 ft 2 in. [6.77]	101 [9.38]	2.05 [0.625]	49.3 [15.0]	163 [6.86]	240 [12.3]
66	5 ft 9 in. [1.75]	12 ft [3.66]	57.2 [5.31]	1.84 [0.561]	31.1 [9.47]	85.9 [3.61]	137 [7.03]
67	5 ft 10 in. [1.78]	16 ft [4.89]	80.7 [7.50]	2.03 [0.619]	39.8 [12.1]	129 [5.44]	195 [10.0]
68	5 ft 10 in. [1.78]	19 ft 10 in. [6.05]	97.2 [9.03]	2.10 [0.640]	46.3 [14.1]	159 [6.71]	235 [12.0]
69	5 ft 10 in. [1.78]	23 ft 9 in. [7.24]	108 [10.1]	2.05 [0.625]	52.8 [16.1]	175 [7.35]	261 [13.4]
70	5 ft 11 in. [1.80]	12 ft 10 in. [3.92]	62.3 [5.79]	1.88 [0.573]	33.1 [10.1]	94.9 [3.99]	152 [7.77]
71	5 ft 11 in. [1.80]	16 ft 8 in. [5.07]	84.7 [7.87]	2.08 [0.634]	40.7 [12.4]	138 [5.81]	206 [10.6]
72	6 ft [1.83]	13 ft 2 in. [4.02]	66.6 [6.19]	1.97 [0.600]	33.8 [10.3]	105 [4.40]	163 [8.37]
73	6 ft 1 in. [1.85]	14 ft [4.27]	72.1 [6.70]	2.01 [0.613]	35.9 [10.9]	115 [4.83]	178 [9.12]
74	6 ft 1 in. [1.85]	17 ft 2 in. [5.23]	91.3 [8.48]	2.15 [0.655]	42.5 [12.9]	152 [6.40]	225 [11.5]
75	6 ft 1 in. [1.85]	19 ft 2 in. [5.85]	97.1 [9.02]	2.17 [0.661]	44.7 [13.6]	163 [6.85]	239 [12.3]
76	6 ft 1 in. [1.85]	23 ft 4 in. [7.10]	114 [10.6]	2.19 [0.668]	51.9 [15.8]	192 [8.07]	280 [14.4]
77	6 ft 2 in. [1.88]	20 ft 11 in. [6.37]	106 [9.80]	2.19 [0.668]	48.2 [14.7]	178 [7.49]	262 [13.4]
78	6 ft 2 in. [1.88]	24 ft 10 in. [7.56]	119 [11.1]	2.19 [0.668]	54.3 [16.6]	201 [8.44]	296 [15.2]
79	6 ft 3 in. [1.91]	14 ft 4 in. [4.37]	76.6 [7.12]	2.09 [0.637]	36.7 [11.2]	125 [5.27]	192 [9.82]
80	6 ft 3 in. [1.91]	18 ft [5.48]	96.9 [9.00]	2.21 [0.674]	43.8 [13.4]	164 [6.92]	242 [12.4]
81	6 ft 4 in. [1.93]	10 ft 10 in. [3.30]	53.8 [5.00]	1.82 [0.555]	29.6 [9.01]	80.2 [3.37]	135 [6.94]
82	6 ft 4 in. [1.93]	15 ft 1 in. [4.61]	82.5 [7.66]	2.13 [0.649]	38.7 [11.8]	137 [5.75]	208 [10.6]
83	6 ft 4 in. [1.93]	18 ft 4 in. [5.60]	102 [9.47]	2.27 [0.692]	44.9 [13.7]	176 [7.41]	256 [13.2]
84	6 ft 5 in. [1.96]	11 ft 9 in. [3.59]	61.2 [5.69]	1.93 [0.588]	31.7 [9.66]	94.9 [3.99]	155 [7.95]
85	6 ft 6 in. [1.98]	15 ft 6 in. [4.72]	87.1 [8.09]	2.22 [0.677]	39.2 [12.0]	148 [6.24]	222 [11.4]
86	6 ft 6 in. [1.98]	19 ft 2 in. [5.85]	107 [9.90]	2.29 [0.698]	46.6 [14.2]	185 [7.79]	272 [13.9]
87	6 ft 6 in. [1.98]	20 ft 2 in. [6.16]	109 [10.1]	2.30 [0.701]	47.5 [14.5]	190 [8.01]	278 [14.3]
88	6 ft 6 in. [1.98]	22 ft 5 in. [6.83]	118 [11.0]	2.32 [0.707]	51.0 [15.6]	207 [8.73]	302 [15.5]
89	6 ft 6 in. [1.98]	24 ft 4 in. [7.40]	127 [11.8]	2.31 [0.704]	55.1 [16.8]	222 [9.35]	324 [16.6]
90	6 ft 7 in. [2.01]	12 ft 5 in. [3.78]	66.4 [6.17]	2.01 [0.613]	33.0 [10.1]	106 [4.45]	170 [8.74]
91	6 ft 7 in. [2.01]	16 ft 3 in. [4.94]	93.5 [8.69]	2.25 [0.686]	41.6 [12.7]	161 [6.75]	240 [12.3]
92	6 ft 8 in. [2.03]	13 ft 1 in. [3.99]	72.3 [6.72]	2.06 [0.628]	35.1 [10.7]	117 [4.93]	187 [9.57]
93	6 ft 8 in. [2.03]	19 ft 8 in. [6.01]	113 [10.5]	2.38 [0.725]	47.6 [14.5]	202 [8.50]	293 [15.0]
94	6 ft 9 in. [2.06]	13 ft 6 in. [4.12]	76.9 [7.14]	2.15 [0.655]	35.8 [10.9]	128 [5.39]	200 [10.2]
95	6 ft 9 in. [2.06]	16 ft 10 in. [5.12]	98.3 [9.13]	2.33 [0.710]	42.2 [12.9]	173 [7.27]	253 [13.1]
96	6 ft 10 in. [2.08]	17 ft 5 in. [5.31]	105 [9.76]	2.37 [0.722]	44.3 [13.5]	187 [7.86]	275 [14.1]
97	6 ft 10 in. [2.08]	2 ft 3 in. [6.48]	122 [11.3]	2.42 [0.738]	50.3 [15.3]	219 [9.23]	318 [16.3]

**TABLE X1.1** *Continued*

Number	Rise, ft [m]	Span, ft [m]	Area, <sup>A</sup> ft <sup>2</sup> [m <sup>2</sup> ]	R, <sup>B</sup> ft [m]	WP, <sup>C</sup> ft [m]	AR <sup>2/3D</sup>	AD <sup>1/2E</sup>
98	6 ft 11 in. [2.11]	14 ft 2 in. [4.32]	83.1 [7.72]	2.20 [0.671]	37.8 [11.5]	141 [5.91]	219 [11.2]
99	6 ft 11 in. [2.11]	19 ft 7 in. [5.97]	112 [10.4]	2.39 [0.728]	46.8 [14.3]	200 [8.42]	294 [15.1]
100	6 ft 11 in. [2.11]	23 ft 5 in. [7.14]	132 [12.3]	2.46 [0.750]	53.7 [16.4]	241 [10.1]	347 [17.8]
101	7 ft [2.13]	14 ft 8 in. [4.48]	88.4 [8.21]	2.28 [0.695]	38.8 [11.8]	153 [6.44]	234 [12.0]
102	7 ft [2.13]	18 ft 1 in. [5.51]	111 [10.3]	2.46 [0.750]	45.2 [13.8]	202 [8.52]	294 [15.1]
103	7 ft [2.13]	21 ft 2 in. [6.44]	127 [11.8]	2.51 [0.765]	50.8 [15.5]	235 [9.90]	337 [17.3]
104	7 ft [2.13]	25 ft 4 in. [7.71]	142 [13.2]	2.47 [0.753]	57.6 [17.5]	260 [10.9]	376 [19.3]
105	7 ft 11 in. [2.16]	15 ft 5 in. [4.69]	94.5 [8.78]	2.33 [0.710]	40.6 [12.4]	166 [6.99]	252 [12.9]
106	7 ft 2 in. [2.18]	11 ft 4 in. [3.44]	63.0 [5.85]	1.98 [0.604]	31.8 [9.70]	99.3 [4.18]	169 [8.65]
107	7 ft 2 in. [2.18]	18 ft 9 in. [5.71]	117 [10.9]	2.52 [0.768]	46.5 [14.2]	217 [9.14]	314 [16.1]
108	7 ft 3 in. [2.21]	12 ft 3 in. [3.73]	71.2 [6.61]	2.07 [0.631]	34.4 [10.5]	116 [4.87]	192 [9.83]
109	7 ft 3 in. [2.21]	15 ft 8 in. [4.79]	98.7 [9.17]	2.40 [0.732]	41.1 [12.5]	177 [7.44]	266 [13.6]
110	7 ft 3 in. [2.21]	20 ft 7 in. [6.27]	125 [11.6]	2.53 [0.771]	49.4 [15.1]	232 [9.77]	337 [17.3]
111	7 ft 3 in. [2.21]	22 ft 7 in. [6.88]	136 [12.6]	2.57 [0.783]	52.9 [16.1]	255 [10.7]	366 [18.8]
112	7 ft 4 in. [2.24]	12 ft 10 in. [3.90]	76.0 [7.06]	2.17 [0.661]	35.0 [10.7]	127 [5.36]	206 [10.6]
113	7 ft 4 in. [2.24]	19 ft 1 in. [5.83]	122 [11.3]	2.55 [0.777]	47.6 [14.5]	227 [9.54]	329 [16.9]
114	7 ft 4 in. [2.24]	24 ft 5 in. [7.44]	147 [13.6]	2.60 [0.792]	56.5 [17.2]	278 [11.7]	398 [20.4]
115	7 ft 5 in. [2.26]	13 ft 4 in. [4.06]	80.4 [7.47]	2.23 [0.680]	36.1 [11.0]	137 [5.77]	219 [11.2]
116	7 ft 5 in. [2.26]	16 ft 6 in. [5.02]	107 [9.89]	2.46 [0.750]	43.3 [13.2]	194 [8.17]	290 [14.9]
117	7 ft 6 in. [2.29]	16 ft 10 in. [5.13]	112 [10.4]	2.53 [0.771]	44.1 [13.4]	207 [8.71]	305 [16.7]
118	7 ft 6 in. [2.29]	19 ft 10 in. [6.03]	130 [12.1]	2.62 [0.799]	49.5 [15.1]	247 [10.4]	355 [18.2]
119	7 ft 7 in. [2.31]	14 ft [4.26]	88.4 [8.21]	2.30 [0.701]	38.4 [11.7]	154 [6.48]	243 [12.5]
120	7 ft 8 in. [2.34]	14 ft 4 in. [4.38]	91.0 [8.45]	2.36 [0.719]	38.6 [11.8]	161 [6.79]	252 [12.9]
121	7 ft 8 in. [2.34]	17 ft 6 in. [5.34]	119 [11.1]	2.61 [0.796]	45.6 [13.9]	226 [9.49]	329 [16.9]
122	7 ft 8 in. [2.34]	20 ft [6.10]	127 [11.8]	2.61 [0.796]	48.7 [14.8]	241 [10.1]	352 [18.0]
123	7 ft 8 in. [2.34]	21 ft 2 in. [6.45]	135 [12.5]	2.65 [0.808]	50.9 [15.5]	258 [10.9]	373 [19.1]
124	7 ft 8 in. [2.34]	23 ft 6 in. [7.18]	151 [14.0]	2.71 [0.826]	55.6 [16.9]	293 [12.3]	417 [21.4]
125	7 ft 9 in. [2.36]	15 ft [4.57]	99.4 [9.23]	2.45 [0.747]	40.6 [12.4]	181 [7.60]	277 [14.2]
126	7 ft 9 in. [2.36]	25 ft 4 in. [7.72]	161 [15.0]	2.73 [0.832]	59.1 [18.0]	315 [13.26]	449 [23.0]
127	7 ft 10 in. [2.39]	18 ft 3 in. [5.56]	126 [11.7]	2.66 [0.811]	47.2 [14.4]	241 [10.1]	351 [18.0]
128	7 ft 11 in. [2.41]	15 ft 8 in. [4.78]	107 [9.92]	2.51 [0.765]	42.5 [13.0]	197 [8.30]	300 [15.4]
129	7 ft 11 in. [2.41]	18 ft 10 in. [5.74]	132 [12.3]	2.71 [0.826]	48.7 [14.9]	257 [10.8]	372 [19.1]
130	7 ft 11 in. [2.41]	20 ft 10 in. [6.34]	143 [13.3]	2.77 [0.844]	51.7 [15.8]	283 [11.9]	403 [20.7]
131	8 ft 1 in. [2.46]	16 ft [4.88]	112 [10.4]	2.59 [0.789]	43.2 [13.2]	211 [8.87]	318 [16.3]
132	8 ft 1 in. [2.46]	19 ft 3 in. [5.86]	136 [12.6]	2.76 [0.841]	49.2 [15.0]	267 [11.3]	386 [19.8]
133	8 ft 1 in. [2.46]	20 ft 11 in. [6.38]	141 [13.1]	2.75 [0.838]	51.3 [15.6]	277 [11.7]	401 [20.6]
134	8 ft 1 in. [2.46]	22 ft 10 in. [6.95]	154 [14.3]	2.81 [0.856]	54.7 [16.7]	306 [12.9]	437 [22.4]
135	8 ft 2 in. [2.49]	16 ft 8 in. [5.08]	120 [11.1]	2.67 [0.814]	44.8 [13.7]	230 [9.68]	342 [17.5]
136	8 ft 2 in. [2.49]	24 ft 6 in. [7.45]	166 [15.4]	2.86 [0.872]	58.1 [17.7]	335 [14.1]	475 [24.4]
137	8 ft 3 in. [2.51]	16 ft 10 in. [5.13]	124 [11.6]	2.73 [0.832]	45.6 [13.9]	243 [10.2]	357 [18.3]
138	8 ft 3 in. [2.51]	20 ft 2 in. [6.15]	146 [13.6]	2.84 [0.866]	51.5 [15.7]	293 [12.3]	420 [21.5]
139	8 ft 3 in. [2.54]	17 ft 1 in. [5.21]	126 [11.7]	2.75 [0.838]	45.7 [13.9]	247 [10.4]	363 [18.6]
140	8 ft 5 in. [2.57]	20 ft 4 in. [6.21]	143 [13.2]	2.81 [0.856]	50.7 [15.5]	284 [11.9]	414 [21.2]
141	8 ft 5 in. [2.57]	21 ft 10 in. [6.65]	156 [14.5]	2.89 [0.881]	53.9 [16.4]	316 [13.3]	452 [23.2]
142	8 ft 6 in. [2.59]	17 ft 8 in. [5.38]	133 [12.4]	2.80 [0.853]	47.5 [14.5]	264 [11.1]	388 [19.9]
143	8 ft 6 in. [2.59]	23 ft 8 in. [7.23]	169 [15.7]	2.96 [0.902]	57.2 [17.4]	349 [14.7]	494 [25.3]
144	8 ft 7 in. [2.62]	18 ft 4 in. [5.58]	140 [13.0]	2.87 [0.875]	48.7 [14.9]	283 [11.9]	410 [21.0]
145	8 ft 7 in. [2.62]	21 ft 2 in. [6.46]	161 [14.9]	2.97 [0.905]	54.1 [16.5]	332 [14.0]	471 [24.1]
146	8 ft 7 in. [2.62]	25 ft 4 in. [7.73]	182 [16.9]	3.00 [0.914]	60.8 [18.5]	379 [16.0]	534 [27.4]
147	8 ft 9 in. [2.67]	18 ft 11 in. [5.77]	147 [13.7]	2.94 [0.896]	50.0 [15.2]	302 [12.7]	435 [22.3]
148	8 ft 10 in. [2.69]	21 ft 3 in. [6.48]	158 [14.6]	2.95 [0.899]	53.4 [16.3]	324 [13.6]	468 [24.0]
149	8 ft 10 in. [2.69]	23 ft [7.01]	172 [15.9]	3.04 [0.927]	56.4 [17.2]	360 [15.2]	510 [26.2]
150	8 ft 11 in. [2.72]	19 ft 4 in. [5.90]	152 [14.1]	2.97 [0.905]	51.2 [15.6]	314 [13.2]	454 [23.3]
151	8 ft 11 in. [2.72]	24 ft 6 in. [7.48]	186 [17.3]	3.10 [0.945]	59.0 [18.3]	395 [16.6]	555 [28.4]
152	9 ft 1 in. [2.77]	20 ft [6.10]	162 [15.0]	3.05 [0.930]	53.0 [10.1]	340 [14.3]	487 [25.0]
153	9 ft 3 in. [2.82]	21 ft 10 in. [6.67]	173 [16.1]	3.10 [0.945]	55.9 [17.0]	368 [15.5]	527 [27.0]
154	9 ft 3 in. [2.82]	23 ft 10 in. [7.26]	188 [17.5]	3.10 [0.969]	59.2 [18.0]	407 [17.1]	572 [29.3]
155	9 ft 5 in. [2.87]	21 ft 3 in. [6.48]	177 [16.5]	3.19 [0.972]	55.6 [16.9]	384 [16.2]	544 [27.9]
156	9 ft 5 in. [2.87]	25 ft 4 in. [7.73]	203 [18.8]	3.26 [0.994]	62.2 [19.0]	446 [18.8]	623 [31.9]
157	9 ft 8 in. [2.95]	23 ft 2 in. [7.07]	190 [17.6]	3.25 [0.991]	58.4 [17.8]	416 [17.5]	590 [30.3]
158	9 ft 9 in. [2.97]	24 ft 8 in. [7.52]	205 [19.1]	3.34 [1.02]	61.5 [18.7]	459 [19.3]	641 [32.9]
159	10 ft 1 in. [3.07]	24 ft [7.32]	207 [19.2]	3.40 [1.04]	60.9 [18.6]	468 [19.7]	657 [33.7]
160	10 ft 2 in. [3.10]	25 ft 5 in. [7.75]	223 [20.7]	3.48 [1.06]	64.0 [19.5]	511 [21.5]	710 [36.4]
161	10 ft 6 in. [3.20]	24 ft 9 in. [7.54]	225 [20.9]	3.56 [1.09]	63.2 [19.3]	525 [22.1]	729 [37.4]

<sup>A</sup>Inside area of box culvert cross section.

<sup>B</sup>Hydraulic radius of box culvert cross section.

<sup>C</sup>Wetted perimeter of box culvert cross section.

<sup>D</sup>Uniform flow section factor.

<sup>E</sup>Inlet control section factor.

**X2. MANUFACTURERS' SUGGESTED DESIGN PROPERTIES**

X2.1 The plastic moment capacities tabulated in Tables X2.1-X2.4 are based on fully effective composite action. For corrugated steel shells, with or without auxiliary stiffeners, the actual plastic moment capacity at ultimate load is a function of

several factors and may be less than theoretical values. The plastic moment capacities tabulated in Table X2.5 for the Type V box are based on cumulative (non-composite) action.

**TABLE X2.1 Type I Box Culvert Plastic Moment Capacity in kip-ft/ft [kN-m/m]**

Stiffener Thickness, in. [mm]	Stiffener Spacing Class	Shell Thickness in in. [mm]				
		0.111 [2.82]	0.140 [3.56]	0.170 [4.32]	0.188 [4.78]	0.218 [5.54]
0.111 [2.82]	A	6.46 [12.7]	7.29 [32.4]	8.02 [35.7]	...	...
	B	9.43 [41.9]	10.7 [47.6]	11.9 [52.9]	...	...
	C	12.0 [53.5]	12.9 [57.5]	13.8 [61.5]	...	...
0.140 [3.56]	A	7.43 [33.0]	8.42 [37.4]	9.21 [41.0]	9.87 [43.9]	...
	B	11.1 [49.4]	12.5 [55.6]	13.7 [60.8]	14.5 [64.5]	...
	C	14.6 [65.1]	15.6 [69.2]	16.6 [73.7]	17.2 [76.3]	...
0.170 [4.32]	A	8.36 [37.3]	9.52 [42.4]	10.4 [46.5]	11.0 [48.8]	11.8 [52.7]
	B	12.0 [53.5]	14.4 [64.0]	15.2 [67.6]	16.2 [71.9]	17.5 [77.8]
	C	17.5 [78.0]	18.3 [81.4]	19.0 [84.5]	19.5 [86.7]	20.3 [90.2]
0.188 [4.78]	A	...	10.1 [45.0]	11.1 [49.3]	11.7 [52.1]	12.6 [56.3]
	B	...	14.7 [65.4]	16.2 [72.2]	17.2 [76.3]	18.6 [82.7]
	C	...	20.0 [89.2]	20.8 [92.4]	21.3 [94.6]	22.0 [98.0]
0.218 [5.54]	A	...	...	12.1 [54.0]	12.8 [57.0]	14.2 [63.1]
	B	...	...	17.7 [78.6]	18.8 [83.5]	20.2 [89.8]
	C	...	...	23.6 [105]	24.0 [107]	24.8 [110]
0.249 [6.33]	A	...	...	...	13.9 [61.7]	15.1 [67.2]
	B	...	...	...	20.0 [89.1]	21.9 [97.2]
	C	...	...	...	26.8 [119]	27.6 [123]

**TABLE X2.2 Type II Box Culvert Plastic Moment Capacity in kip-ft/ft [kN-m/m]**

Shell Thickness, in. [mm]	Stiffener Spacing Class		
	Class A	Class B	Class C
0.111 [2.82]	12.4 [54.9]	14.2 [63.3]	17.2 [76.4]
0.140 [3.56]	13.7 [60.7]	15.7 [69.8]	18.8 [83.7]
0.170 [4.32]	14.9 [66.1]	17.0 [75.8]	20.4 [90.5]
0.188 [4.78]	15.6 [69.4]	17.8 [79.4]	21.4 [95.0]
0.218 [5.54]	16.7 [74.2]	19.0 [84.7]	22.7 [101]
0.249 [6.33]	17.7 [78.8]	20.2 [89.9]	24.0 [107]
0.280 [7.11]	18.7 [83.3]	21.3 [94.7]	25.3 [112]

**TABLE X2.3 Type III Box Culvert Plastic Moment Capacity in kip-ft/ft [kN-m/m]<sup>A</sup>**

Shell Thickness, in. [mm]	Plastic Moment, k-ft/ft [kN-m/m]
0.140 [3.56]	10.8 [48.2]
0.170 [4.32]	13.2 [58.9]
0.188 [4.78]	14.8 [65.9]
0.218 [5.54]	17.3 [77.0]
0.249 [6.33]	19.8 [88.0]
0.280 [7.11]	22.3 [99.2]
0.318 [8.08]	25.3 [112]
0.377 [9.58]	30.4 [135]

<sup>A</sup>Plastic moment capacities listed are not applicable to cross-corrugated plates (plates transversely corrugated to facilitate curving).

**TABLE X2.4 Type IV Box Culvert Plastic Moment Capacity in kip-ft/ft [kN-m/m]**

Stiffener Thickness, in. [mm]	Shell Thickness, in. [mm]						
	0.111 [2.82]	0.140 [3.56]	0.170 [4.32]	0.188 [4.78]	0.218 [5.54]	0.249 [6.33]	0.280 [7.11]
0.111 [2.82]	9.01 [40.08]	10.29 [45.79]	11.46 [50.99]	12.16 [54.10]	13.12 [58.37]	14.15 [62.95]	15.28 [67.98]
0.140 [3.56]	10.29 [45.79]	11.76 [52.29]	13.08 [58.18]	13.90 [61.84]	15.12 [67.27]	16.26 [72.33]	17.20 [76.53]
0.170 [4.32]	11.46 [50.99]	13.08 [58.18]	14.58 [64.84]	15.47 [68.83]	16.83 [74.85]	18.12 [80.60]	19.35 [86.06]
0.188 [4.78]	12.16 [54.10]	13.90 [61.84]	15.47 [68.83]	16.45 [73.18]	17.88 [79.53]	19.23 [85.56]	20.55 [91.41]
0.218 [5.54]	13.12 [58.37]	15.12 [67.27]	16.83 [74.85]	17.88 [79.53]	19.48 [86.67]	20.95 [93.17]	22.35 [99.42]
0.249 [6.33]	14.15 [62.95]	16.26 [72.33]	18.12 [80.60]	19.23 [85.56]	20.95 [93.17]	22.58 [100.47]	24.09 [107.18]
0.280 [7.11]	15.28 [67.98]	17.20 [76.53]	19.35 [86.06]	20.55 [91.41]	22.35 [99.42]	24.09 [107.18]	25.78 [114.68]

**TABLE X2.5 Type V Box Culvert Plastic Moment Capacity in kip-ft/ft [kN-m/m]<sup>4</sup>**

Stiffener Thickness, in. [mm]	Stiffener Spacing Class	Shell Thickness, in. [mm]					
		0.140[3.56]	0.170[4.32]	0.218[5.54]	0.249[6.33]	0.280[7.11]	
No Stiffeners							
Full Section Crown/Leg		14.5[63.8]	17.7[78.0]	23.1[101.9]	26.5[116.6]	29.8[131.3]	
Cross-corrugated Haunch		6.9[30.3]	9.8[43.2]	15.8[69.7]	20.2[89.2]	25.1[111.0]	
0.140 [3.56]	Crown	Continuous	29.0[127.6]	32.2[141.8]	37.6[165.7]	41.0[180.4]	44.3[195.1]
	Haunch	A	11.4[50.4]	14.4[63.3]	20.6[90.9]	24.8[109.3]	29.8[131.1]
	Haunch	B	10.3[45.3]	13.2[58.2]	19.5[85.8]	23.7[104.3]	28.6[126.1]
0.170 [4.32]	Crown	Continuous	32.2[141.8]	35.4[156.0]	40.9[180.0]	44.2[194.6]	47.6[209.4]
	Haunch	A	13.4[59.0]	16.3[71.9]	22.6[99.5]	26.8[118.0]	31.7[139.7]
	Haunch	B	11.7[51.8]	14.7[64.7]	21.0[92.3]	25.1[110.8]	30.1[132.5]
0.218 [5.54]	Crown	Continuous	37.6[165.7]	40.9[180.0]	46.3[203.9]	49.7[218.6]	53.0[233.3]
	Haunch	A	17.6[77.4]	20.5[90.3]	26.8[117.9]	31.0[136.4]	35.9[158.1]
	Haunch	B	14.9[65.6]	17.8[78.5]	24.1[106.1]	28.3[124.6]	33.2[146.3]
0.249 [6.33]	Crown	Continuous	41.0[180.4]	44.2[194.6]	49.7[218.6]	53.0[233.2]	56.3[247.9]
	Haunch	A	20.4[89.7]	23.3[102.6]	29.6[130.2]	33.8[148.7]	38.7[170.4]
	Haunch	B	17.0[74.8]	19.9[87.7]	26.2[115.3]	30.4[133.8]	35.3[155.6]
0.280 [7.11]	Crown	Continuous	44.3[195.1]	47.5[209.4]	53.0[233.3]	56.3[248.0]	59.6[262.7]
	Haunch	A	23.7[104.2]	26.6[117.1]	32.9[144.7]	37.1[163.2]	42.0[185.0]
	Haunch	B	19.4[85.7]	22.4[98.6]	28.7[126.2]	32.9[144.7]	37.8[166.4]

<sup>4</sup>Plastic moment capacities for Type V box based on minimum design yield strength of 44.0 ksi [300 MPa] for the formed plate, manufactured from flat plate with a minimum yield strength of 40.0 ksi [275 MPa]. Moment capacities with stiffeners based on cumulative (non-composite) properties. Moment capacities for plain and stiffened haunch sections have been adjusted by applying a haunch reduction factor to account for cross-corrugated plates (see Fig. 8). See proceedings of CSCE 2<sup>nd</sup> Engineering Materials Symposium, Ottawa, Ontario, Canada, June 1995, for further information.

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## Standard Specification for Welded Wire Fabric Gabions and Gabion Mattresses (Metallic-Coated or Polyvinyl Chloride (PVC) Coated)<sup>1</sup>

This standard is issued under the fixed designation A 974; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon ( $\epsilon$ ) indicates an editorial change since the last revision or reapproval.

### 1. Scope

1.1 This specification covers gabions and gabion mattresses produced from metallic-coated welded wire fabric, and metallic-coated wire for spiral binders, lacing wire, and stiffeners used to assemble the product. The metallic-coated fabric may be polyvinyl chloride (PVC) coated after fabrication. The spiral binders, lacing wire, and stiffeners may be PVC coated after metallic coating. Polyvinyl chloride hereinafter will be designated as PVC.

1.2 Welded wire fabric for gabions and gabion mattresses is produced in five styles, based on the kind of coating, as described in Section 4.

1.3 The values stated in inch-pound units are to be regarded as the standard. The values given in brackets are for information only.

1.4 This specification references notes and footnotes which provide explanatory material. These notes and footnotes (excluding those in tables and figures) shall not be considered as requirements of this specification.

1.5 The following safety hazards caveat pertains only to the test methods portion, Section 13, of this specification: *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

### 2. Referenced Documents

#### 2.1 ASTM Standards:

A 90/A 90M Test Method for Weight (Mass) of Coating on Iron and Steel Articles with Zinc or Zinc-Alloy Coating<sup>2</sup>

A 185 Specification for Steel Welded Wire Fabric, Plain, for Concrete Reinforcement<sup>3</sup>

A 370 Test Methods and Definitions for Mechanical Testing of Steel Products<sup>4</sup>

A 428 Test Method for Weight of Coating on Aluminum Coated Iron and Steel Articles<sup>2</sup>

A 641 Specification for Zinc Coated (Galvanized) Carbon Steel Wire<sup>2</sup>

A 809 Specification for Aluminum Coated (Aluminized) Steel Wire<sup>2</sup>

A 853 Specification for Steel Wire, Carbon, for General Use<sup>4</sup>

A 856/A 856M Specification for Zinc-5 % Aluminum-Mischmetal Alloy-Coated Carbon Steel Wire<sup>2</sup>

A 902 Terminology Relating to Metallic Coated Steel Products<sup>2</sup>

B 117 Practice for Operating Salt Spray (Fog) Testing Apparatus<sup>5</sup>

D 638 Test Method for Tensile Properties of Plastics<sup>6</sup>

D 746 Test Method for Brittleness Temperature of Plastics and Elastomers by Impact<sup>6</sup>

D 792 Test Method for Specific Gravity (Relative Density) and Density of Plastics by Displacement<sup>6</sup>

D 1242 Test Methods for Resistance of Plastic Materials to Abrasion<sup>6</sup>

D 1499 Practice for Operating Light- and Water-Exposure Apparatus (Carbon-Arc Type) for Exposure of Plastics<sup>6</sup>

D 2240 Test Method for Rubber Property-Durometer Hardness<sup>7</sup>

G 23 Practice for Operating Light-Exposure Apparatus (Carbon-Arc Type) With and Without Water for Exposure of Nonmetallic Materials<sup>8</sup>

### 3. Terminology

3.1 *Definitions*—Refer to Terminology A 902 for general terminology relating to metallic-coated steel products.

3.2 *Definitions of Terms Specific to This Standard:*

3.2.1 *gabion, n*—a wire fabric container, uniformly partitioned, of variable size, interconnected with other similar containers, and filled with stone at the site of use, to form flexible, permeable, monolithic structures such as retaining

<sup>1</sup> This specification is under the jurisdiction of ASTM Committee A05 on Metallic Coated Iron and Steel Products and is the direct responsibility of Subcommittee A05.12 on Wire Specifications.

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<sup>2</sup> *Annual Book of ASTM Standards*, Vol 01.06.

<sup>3</sup> *Annual Book of ASTM Standards*, Vol 01.04.

<sup>4</sup> *Annual Book of ASTM Standards*, Vol 01.03.

<sup>5</sup> *Annual Book of ASTM Standards*, Vol 03.02.

<sup>6</sup> *Annual Book of ASTM Standards*, Vol 08.01.

<sup>7</sup> *Annual Book of ASTM Standards*, Vol 09.01.

<sup>8</sup> *Annual Book of ASTM Standards*, Vol 14.02.

walls, sea walls, channel linings, revetments, and weirs for erosion control (see Fig. 1). Typical gabion sizes are shown in Table 1.

3.2.2 *gabion mattress, n*—a gabion with relatively small height in relation to the lateral dimensions, generally used for lining channels (see Fig. 2). Typical gabion mattress sizes are shown in Table 2.

3.2.3 *lacing wire, n*—for gabions and gabion mattresses, a metallic-coated steel wire or metallic-coated steel wire with PVC coating used to assemble and interconnect empty gabion units, and to close and secure stone-filled units, used as an alternate to spiral binders.

3.2.4 *spiral binder, n*—for gabions and gabion mattresses, a length of metallic-coated steel wire or metallic-coated steel wire with PVC coating preformed into a spiral, used to assemble and interconnect empty gabion units, and to close and secure stone-filled units, used as an alternate to lacing wire.

3.2.5 *stiffener, n*—for gabions, a length of metallic-coated steel wire or metallic-coated steel wire with PVC coating used for support by forming a diagonal brace across the corners, inside of the gabion container. Stiffeners are produced using lacing wire for on-site applications or shipped preformed using heavier wire gage as shown in Table 3.

3.2.6 *welded wire fabric, n*—material composed of a series of longitudinal and transverse steel wires arranged substantially at right angles to each other, and welded together at the points of intersection by electrical resistance welding to form fabricated sheets.

#### 4. Classification

4.1 Welded wire gabions are classified according to coating, as follows:

4.1.1 *Style 1*, consists of welded wire fabric made from wire which is zinc-coated before being welded into fabric. Spiral binders, lacing wire, and stiffeners are produced from zinc-coated wire.

4.1.2 *Style 2*, consists of welded wire fabric which is made from uncoated wire and the fabric is subsequently zinc-coated after fabrication. Spiral binders, lacing wire, and stiffeners are produced from zinc-coated wire.

4.1.3 *Style 3*, consists of welded wire fabric made from wire which is coated with zinc-5 % aluminum-mischmetal alloy (Zn-5Al-MM) before being welded into fabric. Spiral binders, lacing wire, and stiffeners are also produced from zinc-5 % aluminum-mischmetal alloy (Zn-5Al-MM) coated wire.

4.1.4 *Style 4*, consists of welded wire fabric made from wire which is aluminum-coated before being welded into fabric. Spiral binders, lacing wire, and stiffeners are also produced from aluminum-coated (aluminized) wire.

4.1.5 *Style 5*, consists of welded wire fabric, spiral binders, lacing wire, and stiffeners as Styles 1, 2, 3, or 4, and overcoated with PVC.

#### 5. Ordering Information

5.1 Orders for material to this specification should include the following information:

5.1.1 Quantity (number of units) as shown on plan,

5.1.2 Gabions or gabion mattresses,

5.1.3 Size (length by width by height),

5.1.4 Style of coating (Section 4), including the specific style to be furnished, or all acceptable styles,

5.1.5 ASTM designation and year of issue,

5.1.6 Any special requirements (see 8.2.5 and Note 2), and

5.1.7 Certification, if required (see 15.1).

NOTE 1—A typical ordering description is as follows: 100 gabions, 6 by 3 by 3 ft, as shown on plans; Style 1, 2, 3, or 4; with required spiral binders, lacing wire, and stiffeners; conforming to ASTM A 974.

#### 6. Material and Manufacture

6.1 The wire used in the manufacture of welded wire fabric for use in gabions shall conform to the specifications in 6.1.1 as appropriate for the style ordered, except the tensile strength shall conform to 7.1. The wire may be produced from any grade of steel listed in Specification A 853.

6.1.1 Style 1 welded wire fabric shall be manufactured from zinc-coated steel wire conforming to Specification A 641. Style 2 welded wire fabric shall be manufactured from uncoated steel wire conforming to Specification A 853, and the fabric subsequently zinc-coated by the hot-dip process. Style 3 welded wire fabric shall be manufactured from Zn-5Al-MM coated steel wire conforming to Specification A 856/A 856M. Style 4 welded wire fabric shall be manufactured from aluminum-coated steel wire conforming to Specification A 809.

6.2 Spiral binders, lacing wire, and stiffeners shall be made of wire having a tensile strength in accordance with 7.1, having the same coating material as the welded wire fabric furnished on the order, and conforming to Specification A 641, A 856/A 856M, or A 809, as appropriate.

6.3 Wire for welded wire fabric shall be assembled by automatic machines or other suitable mechanical means that will ensure accurate spacing and alignment of all members of the finished fabric. Longitudinal and transverse members of the welded wire fabric shall be connected at every intersection in accordance with the requirements of 7.2 by the process of electric resistance welding, which employs the principle of fusion combined with pressure.

6.4 The PVC coating used in the manufacture of PVC-coated gabions and gabion mattresses shall conform to the properties in 8.2 and 8.3.

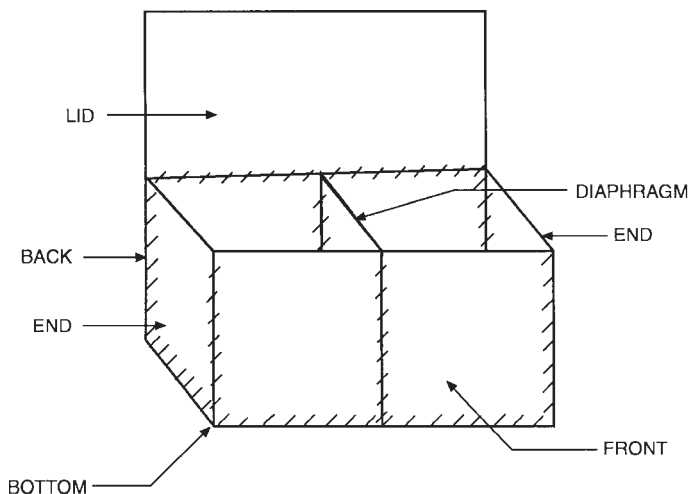
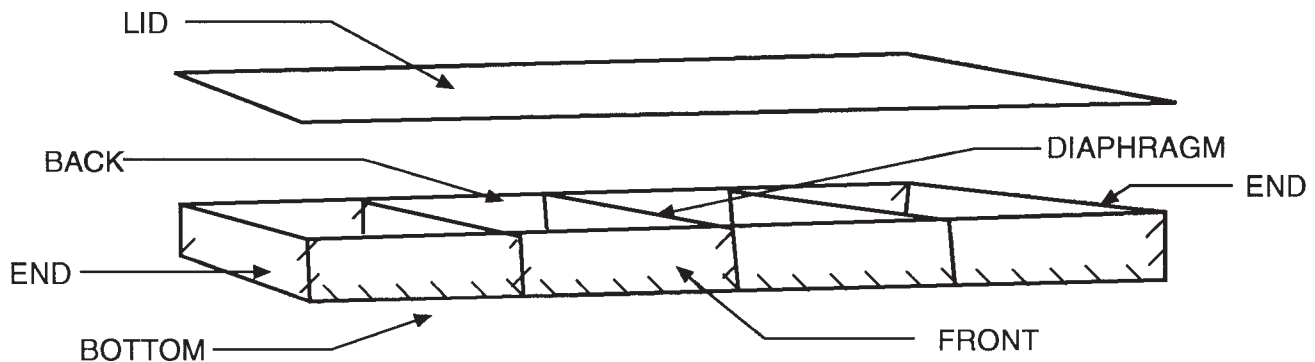


FIG. 1 Gabion

**TABLE 1 Typical Gabion Sizes**

Length, ft [cm]	Width, ft [cm]	Height, ft [cm]	Number of Cells	Capacity, yd <sup>3</sup> [m <sup>3</sup> ]
6 [182.9]	3 [91.4]	3 [91.4]	2	2.0 [1.53]
9 [274.3]	3 [91.4]	3 [91.4]	3	3.0 [2.29]
12 [365.8]	3 [91.4]	3 [91.4]	4	4.0 [3.06]
6 [182.9]	3 [91.4]	1.5 [45.7]	2	1.0 [0.765]
9 [274.3]	3 [91.4]	1.5 [45.7]	3	1.5 [1.15]
12 [365.8]	3 [91.4]	1.5 [45.7]	4	2.0 [1.53]
6 [182.9]	3 [91.4]	1 [30.5]	2	0.66 [0.50]
9 [274.3]	3 [91.4]	1 [30.5]	3	1.0 [0.765]
12 [365.8]	3 [91.4]	1 [30.5]	4	1.33 [1.02]



**FIG. 2 Gabion Mattress**

**TABLE 2 Typical Gabion Mattress Sizes**

Length, ft [cm]	Width, ft [cm]	Height, ft [cm]	Number of Cells	Area, yd <sup>2</sup> [m <sup>2</sup> ]
9 [274.3]	6 [182.9]	0.5 [15.2]	3	6.0 [5.2]
12 [365.8]	6 [182.9]	0.5 [15.2]	4	8.0 [6.69]
9 [274.3]	6 [182.9]	0.75 [22.9]	3	6.0 [5.2]
12 [365.8]	6 [182.9]	0.75 [22.9]	4	8.0 [6.69]
9 [274.3]	6 [182.9]	1.0 [30.0]	3	6.0 [5.2]
12 [365.8]	6 [182.9]	1.0 [30.0]	4	8.0 [6.69]

**TABLE 3 Wire Diameters**

	Minimum Nominal Diameter, Metallic-Coated Wire, in. [mm] <sup>A</sup>	Minimum Diameter PVC-Coated Wire (Including Coating), in. [mm] <sup>B</sup>	Nominal Diameter, PVC-Coated Wire (Including Coating), in. [mm] <sup>C</sup>
Wire for PVC-coated gabions	0.106 [2.7]	0.136 [3.5]	0.146 [3.7]
Wire for metallic-coated gabions	0.120 [3.05]	N/A	N/A
Wire for gabion mattresses	0.087 [2.2]	0.117 [3.0]	0.127 [3.2]
Spiral binders for gabions:			
PVC-coated	0.106 [2.7]	0.136 [3.5]	0.146 [3.7]
Metallic-coated	0.120 [3.05]	N/A	N/A
Spiral binders for gabion mattresses, metallic- or PVC-coated	0.087 [2.2]	0.117 [3.0]	0.127 [3.2]
Lacing wire	0.087 [2.2]	0.117 [3.0]	0.127 [3.2]
Stiffeners:			
Lacing wire	0.087 [2.2]	0.117 [3.0]	0.127 [3.2]
Preformed	0.120 [3.05]	0.150 [3.8]	0.160 [4.0]

<sup>A</sup>The metallic-coated wire shall have the size tolerances in accordance with Specifications A 641, A 856/A 856M, and A 809, as applicable.

<sup>B</sup>The minimum thickness of PVC which covers the wire shall be 15 mils [0.015 in. or 0.38 mm], measured radially at any cross section transverse to the wire length.

<sup>C</sup>The nominal thickness of PVC which covers the wire shall be 20 mils [0.020 in. or 0.51 mm], measured radially at any cross section transverse to the wire length.

6.4.1 The PVC-coated welded wire fabric shall have the PVC coating fused and bonded onto the metallic-coated welded wire fabric after fabrication of mesh. No cutting of the panels closer than  $\frac{1}{4} \pm \frac{1}{8}$  in. [ $6 \pm 3.18$  mm] to the weld shall be permitted after fabrication in order to prevent exposure near the welds.

6.4.2 The PVC-coated wire for spiral binders, lacing wire, and stiffeners shall have the PVC coating fused and bonded or extruded and adhered, onto the metallic-coated wire.

6.5 Gabions and gabion mattresses shall be manufactured with all components mechanically connected at the production facility with the exception of the mattress lid which is produced



separately from the base (Fig. 1 and Fig. 2). All gabions (Fig. 3) and gabion mattresses (Fig. 4) shall be supplied in the collapsed form, either folded and bundled or rolled, for shipping.

### 7. Mechanical Properties

**7.1 Tensile Strength**—The tensile strength of the wire used for the welded wire fabric, spiral binders, lacing wire, and stiffeners shall be soft or medium in accordance with the requirements of Specifications A 641 (Style 1), A 856/A 856M (Style 3), and A 809 (Style 4) or hard drawn in accordance with Specification A 853 (Style 2). The cross-sectional area of the test specimen shall be based on the diameter of the metallic coated wire. All the wires used in the fabrication of gabions and gabion mattresses must use the same temper wire per given order.

**7.2 Weld Shear Strength**—The minimum average shear value in pounds-force shall be 70 % of the breaking strength of the wire or as indicated in the table as follows, whichever is greater, when tested in accordance with 13.4 (see Specification A 185). Typical minimum average shear strengths as specified are as follows:

Wire Diameter, in. [mm]	Minimum Average Shear Strength, lb [N]	Minimum Shear Strength, lb [N]
0.087 [2.2]	292 [1300]	225 [1000]
0.106 [2.7]	472 [2100]	360 [1600]
0.120 [3.05]	584 [2600]	450 [2000]

**7.2.1 Conformance to Requirement**—The material shall be deemed to conform with the requirements for weld shear strength if the average of the test results of the first four specimens tested complies with the value in 7.2, or if the average of the test results for all welds tested complies with the value in 7.2.

**7.3 Panel to Panel Joint Strength**—The minimum strength of the joined panels, when tested as described in 13.5, shall be as follows:

	Exterior Panels, lb/ft [kN/ m]	Diaphragm Panels, lb/ft [kN/m]
Gabions	1400 [20.4]	600 [8.7]
Gabion mattresses	600 [8.7]	300 [4.35]

### 8. Physical Properties

**8.1 Metallic Coating**—The coating weights shall conform to the requirements of Specification A 641 Class 3 for zinc

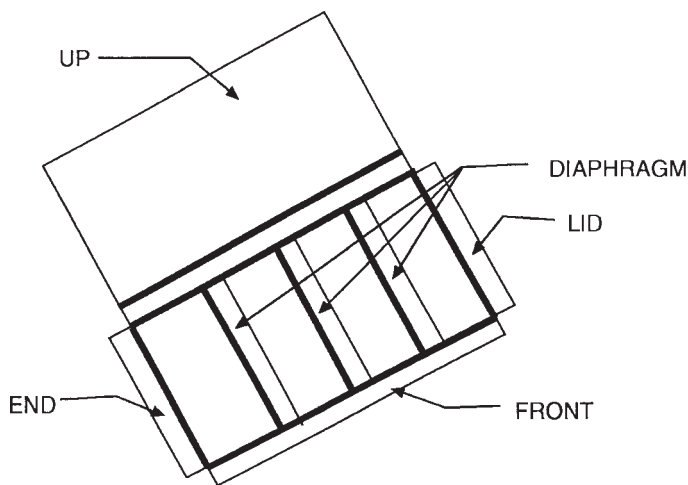


FIG. 4 Pre-Assembled Gabion Mattress

coating (including the zinc coating on the Style 2 fabric), Specification A 856/A 856M Class 3 for Zn-5Al-MM coating, or Specification A 809 for aluminum coating.

**8.2 PVC for Coating**—The initial properties of PVC coating material shall have a demonstrated ability to conform to the following requirements:

**8.2.1 Specific Gravity**—In the range from 1.20 to 1.40, when tested in accordance with Test Method D 792.

**8.2.2 Tensile Strength**—Not less than 2275 psi [15.7 MPa], when tested in accordance with Test Method D 638.

**8.2.3 Modulus of Elasticity**—Not less than 1980 psi [13.7 MPa] at 100 strain, when tested in accordance with Test Method D 638.

**8.2.4 Hardness**—Shore “A” not less than 75, when tested in accordance with Test Method D 2240.

**8.2.5 Brittleness Temperature**—Not higher than 15°F [-9°C], or lower temperature when specified by the purchaser, when tested in accordance with Test Method D 746.

**NOTE 2**—The maximum brittleness temperature should be at least 15°F [8°C] below the minimum temperature at which the gabions will be handled or filled.

**8.2.6 Resistance to Abrasion**—The percentage of the weight loss shall be less than 12 %, when tested in accordance with Test Methods D 1242, Method B, at 200 cycles, CSI-A abrader tape, 80 grit.

**8.2.7 Salt Spray Exposure and Ultraviolet Light Exposure:**

**8.2.7.1** The PVC shall show no effect after 3000 h of salt spray exposure in accordance with Practice B 117.

**8.2.7.2** The PVC shall show no effect of exposure to ultraviolet light with test exposure of 3000 h, using apparatus Type E and 63°C, when tested in accordance with Practices D 1499 and G 23.

**8.2.7.3 Evaluation of Coating After Salt Spray and Ultraviolet Exposure Test**—After the salt spray test and exposure to ultraviolet light as specified in 8.2.7.1 and 8.2.7.2, the PVC coating shall not show cracks nor noticeable change of color, or blisters or splits. In addition, the specific gravity, tensile strength, modulus of elasticity, and resistance to abrasion shall not change more than 6 %, 25 %, 25 %, and 10 %, respectively, from their initial values.

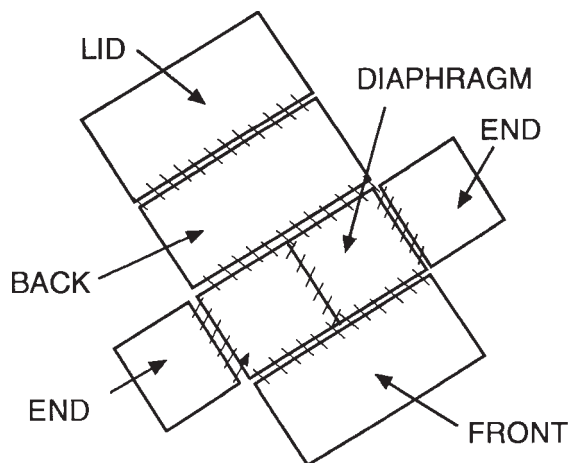


FIG. 3 Pre-Assembled Gabion

8.3 *PVC Coating on Wire*—The initial properties of the PVC coating on the wire and welded wire fabric shall have a demonstrated ability to conform to the following requirements:

8.3.1 *Adhesion*—The PVC coating shall adhere to the wire such that the coating breaks rather than separates from the wire when tested in accordance with 13.3.

8.3.2 *Mandrel Bend*— The PVC-coated wire when subjected to a single 360° bend at -0°F [-18°C] around a mandrel ten times the diameter of the wire, shall not exhibit breaks or cracks in the PVC coating.

## 9. Dimensions and Tolerances

9.1 The diameter of metallic-coated wire shall conform to Table 1

9.2 The minimum thickness of the PVC coating and the wire shall be as shown in Table 1.

9.3 Gabions shall have a mesh opening of 3 by 3 in. [76 by 76 mm]. Gabion mattresses shall have a mesh opening of 1½ by 3 in. [38 by 76 mm]. Mesh opening shall be considered to be center-to-center distance between two consecutive longitudinal or transverse wires. The permissible tolerance is ± ⅛ in. [±3.2 mm] maximum.

9.4 Spiral binders shall have the maximum inside diameter of 2½ in. [63.5 mm] and a maximum pitch of 3 in. [76.2 mm].

9.5 The width, height, and length of the gabion as assembled shall not differ more than ±5 % from the ordered size prior to filling.

9.6 The width and length of the gabion mattress as assembled shall not differ more than ±5 %, and the height shall not differ more than ±10 % from the ordered size prior to filling.

## 10. Workmanship

10.1 Wire of proper grade and quality, when fabricated in the manner herein required, shall result in a strong, serviceable mesh-type product having substantially square or rectangular openings. It shall be fabricated and finished in a workmanlike manner, as determined by visual inspection, and shall conform to this specification.

## 11. Sampling

11.1 Samples for determining the mechanical and physical properties of welded wire fabric shall be obtained by cutting from the finished fabric a full-width section of sufficient length to perform the testing. Samples for determining the mechanical and physical properties of coated wire used for spiral binders, lacing wire, and stiffeners shall be selected at random in sufficient number to perform the testing.

## 12. Number of Tests

12.1 Perform a minimum of four tests for conformance to tensile strength of metallic-coated wire, weld shear strength, wire and fabric dimensions, metallic coating weight, PVC coating thickness, adhesion of PVC coating, and mandrel bend from each 200 000 ft<sup>2</sup> [19 000 m<sup>2</sup>] of fabric or remaining fraction thereof. Perform a minimum of four tests for conformance to tensile strength, wire dimensions, coating weight, PVC coating thickness, adhesion of PVC coating, and mandrel bend

from the wire accessories used with each 200 000 ft<sup>2</sup> of fabric. The lot will be acceptable if the results of all four tests conform to the requirements.

## 13. Test Methods

13.1 *Metallic Coating Weight*—Perform coating weight tests in accordance with Test Methods A 90/A 90M or A 428 as applicable. For coating weight tests on wire of the welded wire fabric, secure multiple lengths between welds, including both longitudinal and transverse wire, and cut no closer than ¼ in. [6.4 mm] from any weld. The combined length shall be 12 in. [305 mm], minimum, but preferably about 24 in. [610 mm].

13.2 *PVC Coating Thickness*:

13.2.1 Determine the thickness of the PVC coating on an individual piece of wire removed from the fabric.

13.2.2 Determine the diameter of the metallic coated wire after stripping the PVC coating by chemical means. Determine the thickness of the PVC coating by scraping the coating from one side of the wire and measuring the reduced diameter with a micrometer. The thickness of the coating at this point is the difference between the measurement thus obtained and the measured diameter of the metallic coated wire. Determine the thickness of the coating at right angles to the first determination in a similar manner. When removing the PVC coating by scraping, take care not to remove any of the metallic surface.

13.3 *PVC Adhesion Test*—Make two cuts parallel to the axis of the wire through the coating, approximately ⅛ in. [1.6 mm] apart, at least ½ in. [12.7 mm] long. With a knife, peel back a section of the coating between ⅛ in. [3.2 mm] and ¼ in. [6.4 mm] long to produce a tab. Attempt to remove the ⅛-in. strip of coating by pulling the tab. The lot shall be acceptable if the coating breaks rather than separates from the core wire on all four specimens.

13.4 *Weld Shear Strength of Fabric*:

13.4.1 *Scope*—This test method covers the procedure for determining the strength of welded intersections of welded wire fabric.

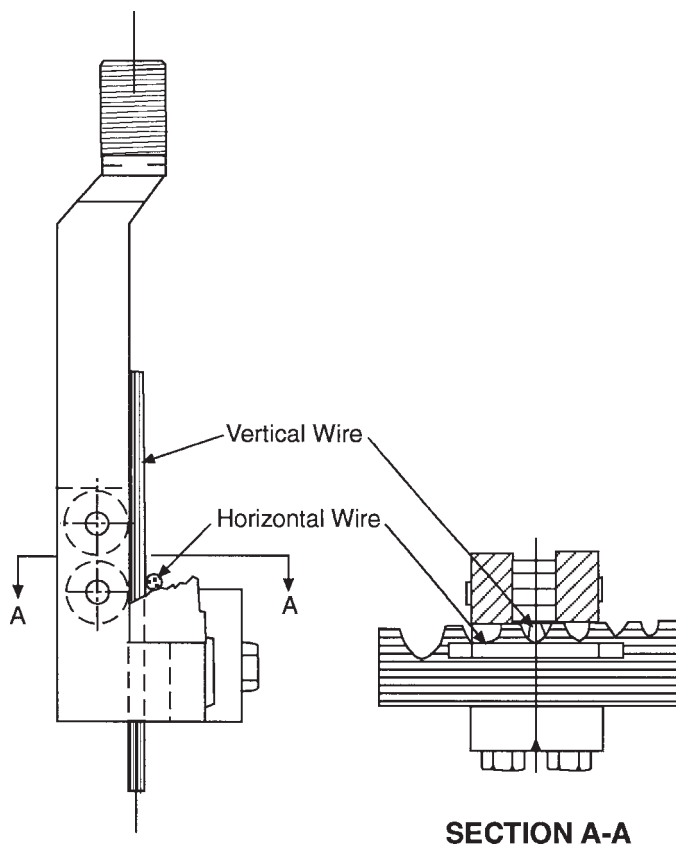
13.4.2 *Significance and Use*—The weld shear strength is a measure of the ability of welds in wire fabric to resist the forces imposed on the wires tending to pull them apart.

13.4.3 *Apparatus*—Use a testing fixture such as shown in Fig. 5, which is intended to stress the vertical wire close to its centerline, and to prevent rotation of the horizontal wire. This fixture can be used in most tensile testing machines and should be hung in a ball and socket arrangement at the center of the machine. This or a similarly effective fixture designed on the same principle, is acceptable (see Specification A 185).

13.4.4 *Test Specimens*— Test specimens shall be obtained by cutting, from the finished fabric, a full-width section including at least two transverse wires.

13.4.4.1 The transverse wire of each specimen shall extend approximately 1 in. [25 mm] on each side of the longitudinal wire. The longitudinal wire of each test specimen shall be of such length below the transverse wire so as to be adequately engaged by the grips of the testing machine. It shall be of such length above the transverse wire that its end shall be above the centerline of the upper bearing of the testing device.

13.4.4.2 A test specimen shall consist of four welds selected at random from one transverse wire for weld shear strength. If



NOTE 1—See Specification A 185 for additional information on weld shear testing. A detailed drawing showing complete dimensions of testing fixture may be obtained from ASTM. Order Adjunct No. 12-101850-00.

FIG. 5 Welded Wire Fabric Weld Tester

the width of the fabric is such as to not include four welds that are suitable for testing, additional welds shall be taken from a second transverse wire to total four. (Welds at the edge wire are excluded from testing as there is no overhang to permit proper testing). If the average weld shear strength from the four specimens does not conform to the requirement of 7.2, test all the welds across the width (excluding edge welds) on one transverse wire, or on two transverse wires if some of the initial specimens were from the second transverse wire.

13.4.5 *Weld Shear Test Procedure*—Insert the long end of the vertical wire through the notch in the anvil. The vertical wire shall be in contact with the surface of the free-rotating rollers while the horizontal wires shall be supported by the anvil on each side of the slot. The bottom jaws of the testing machine shall grip the lower end of the vertical wire and the load shall be applied at a rate of stressing not to exceed 100 000 psi/min [689 MPa/min]

13.4.6 *Report*—Report the test results to the nearest 5 lbf [25 N] for both individual results and the average of all tests.

13.4.7 *Precision and Bias*—The precision and bias of this test method for measuring weld shear strength are as specified in the test method included in Specification A 185.

13.5 *Panel to Panel Connection*—Join a set of two identical rectangular gabion panels, each with a width of 36 in. and a minimum length of 9 in., by any of the following methods:

13.5.1 *Lacing Wire*—Lacing wire shall be alternately single- and double-looped with spacing not to exceed 6 in. Secure ends with two complete revolutions and finish with a one-half hitch.

13.5.2 *Spiral Binders*—Spiral binders shall pass through the openings. Securely tie at both ends to prevent unraveling when a load is applied in accordance with the minimum strength requirements of 7.3.

13.5.3 Mount each of the two panels on a loading machine with grips or clamps such that panels are uniformly secured along the full-width. The grips or clamps shall be designed to transmit only tension forces. The load then will be applied at a uniform rate not exceeding 50 lb/s until maximum load is obtained. The maximum load is reached when a drop of strength is observed with subsequent loading.

## 14. Inspection

14.1 Unless otherwise specified in the contract or purchase order, the producer is responsible for the performance of all inspection and test requirements of this specification. The producer may use his own or any other suitable facilities for the performance of the tests unless disapproved by the purchaser at the time the order is placed. The purchaser at their own expense shall have the right to perform any of the inspections and tests set forth in this specification when such tests are deemed necessary to ensure that the material conforms to the prescribed requirements.

**15. Certification**

15.1 When specified in the purchase order or contract, a producer's or supplier's certification shall be furnished to the purchaser that the material was manufactured, sampled, tested, and inspected in accordance with this specification and has been found to meet the requirements. When specified in the contract or purchase order, a report of the test results shall be furnished.

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**16. Keywords**

16.1 gabion mattresses; gabions; metallic-coated fabric; PVC-coated fabric; steel wire; welded wire fabric



# Standard Specification for Double-Twisted Hexagonal Mesh Gabions and Revet Mattresses (Metallic-Coated Steel Wire or Metallic-Coated Steel Wire With Poly(Vinyl Chloride) (PVC) Coating)<sup>1</sup>

This standard is issued under the fixed designation A 975; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon ( $\epsilon$ ) indicates an editorial change since the last revision or reapproval.

## 1. Scope

1.1 This specification covers gabions and revet mattresses produced from double-twisted metallic-coated wire mesh, and metallic-coated wire for lacing wire, stiffeners, and fasteners used for manufacturing, assembling, and installation of the product. This specification also covers gabions and revet mattresses in which the wire mesh, lacing wire, and stiffeners are poly(vinyl chloride) (PVC) coated after the metallic coating.

1.2 Double-twisted wire mesh for gabions and revet mattresses is produced in different styles, based on type of coating, as described in Section 4.

1.3 The values stated in SI units are to be regarded as the standard. The values given in brackets are for information only.

1.4 This specification references notes and footnotes which provide explanatory material. These notes and footnotes (excluding those in tables and figures) shall not be considered as requirements of this specification.

1.5 The following safety hazards caveat pertains only to the test methods portion, Section 13, of this specification: *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to consult and establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

## 2. Referenced Documents

### 2.1 ASTM Standards:

A 90/A 90M Test Method for Weight (Mass) of Coating on Iron and Steel Articles with Zinc or Zinc-Alloy Coating<sup>2</sup>

A 313 Specification for Chromium-Nickel Stainless and Heat-Resisting Steel Spring Wire<sup>3</sup>

A 370 Test Methods and Definitions for Mechanical Testing of Steel Products<sup>3</sup>

A 428 Test Method for Weight of Coating on Aluminum Coated Iron and Steel Articles<sup>2</sup>

A 641 Specification for Zinc Coated (Galvanized) Carbon Steel Wire<sup>2</sup>

A 764 Specification for Steel Wire, Carbon, Drawn Galvanized and Galvanized at Size for Mechanical Springs<sup>3</sup>

A 809 Specification for Aluminum-Coated (Aluminized) Carbon Steel Wire<sup>2</sup>

A 856/A 856M Specification for Zinc-5% Aluminum-Mischmetal Alloy-Coated Carbon Steel Wire<sup>2</sup>

A 902 Terminology Relating to Metallic Coated Steel Products<sup>2</sup>

B 117 Test Method of Salt Spray (Fog) Testing<sup>4</sup>

D 412 Test Methods for Vulcanized Rubber and Thermoplastic Rubbers and Thermoplastic Elastomers-Tension<sup>5</sup>

D 746 Test Method for Brittleness Temperature of Plastics and Elastomers by Impact<sup>6</sup>

D 792 Test Methods for Specific Gravity (Relative density) and Density of Plastics by Displacement<sup>6</sup>

D 1242 Test Methods for Resistance of Plastic Materials to Abrasion<sup>6</sup>

D 1499 Practice for Operating Light-and Water-Exposure Apparatus (Carbon-Arc Type) for Exposure of Plastics<sup>6</sup>

D 2240 Test Method for Rubber Property-Durometer Hardness<sup>5</sup>

G 23 Practice for Operating Light-Exposure Apparatus (Carbon-Arc Type) With and Without Water for Exposure of Nonmetallic Materials<sup>7</sup>

## 3. Terminology

### 3.1 Definitions:

3.1.1 Refer to Terminology A 902 for general terminology relating to metallic-coated steel products.

### 3.2 Definitions of Terms Specific to This Standard:

3.2.1 *gabion, n*—a double-twisted wire mesh container of variable sizes, uniformly partitioned into internal cells, interconnected with other similar units, and filled with stone at the

<sup>1</sup> This specification is under the jurisdiction of ASTM Committee A05 on Metallic Coated Iron and Steel Products and is the direct responsibility of Subcommittee A05.12 on Wire Specifications.

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<sup>2</sup> Annual Book of ASTM Standards, Vol 01.06.

<sup>3</sup> Annual Book of ASTM Standards, Vol 01.03.

<sup>4</sup> Annual Book of ASTM Standards, Vol 03.02.

<sup>5</sup> Annual Book of ASTM Standards, Vol 09.01.

<sup>6</sup> Annual Book of ASTM Standards, Vol 08.01.

<sup>7</sup> Annual Book of ASTM Standards, Vol 14.02.

project site to form flexible, permeable, monolithic structures such as retaining walls, sea wall, channel linings, revetments, and weirs for erosion control projects (see Fig. 1 and Fig. 2).

3.2.2 *revet mattress, n*—a double-twisted wire mesh container uniformly partitioned into internal cells with relatively small height in relation to other dimensions, having smaller mesh openings than the mesh used for gabions; revet mattresses are generally used for riverbank protection and channel linings (see Fig. 3).

3.2.3 *double-twisted wire mesh, n*—a nonraveling mesh made by twisting continuous pairs of wires through three one-half turns (commonly called double-twisted) to form hexagonal-shaped openings which are then interconnected to adjacent wires to form hexagonal openings.

3.2.4 *selvedge wire, n*—a terminal wire used to edge the wire mesh perpendicular to the double twist by mechanically wrapping the mesh wires around it at least 2.5 times or by inserting it throughout the twists and folding one mesh length.

3.2.5 *edge wire, n*—a terminal wire used to edge the wire mesh parallel to the double twist by continuously weaving it into the wire mesh.

3.2.6 *lacing wire, n*—for gabions and revet mattresses, a metallic-coated steel wire or metallic-coated steel wire with PVC coating used to assemble and interconnect empty units, to close and secure stone-filled units, and for internal stiffeners.

3.2.7 *fastener, n*—an alternate method to lacing wire used for binding operations for gabions and revet mattresses.

3.2.8 *stiffener, n*—for gabions, a length of metallic-coated steel wire or metallic-coated steel wire with PVC coating used for support of facing by connecting the front panel to the back panel of a gabion (stiffener formed at the project site using wire having the same diameter as for the lacing wire (see Table 1) or across the corners of a gabion cell (preformed stiffener having a diameter as specified in Table 1).

3.3 *Abbreviations: Abbreviations:*

3.3.1 *PVC*—poly(vinyl chloride).

3.3.2 *Zn-5Al-MM*—zinc-5 % aluminum-mischmetal alloy.

#### 4. Classification

4.1 Double-twisted wire gabions and revet mattresses are classified according to coating, as follows:

4.1.1 *Style 1*, consists of double-twisted wire mesh made from wire which is zinc coated before being double-twisted into mesh. Fasteners, lacing wire, and stiffeners are produced from zinc-coated wire.

4.1.2 *Style 2*, consists of double-twisted wire mesh made from wire which is coated with Zn-5Al-MM before being double-twisted into mesh. Fasteners, lacing wire, and stiffeners are also produced from Zn-5Al-MM coated wire.

4.1.3 *Style 3*, consists of double-twisted mesh, lacing wire, and stiffeners as Style 1 and overcoated with PVC. Fasteners shall be of stainless steel wire.

4.1.4 *Style 4*, consists of double-twisted mesh made from wire which is aluminum-coated before being double-twisted into mesh. Fasteners, lacing wire, and stiffeners are also produced from aluminum-coated wire.

#### 5. Ordering Information

5.1 Orders for material to this specification shall include the following information:

5.1.1 Quantity (number of units) as shown on plan,

5.1.2 Product type (gabions or revet mattresses),

5.1.3 Size (length by width by height),

5.1.4 Style of coating (Section 4), including the specific style to be furnished, or all acceptable styles,

5.1.5 ASTM designation and year of issue,

5.1.6 Any special requirements (see 8.2.5), and

5.1.7 Certification, if required (see Section 15).

NOTE 1—A typical ordering description is as follows: 100 gabions, 2 by 1 by 1 m or [6 by 3 by 3 ft], 100 revet mattresses 4 by 2 by 0.23 m or [12 by 6 by 0.75 ft] and 100 lids 4 by 2 m or [12 by 6 ft] as shown on plans; Style 1, 2, 3, or 4 with required fasteners or lacing wire and stiffeners; conforming to ASTM A-975.

#### 6. Material and Manufacture

6.1 The wire used in the manufacture of double-twisted mesh for use in gabions and revet mattresses shall conform to the specifications shown in 6.1.1, 6.1.2, 6.1.3, or 6.1.4 as appropriate for the style ordered, except that the tensile strength shall conform to 7.1.

6.1.1 Style 1 double-twisted mesh shall be manufactured from zinc-coated steel wire conforming to Specification A 641, Class 3 coating, soft temper.

6.1.2 Style 2 double-twisted mesh shall be manufactured from Zn-5Al-MM-coated steel wire conforming to Specification A 856/A 856M, Class 3 coating, soft temper.

6.1.3 Style 3 double-twisted mesh shall be manufactured from the same type of metallic-coated steel wire as Style 1 with an additional PVC coating extruded onto the metallic-coated steel wire. The PVC coating shall conform to the properties in 8.2.

6.1.3.1 Original or modified thermoplastic polymers along with their application methods can be permitted as a substitute for PVC coatings, as long as their performance is equivalent to the performance requirements of the PVC coating.

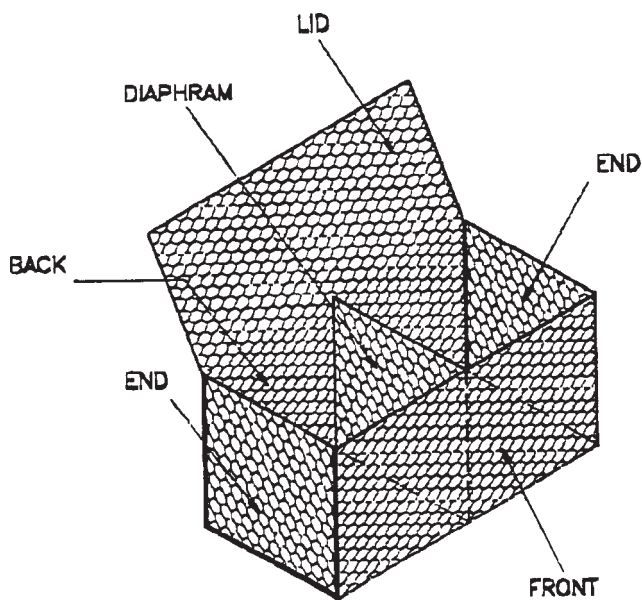


FIG. 1 Gabion

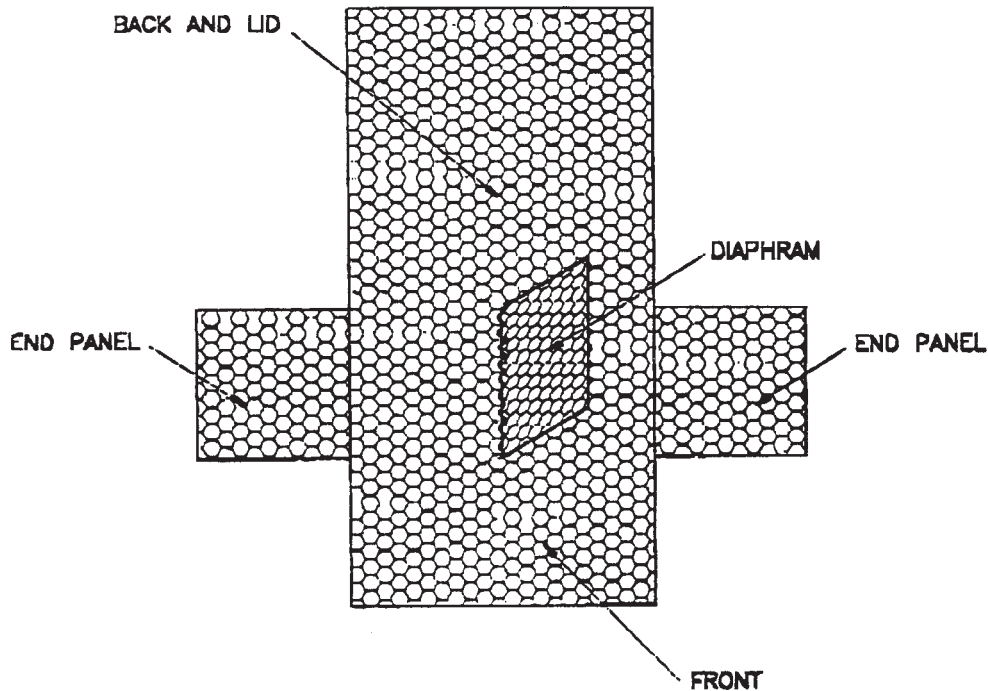


FIG. 2 Mechanically Manufactured Gabion

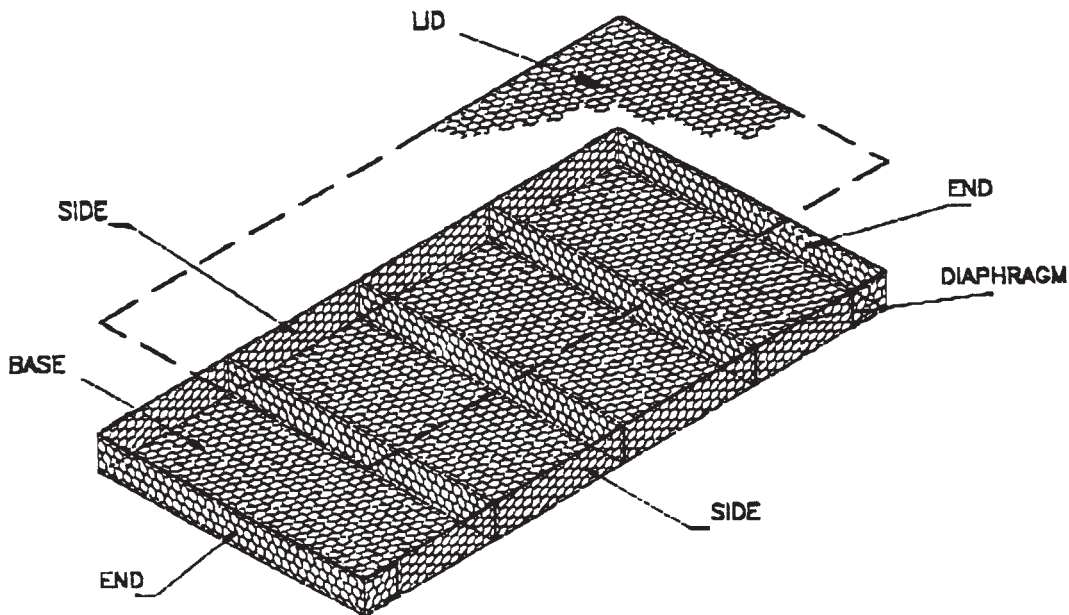


FIG. 3 Revet Mattress

6.1.4 Style 4 double-twisted mesh shall be manufactured from aluminum-coated steel wire conforming to Specification A 809, soft temper.

6.2 Lacing wire and stiffeners shall be made of wire having the same coating material as the double-twisted wire mesh furnished on the order and conforming to Specification A 641, A 856/A 856M, or A 809, with a tensile strength in accordance with 7.1

6.3 Fasteners made from zinc-coated steel wire, zinc-5 % aluminum mischmetal alloy-coated steel wire and aluminum-coated steel wire shall conform to Specification A 764, Type A,

B, or C, Class 3, with a tensile strength in accordance with 7.2. Fasteners made from stainless steel wire shall conform to Specification A 313, Type 302, with a tensile strength in accordance with 7.2.

6.4 Gabions and revet mattresses shall be manufactured with all components mechanically connected at the production facility with the exception of the mattress lid which is produced separately from the base (see Fig. 1, Fig. 2, and Fig. 3). All gabions (Fig. 1 and Fig. 2) and revet mattresses (Fig. 3) shall be supplied in the collapsed form, either folded and bundled or rolled, for shipping.

**TABLE 1 Mesh Characteristics<sup>A</sup>**

Characteristics	Gabion		Revet Mattresses	
	Metallic Coated	PVC Coated	Metallic Coated	PVC Coated
Mesh Type	8 by 10		6 by 8	
Mesh Opening	83 by 114 mm [3.25 by 4.5 in.]	83 by 114 mm [3.25 by 4.5 in.]	64 by 83 mm [2.5 by 3.25 in.]	64 by 83 mm [2.5 by 3.25 in.]
Mesh wire	3.05 mm [0.120 in.]	2.7 mm [0.106 in.]	2.2 mm [0.087 in.]	2.2 mm [0.087 in.]
Selvedge wire	3.8 mm [0.150 in.]	3.4 mm [0.134 in.]	2.7 mm [0.105 in.]	2.7 mm [0.105 in.]
Lacing wire	2.2 mm [0.087 in.]	2.2 mm [0.087 in.]	2.2 mm [0.087 in.]	2.2 mm [0.087 in.]
Fasteners	3.0 mm [0.118 in.]	3.0 mm [0.118 in.]	3.0 mm [0.118 in.]	3.0 mm [0.118 in.]
Stiffeners:				
Using lacing wire	2.2 mm [0.087 in.]	2.2 mm [0.087 in.]	2.2 mm [0.087 in.]	2.2 mm [0.087 in.]
Preformed	3.8 mm [0.150 in.]	3.4 mm [0.134 in.]	N/A	N/A
PVC coating thickness:				
Nominal	N/A	0.50 mm [0.02 in.]	N/A	0.50 mm [0.02 in.]
Minimum	N/A	0.38 mm [0.015 in.]	N/A	0.38 mm [0.015 in.]

<sup>A</sup>All dimensions and wire diameters are minimum nominal values.

## 7. Mechanical Properties

7.1 *Tensile Strength*—The tensile strength of wire used for double-twisted mesh, lacing wire, and stiffener, when tested in accordance with Test Methods and Definitions A 370, shall be in accordance with the requirements of Specification A 641, A 809, and A 856/A 856M for soft temper wire.

7.2 *Fasteners*—The tensile strength of zinc-coated steel wire, zinc-5 % aluminum mischmetal alloy-coated steel wire and aluminum-coated steel wire used for fasteners shall be in accordance with the requirements of Specification A 764, Type A, B, or C, Table 2 or Table 3. The tensile strength of stainless steel wire used for fasteners shall be in accordance with the requirements of Specification A 313, Type 302, Table 2. Any fastener system shall give the number of fasteners required to comply with Table 2 in accordance with the pull-part resistance

**TABLE 2 Minimum Strength Requirements of Mesh and Connections**

Test Description	Gabions, Metallic Coated		Gabion, PVC Coated		Revet Mattress Metallic Coated and PVC Coated	
	kN/m	[lbf/ft]	kN/m	[lbf/ft]	kN/m	[lbf/ft]
Parallel to twist	51.1	[3500]	42.3	[2900]	33.6	[2300]
Perpendicular to twist	26.3	[1800]	20.4	[1400]	13.1	[900]
Connection to selvedges	20.4	[1400]	17.5	[1200]	10.2	[700]
Panel to panel connection using lacing wire or fasteners	20.4	[1400]	17.5	[1200]	10.2	[700]
	kN	[lbf]	kN	[lbf]	kN	[lbf]
Punch Test	26.7	[6000]	23.6	[5300]	17.8	[4000]

test (see 13.1.2). The manufacturer or supplier shall state the number of fasteners required for all vertical and horizontal connections for single- and multiple-basket joinings and shall include a description of a properly installed fastener including drawings or photographs.

7.3 *Mesh and Panel to Panel Joint Strength*—The minimum strength requirements of the mesh, selvedge wire to mesh connection, panel to panel connection, and punch test, when tested in accordance with 13.1, shall be as shown in Table 2.

## 8. Physical Properties

8.1 *Metallic Coating*—The coating weights shall conform to the requirements of Specification A 641, Class 3, for zinc coating or Specification A 856/A 856M, Class 3, for Zn-5A1-MM coating, or Specification A 809 for aluminum coating.

8.2 *PVC for Coating*—The initial properties of PVC coating material shall have a demonstrated ability to conform to the following requirements:

8.2.1 *Specific Gravity*—In the range from 1.30 to 1.35 when tested in accordance with Test Method D 792.

8.2.2 *Tensile Strength*—Not less than 20.6 MPa [2985 psi] when tested in accordance with Test Methods D 412.

8.2.3 *Modulus of Elasticity*—Not less than 18.6 MPa [2700 psi] when tested in accordance with Test Methods D 412.

8.2.4 *Hardness*—Shore“ D” between 50 and 60, when tested in accordance with Test Method D 2240.

8.2.5 *Brittleness Temperature*—Not higher than  $-9^{\circ}\text{C}$  [ $15^{\circ}\text{F}$ ], or lower temperature when specified by the purchaser, when tested in accordance with Test Method D 746 (see Note 2).

NOTE 2—The maximum brittleness temperature should be at least  $8^{\circ}\text{C}$  [ $15^{\circ}\text{F}$ ] below the minimum temperature at which the gabions will be filled.

8.2.6 *Resistance to Abrasion*—The percentage of the weight loss shall be less than 12 %, when tested in accordance with Test Method D 1242.

8.2.7 *Salt Spray Exposure and Ultraviolet Light Exposure:*

8.2.7.1 The PVC shall show no effect after 3000 h of salt spray exposure in accordance with Test Method B 117.

8.2.7.2 The PVC shall show no effect of exposure to ultraviolet light with test exposure of 3000 h, using apparatus Type E and  $63^{\circ}\text{C}$  [ $145^{\circ}\text{F}$ ], when tested in accordance with Practice D 1499 and G 23.

8.2.7.3 *Evaluation of Coating After Salt Spray and Ultraviolet Exposure Test*—After the salt spray test and exposure to ultraviolet light as specified in 8.2.7.1 and 8.2.7.2, the PVC coating shall not show cracks nor noticeable change of color, or blisters or splits. In addition, the specific gravity, tensile strength, hardness, and resistance to abrasion shall not change more than 6 %, 25 %, 10 %, and 10 %, respectively, from their initial values.

8.2.8 The PVC coating shall not show cracks or breaks after the wires are twisted in the fabrication of the mesh.

8.3 *Salt Spray Resistance for Fastener*—After testing in accordance with 13.1.3, the fasteners, the selvedge, or mesh wire confined by the fasteners shall show no rusty spots on any part of the surface excluding the cut ends.



### 9. Dimensions and Tolerances

9.1 The diameter of metallic coated wire shall conform to Table 1 plus or minus the tolerances shown in Specifications A 641, A 856/A 856 M, and A 809, as applicable.

9.2 The diameter of metallic-coated wire and stainless steel wire used in the fabrication of fasteners shall conform to Table 7 plus or minus the tolerances shown in Specification A 764.

9.3 The minimum and nominal thickness of PVC coating uniformly applied in a quality workmanlike manner shall be as shown in Table 1.

9.4 Gabions shall be manufactured with an 8 by 10-mesh type having a nominal mesh opening of 83 by 114 mm [3.25 by 4.5 in.]. Dimensions are measured at right angles to the center axis of the opening ( $D = 83$  mm, see Fig. 4) and parallel to the twist along the same axis.

9.5 Revet mattresses shall be manufactured with a 6 by 8-mesh type having a nominal mesh opening of 64 by 83 mm [2.5 by 3.25 in.]. Dimensions are measured at right angles to the center axis of the opening ( $D = 64$  mm, see Fig. 4) and parallel to the twist along the same axis.

9.6 The width, height, and length of the gabion as manufactured shall not differ more than  $\pm 5\%$  from the ordered size prior to filling. (Typical gabion sizes are shown in Tables 3 and 4).

9.7 The width and length of the revet mattress as manufactured shall not differ more than  $\pm 5\%$ , and the height shall not differ more than  $\pm 10\%$  from the ordered size prior to filling. (Typical revet mattress sizes are shown in Tables 5 and 6).

9.8 *Mesh Opening Tolerances*—Tolerances on the hexagonal, double-twisted wire mesh opening shall not exceed  $\pm 10\%$  on the nominal dimension  $D$  values, as follows (see Fig. 4):

Mesh Type	Nominal Dimension $D$ Values
6 by 8	64 mm [2.50 in.]
8 by 10	83 mm [3.25 in.]

### 10. Workmanship

10.1 Wire of proper grade and quality, when fabricated in the manner herein required, shall result in a strong, serviceable mesh-type product having substantially uniform openings. It shall be fabricated and finished in a workmanlike manner, as determined by visual inspection, and shall conform to this specification.

### 11. Sampling

11.1 Samples for determining the mechanical and physical properties of double-twisted wire mesh shall be in accordance with the samples, dimensions, and requirements described in Section 13.

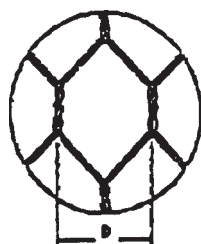


FIG. 4 Wire Mesh Opening Nominal Dimension  $D$

TABLE 3 Typical Gabion Sizes (SI Units)

Length, m	Width, m	Height, m	Number of Cells, each	Volume, m <sup>3</sup>
2.0	1.0	1.0	2.0	2.0
3.0	1.0	1.0	3.0	3.0
4.0	1.0	1.0	4.0	4.0
2.0	1.0	0.5	2.0	1.0
3.0	1.0	0.5	3.0	1.5
4.0	1.0	0.5	4.0	2.0
2.0	1.0	0.3	2.0	0.6
3.0	1.0	0.3	3.0	0.9
4.0	1.0	0.3	4.0	1.2

TABLE 4 Typical Gabion Sizes (Inch-Pound Units)

Length, ft	Width, ft	Height, ft	Number of Cells, Each	Volume, yd <sup>3</sup>
6.0	3.0	3.0	2.0	2.0
9.0	3.0	3.0	3.0	3.0
12.0	3.0	3.0	4.0	4.0
6.0	3.0	1.5	2.0	1.0
9.0	3.0	1.5	3.0	1.5
12.0	3.0	1.5	4.0	2.0
6.0	3.0	1.5	2.0	0.67
9.0	3.0	1.0	3.0	1.0
12.0	3.0	1.0	4.0	1.33

TABLE 5 Typical Revet Mattress Sizes (SI Units)

Length, m	Width, m	Height, m	Number of Cells, Each	Area, m <sup>2</sup>
3.0	2.0	0.17	3.0	6.0
4.0	2.0	0.17	4.0	8.0
3.0	2.0	0.23	3.0	6.0
4.0	2.0	0.23	4.0	8.0
3.0	2.0	0.3	3.0	6.0
4.0	2.0	0.3	4.0	8.0

TABLE 6 Typical Revet Mattress Sizes (Inch-Pound Units)

Length, ft	Width, ft	Height, ft	Number of Cells, Each	Area, yd <sup>2</sup>
9.0	6.0	0.5	3.0	6.0
12.0	6.0	0.5	4.0	8.0
9.0	6.0	0.75	3.0	6.0
12.0	6.0	0.75	4.0	8.0
9.0	6.0	1.0	3.0	6.0
12.0	6.0	1.0	4.0	8.0

11.2 Samples for determining the mechanical and physical properties of coated steel wire used for mesh, lacing wire, and stiffeners shall be selected at random from wire coils used for manufacturing.

### 12. Number of Tests

12.1 A minimum of three tests each for conformance to strength of metallic-coated steel wire mesh parallel to twist, perpendicular to twists, connection of metallic-coated steel wire mesh to selvedge, and punch test shall be performed. A retest for conformance with the aforementioned strength and connection tests shall be required when changes of the physical characteristics of the mesh products occur. For metallic-coated steel wire with PVC coating, follow the same requirements as for the metallic-coated steel wire mesh. The results of all three tests must meet the requirements of Table 2.

12.2 The tensile strength, metallic coating weight, and PVC coating thickness of the metallic steel wire used in the fabrication of mesh, lacing wire, stiffeners, and fasteners must be certified by the steel wire producers for conformance to the requirements of Sections 6 and 7 and Table 1 for each lot shipment to the gabion manufacturer's facility.

### 13. Test Methods

#### 13.1 *Mechanical Property Tests:*

13.1.1 *Tensile Strength Test*—The wire mesh specimens shall be representative of proper field construction as to materials, mesh geometry, and workmanship, and shall be as large as practical to minimize the effect of variations. The width of a specimen shall not be less than seven repetitions of a mesh pattern, nor shall the length be less than fourteen repetitions. The tests shall be run with the load applied parallel to the axis of twist and repeated on a separate test specimen with the load applied perpendicular to the axis of twist.

13.1.1.1 The apparatus shall grip the wire in such a manner as to allow the wire failures to occur at least one mesh pattern away from the gripping points. If a failure occurs in a wire leading directly to a gripping point that specimen shall be rejected, and not included among the tests reported.

13.1.1.2 Insert the wire into the machine grips and the axially free sliding adjustable spreader system attachment points such that the gripped wires will be maintained in the mesh geometry characteristic of field use and attached in such a manner as to eliminate failure at the grips. The grips may be left loose until the preload is applied to allow the wires to seat. The load is then applied at a uniform rate not to exceed 50 nor 3 % of the mesh ultimate strength per second (see Table 2). The load shall initially be taken to a preload of 20 % of the specified minimum strength and the machine head travel stopped. The mesh gage dimensions shall be recorded at this time and taken as the initial dimensions of the specimen where such dimensions are required. Loading shall then continue uniformly in increments of 10 % of the specified minimum strength until first fracture or unwrapping of an individual wire in the system occurs. The machine head travel at each load increment or sequential incident of wire failure may be stopped for recording pertinent information such as load, fracture type, resulting mesh geometry and elongation, and resulting reduction in wire gage. The distortion of the mesh or changes in gage length shall be measured to an accuracy consistent with reporting the percent elongation to the nearest 0.5 %. The results of the tests shall be in accordance with the requirements shown in Table 2.

13.1.2 *Pull-Apart Resistance Test*—A set of the jointed panels, which are prepared by the same method as specified in the salt spray test but without being subject to the 48-h salt spray test, shall be mounted on a loading machine with grips or clamps such that the panels are uniformly secured along the full width. The grips or clamps shall be designed to only transmit tension forces. The load will then be applied at a uniform rate not to exceed 220 N/s [50 lb/s] until failure occurs. The failure is defined as when the maximum load is reached and a drop of strength is observed with subsequent loading or alternately the opening between any two closest selvedge wires, applicable to a fastener confining either two or

four selvedge wires, becomes greater than 50 mm [2 in.] at any place along the panel width. The strength requirements of the jointed panels at failure shall be as shown in Table 2.

13.1.3 *Salt Spray Test*—A set of two identical rectangular gabion panels, each with a width about 10½ mesh openings along a selvedge wire, shall be jointed by properly installed wire fasteners along the two selvedge wires so that each fastener confines two selvedge and two mesh wires. If the fasteners are also to be used to join two individual empty gabion baskets, two additional selvedge wires that are each mechanically wrapped with mesh wires shall be included so that each fastener confines four selvedge and four mesh wires. A properly installed fastener shall meet the following requirements:

13.1.3.1 Each interlocking fastener type shall be in a locked and closed position. Each overlapping fastener type shall be closed and the free ends of the fastener shall overlap a minimum of 1 in. The set of the jointed panels shall be subject to Salt Spray Test of Test Method B 117 for a period of not less than  $48 \pm 1$  h cycle length.

13.1.4 *Punch Test*—An uncut section of 1.82 m [6 ft] in length (unselvedged) and not less than 0.91 m [3 ft] in width (selvedged), including all selvedge bindings, shall have the ends securely clamped for 0.91 m along the width of the sample. When the width of the section under test exceeds 0.91 m, the clamps shall be centered along the width and the excess width will be allowed to fall free on each side of the clamped section. The sample shall then be subjected to tension sufficient to cause 10 % elongation of the sample section between the clamps. After elongation and while clamped as described above (and otherwise unsupported), the section shall be subjected to a load applied to a 1-ft<sup>2</sup> area applied to an area of 900 cm<sup>2</sup> [1 ft<sup>2</sup>] in the approximate center of the sample section between the clamps and in a direction perpendicular to the direction of the tension force. The sample shall withstand, without rupture of any strand or opening of any mesh fastening, an actual load applied by means of a circular ram at a rate as indicated in 13.1.2 equaling or exceeding the values shown in Table 2. The ram head used in the test shall be circular with a 305-mm [12-in.] diameter and have its edges beveled or rounded to prevent cutting of the wire strands.

13.2 *Metallic Coating Weight*—Perform coating weight tests as prescribed in Test Methods A 90/A 90M or A 428 as applicable.

#### 13.3 *PVC Coating Thickness:*

13.3.1 The thickness of the PVC coating shall be determined on a randomly chosen individual piece of wire removed from the mesh.

13.3.2 Measure with a micrometer the diameter of the metallic coated steel wire with PVC coating. Determine the thickness of the PVC coating by stripping the PVC coating from the wire and measure the reduced diameter with a micrometer. The thickness of the coating is the difference between the diameter of the metallic-coated steel wire with PVC coating and the measured diameter of the metallic-coated wire divided by two. This value shall be in accordance with Table 1. When removing the PVC coating by stripping, take care not to remove any of the metallic surface.

#### **14. Inspection**

14.1 Unless otherwise specified in the contract or purchase order, the producer is responsible for the performance of all inspection and test requirements of this specification. The producer shall use his own or any other suitable facilities for the performance of the inspection and test requirements, at his option, unless disapproved by the purchaser at the time the order is placed. The purchaser at their own expense shall have the right to perform any of the inspections and tests set forth in this specification when such tests are deemed necessary to ensure that the material conforms to the prescribed requirements.

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#### **15. Certification**

15.1 When specified in the purchase order or contract, a producer's or supplier's certification that the material meets the contract specifications shall be furnished to the purchaser.

#### **16. Keywords**

16.1 double-twisted wire mesh; fasteners; gabions; lacing wire; metallic-coated mesh; metallic-coated steel wire; metallic-coated steel wire with PVC coating; preformed stiffeners; revet mattresses; selvage edge wire; stiffeners



Designation: A 978/A 978M – 97 (Reapproved 2002)<sup>ε1</sup>

## Standard Specification for Composite Ribbed Steel Pipe, Precoated and Polyethylene Lined for Gravity Flow Sanitary Sewers, Storm Sewers, and Other Special Applications<sup>1</sup>

This standard is issued under the fixed designation A 978/A 978M; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

<sup>ε1</sup> NOTE—Several editorial corrections were made throughout the specification in September 2002.

### 1. Scope

1.1 This specification covers composite ribbed steel pipe, precoated and polyethylene lined intended for use for gravity flow sanitary sewers, storm sewers, and other special applications such as water transmission pipe, rehabilitation pipe, slip line pipe, and irrigation pipe where extra corrosion and abrasion resistance are required. The steel sheet used in the fabrication of the pipe has a polymer coating over a metallic coating of zinc on both sides. In addition, as the pipe is being fabricated, the ribs are filled with polyethylene and then a polyethylene liner is extruded onto the interior surface.

1.2 The exterior polymer precoating provides extra protection of the steel against soilside corrosion, in addition to that provided by the metallic coating, and also provides a dielectric barrier for cathodic protection. The interior polymer precoating provides an adhesive layer between the galvanized steel and the polyethylene lining. The applied lining provides internal protection against corrosion, erosion, and abrasion. By filling the rib which has a deltoid shape (smaller at the opening in the pipe wall than at the bottom of the rib), the polyethylene is mechanically connected to the pipe wall and the polyethylene liner is then thermally bonded to the filled rib.

1.3 This specification does not include requirements for bedding, backfill, or the relationship between earth cover load and sheet thickness of the pipe. Experience has shown that the successful performance of this product depends upon the proper selection of sheet thickness, type of bedding and backfill, controlled manufacture in the plant, and care in the installation. The installation procedure is described in Practice A 798.

1.4 This specification is applicable to orders in either inch-pound units as A 978, or in SI units as A 978M. Inch-pound units and SI units are not necessarily equivalent. SI units are shown in brackets in the text for clarity, but they are the applicable values when the material is ordered to A 978M.

1.5 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

### 2. Referenced Documents

#### 2.1 ASTM Standards:

- A 90/A 90M Test Method for Weight (Mass) of Coating on Iron and Steel Articles with Zinc or Zinc-Alloy Coating<sup>2</sup>
- A 153/A 153M Specification for Zinc Coating (Hot-Dip) on Iron and Steel Hardware<sup>2</sup>
- A 307 Specification for Carbon Steel Bolts and Studs, 60 000 psi Tensile Strength<sup>3</sup>
- A 563 Specification for Carbon and Alloy Steel Nuts<sup>3</sup>
- A 563M Specification for Carbon and Alloy Steel Nuts [Metric]<sup>3</sup>
- A 742/A 742M Specification for Steel Sheet Metallic Coated and Polymer Precoated for Corrugated Steel Pipe<sup>2</sup>
- A 780 Practice for Repair of Damaged and Uncoated Areas of Hot Dip Galvanized Coatings<sup>2</sup>
- A 796/A 796M Practice for Structural Design of Corrugated Steel Pipe, Pipe-Arches, and Arches for Storm and Sanitary Sewers and Other Applications<sup>2</sup>
- A 798 Practice for Installing Factory-Made Corrugated Steel Pipe for Sewers and Other Applications<sup>2</sup>
- A 902 Terminology Relating to Metallic Coated Steel Products<sup>2</sup>
- A 926 Test Method for Comparing the Abrasion Resistance of Coating Materials for Corrugated Metal Pipe<sup>2</sup>
- A 929/A 929M Specification for Steel Sheet, Metallic-Coated by the Hot-Dip Process for Corrugated Steel Pipe<sup>2</sup>
- B 633 Specification for Electrodeposited Coatings of Zinc on Iron and Steel<sup>4</sup>
- B 695 Specification for Coatings of Zinc Mechanically Deposited on Iron and Steel<sup>4</sup>

<sup>1</sup> This specification is under the jurisdiction of ASTM Committee A05 on Metallic Coated Iron and Steel Products and is the direct responsibility of Subcommittee A05.17 on Corrugated Steel Pipe Specification.

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<sup>2</sup> *Annual Book of ASTM Standards*, Vol 01.06.

<sup>3</sup> *Annual Book of ASTM Standards*, Vol 15.08.

<sup>4</sup> *Annual Book of ASTM Standards*, Vol 02.05.

- C 443 Specification for Joints for Circular Concrete Sewer and Culvert Pipe, Using Rubber Gaskets<sup>5</sup>
- C 443M Specification for Joints for Circular Concrete Sewer and Culvert Pipe, Using Rubber Gaskets [Metric]<sup>5</sup>
- D 638/D 638M Test Method for Tensile Properties of Plastics<sup>6</sup>
- D 792 Test Methods for Density and Specific Gravity (Relative Density) of Plastics by Displacement<sup>6</sup>
- D 1005 Test Methods for Measurement of Dry-Film Thickness of Organic Coatings Using Micrometers<sup>7</sup>
- D 1056 Specification for Flexible Cellular Materials, Sponge or Expanded Rubber<sup>8</sup>
- D 1238 Test Method for Flow Rates of Thermoplastics by Extrusion Plastometer<sup>6</sup>
- D 2240 Test Method for Rubber Property—Durometer Hardness<sup>9</sup>
- D 1435 Practice for Outdoor Weathering of Plastics<sup>6</sup>
- D 3212 Specification for Joints for Drain and Sewer Plastic Pipes Using Flexible Elastomeric Seals<sup>10</sup>
- D 5576 Practice for Determination of Structural Entities in Polyolefins by Fourier Transform Infrared Spectroscopy (FT-IR)<sup>11</sup>
- D 5630 Test Method for Ash Content in Thermoplastics<sup>11</sup>
- F 568 Specification for Carbon and Alloy Steel Externally Threaded Metric Fasteners<sup>3</sup>
- F 593 Specification for Stainless Steel Bolts, Hex Cap Screws, and Studs<sup>3</sup>
- F 594 Specification for Stainless Steel Nuts<sup>3</sup>
- F 738M Specification for Stainless Steel Metric Bolts, Screws, and Studs<sup>3</sup>
- F 836M Specification for Stainless Steel Metric Nuts<sup>3</sup>
- 2.2 AASHTO Standard:

T 249 Test for Helical Lock Seam Corrugated Pipe<sup>12</sup>

Specifications for Highway Bridges, Division 2, Section 26<sup>12</sup>

### 3. Terminology

3.1 *Definitions*—For definitions of terms used in this specification, refer to Terminology A 902.

3.2 *Definitions of Terms Specific to This Standard:*

3.2.1 *composite, n*—the joining of steel and plastic to achieve a synergy of desirable characteristics not attainable by either material alone.

3.2.2 *deltoid shape, n*—the open triangular shape of the rib profile, which has a greater dimension at the base (away from the pipe wall) than at the peak (opening at the interior wall of the pipe).

3.2.3 *extruded liner, n*—a liner produced by a process that applies melted polyethylene into the ribs and sequentially extrudes a liner over the top of the rib openings and across the adjacent flats while the pipe is being fabricated.

### 4. Ordering Information

4.1 Orders for material to this specification shall include the following information as necessary, to adequately describe the desired product.

4.1.1 Name of material (composite ribbed steel pipe, pre-coated and polyethylene lined),

4.1.2 Type of metallic coating (zinc) (see 5.1),

4.1.3 ASTM designation and year of issue, as A 978 for inch-pound units or as A 978M for SI units,

4.1.4 Rib size and spacing (see Table 1). If not stated, the size and spacing combination furnished shall be at the fabricator's option,

4.1.5 Diameter of pipe (see 7.1),

4.1.6 Length, either total length or length of each piece and number of pieces,

4.1.7 Sheet thickness (see 7.2),

4.1.8 Joint connectors, number, and type (soil tight, water-resistant, or watertight),

<sup>12</sup> Available from American Association of State Highway and Transportation Officials, 444 N. Capital, Washington, DC 20001.

<sup>5</sup> Annual Book of ASTM Standards, Vol 04.05.

<sup>6</sup> Annual Book of ASTM Standards, Vol 08.01.

<sup>7</sup> Annual Book of ASTM Standards, Vol 06.01.

<sup>8</sup> Annual Book of ASTM Standards, Vol 09.02.

<sup>9</sup> Annual Book of ASTM Standards, Vol 09.01.

<sup>10</sup> Annual Book of ASTM Standards, Vol 08.04.

<sup>11</sup> Annual Book of ASTM Standards, Vol 08.03.

**TABLE 1 Rib Requirements for Steel Pipe**

Nominal Size	Deltoid Shaped Rib							
	Narrowest Width, <sup>A</sup> Min	Widest Width, <sup>B</sup> Min	Depth, <sup>C</sup> Min	Spacing, <sup>D</sup> Max	Bottom Outside Radius, Min	Bottom Outside Radius, <sup>E</sup> Max Avg	Top Outside Radius, Min	Top Outside Radius, <sup>E</sup> Max Avg
A 978, in.								
¾ by ¾ by 7 ½	0.45	0.68	0.73	7 ½	0.10	0.25	0.10+t	0.25+t
¾ by 1 by 11 ½	0.45	0.68	0.90	11 ¾	0.10	0.25	0.10+t	0.25+t
A 978M, mm								
19 by 19 by 190	12	17	19	190	2.5	6.0	2.5+t	6.0+t
19 by 25 by 292	12	17	23	298	2.5	6.0	2.5+t	6.0+t

<sup>A</sup>Narrowest width is a dimension of the inside of the rib measured on the inside of the pipe.

<sup>B</sup>Widest width is a dimension of the inside of the rib but is measured on the outside of the pipe (outside of the rib) and shall meet or exceed the stated minimum width plus two times the wall thickness (that is, 2t + 0.68 in. (2t + 17mm)).

<sup>C</sup>Depth is an average of the ribs within a sheet width measured from the inside by placing a straight edge across the open rib and measuring to the bottom of the rib.

<sup>D</sup>Spacing is an average of three adjacent ribs (one sheet width) spacings for ¾ by ¾ × 7 ½ in. pipe and two adjacent rib (one sheet width) spacings for the ¾ × 1 × 11 ½ in. pipe measured center-to-center of the ribs, at 90° to the direction of the ribs.

<sup>E</sup>The average of the two top rib radii and of the two bottom radii shall be within the minimum and maximum tolerances. The term "outside" refers to the outside surface of the pipe.



- 4.1.9 Certification, if required (see 13.1), and
- 4.1.10 Special requirements.

NOTE 1—Typical ordering information may be described as: (1) Composite ribbed steel pipe, precoated and polyethylene lined, zinc-coated, in accordance with Specification A 978, ¾ by ¾ by 7 ½ in., 72 in. diameter, 600 ft. in length, 0.109 in. sheet thickness, 30-soil tight joint connectors; (2) Composite ribbed steel pipe, precoated and polyethylene lined, zinc-coated, in accordance with Specification A 978M, 19 by 19 by 190 mm, 1800 mm diameter, 182.9 m in length, 2.77 mm sheet thickness, 30-soil tight joint connectors.

## 5. Material

5.1 *Steel Sheets for Pipe*—All pipe fabricated under this specification shall be formed from polymer precoated sheet conforming to Specification A 742/A 742M, except that one side of the sheet (interior side of pipe) shall have additives that will enhance the bond with the extruded polyethylene liner.

5.1.1 The polymer shall have a minimum thickness of 10 mils [250 µm] on each side.

5.1.2 The polymer coating is applied to steel having a metallic coating of zinc as described in Specification A 929/A 929M.

5.2 *Polyethylene for Rib Filling and the Internal Liner*—The polyethylene for rib filling and the internal liner shall be a virgin resin which is predominantly an ethylene octene copolymer. The polymer shall be stabilized for processing at 500°F [260°C] and to endure a 180-day exposure to sunlight. The polymer can contain pigments and stabilizer but shall be 99 % minimum polyethylene resin.

5.2.1 The resin properties shall be:

Melt index: I <sub>2</sub> = 7.5 g/10 min (± 1.5)	Test Method D 1238
Flow Rate Ratio: I <sub>10</sub> /I <sub>2</sub> = 7-8	Test Method D 1238
Density: 0.902 g/cc (± .002)	Test Methods D 792
Hardness: Shore D = 45 (± 5)	Test Method D 2240
Ash Content: <1.0 %	Test Method D 5630

5.2.2 Analyze the precoated film and the polymer by FTIR spectrophotometry in accordance with Practice D 5576 and liquid chromatography methods and compare to standards to verify the polymer is suitable for the application. A lot identification system shall be used to allow traceability of resin.

5.3 *Steel Sheet for Joint Connectors*—The sheet used in fabricating joint connectors shall conform to the same specification listed in 5.1 as that used for fabricating of the pipe furnished under the order.

5.4 *Polyethylene for Joint Connectors*—The polyethylene used in fabricating joint connectors shall be compatible with the polymer precoated sheet conforming to the specification listed in 5.1 or with the polyethylene used to fill the ribs and fabricate the liner as listed in 5.2, or both.

5.5 *Hardware for Storm Sewer Joint Connectors*—External bolts and nuts for storm sewer joint connectors shall conform to the following requirements:

	Bolts	Nuts
For A 978 pipe	Specification A 307	Specification A 563, Grade A
[For A 978M pipe]	[Specification F 568, Class 4.6]	[Specification A 563M, Class 5]

5.5.1 Bolts, nuts, and other threaded items used with joint connectors shall be zinc coated by one of the following

processes: hot-dip process as provided in Specification A 153/A 153M; electroplating process as provided in Specification B 633, Class Fe/Zn 25; or mechanical process as provided in Specification B 695, Class 8. Other hardware items used with joint connectors shall be zinc coated by one of the following processes: hot-dip process as provided in Specification A 153/A 153M; electroplating process as provided in Specification B 633, Class Fe/Zn 25; or mechanical process as provided in Specification B 695, Class 25.

5.6 *Hardware for Sanitary Sewer Joint Connectors*—External bolts and nuts for sanitary sewer joint connectors shall conform to the following requirements:

	Bolts	Nuts
For A 978 pipe	Specification F 593 Martensitic Alloy 410	Specification F 594 Martensitic Alloy 410
[For A 978M pipe]	Specification F 738M Martensitic Alloy 410	Specification F 836M Martensitic Alloy 410

5.7 *Gaskets*—If gaskets are used in connecting, they shall be a band of expanded rubber meeting the requirements of Specification D 1056 for the “RE” closed-cell grades, or O-rings meeting the requirements of Specification C 443 or Specification C 443M, butyl rubber base joint sealant, or other approved resilient materials.

## 6. Fabrication

6.1 *General Requirements*—Pipe shall be fabricated in full circular cross-section with helical lock seams and helical ribs projecting outwardly.

6.2 *Profile*—The profile shall be essentially deltoid shaped ribs projecting outward from the pipe wall. The dimensions of the ribs shall be in accordance with Table 1 for the size indicated on the order. For the 11.5-in. [292 mm] rib spacing, if the sheet between the ribs does not include a lock seam, a stiffener shall be included midway between the ribs. This stiffener shall have a nominal radius of 0.25 in. [6.4 mm] and a minimum height of 0.20 in. [5.1 mm] toward the outside of the pipe.

6.3 *Helical Lock Seams*—The lock seam shall be formed in the flat zone of the pipe wall, between two ribs.

6.3.1 The edges of the sheets within the cross section of the lock seam shall lap at least 5/16 in. [7.9 mm] with an occasional tolerance of –10 % of the lap width allowable. The lapped surfaces shall be in tight contact. The profile of the sheet shall include a retaining offset adjacent to the 180° fold (as described in AASHTO T249) of one sheet thickness on one side of the lock seam. There shall be no visible cracks in the metal, loss of sheet-to-sheet contact, or excessive angularity on the interior of the 180° fold of metal at the completion of forming the lock seam.

6.3.2 Specimens cut from production pipe normal to and across the lock seam shall develop the tensile strength as provided in Table 2, when tested in accordance with AASHTO T249.

## 7. Pipe Requirements

7.1 *Pipe Dimensions*—The nominal diameter of the pipe shall be as stated in the order, selected from the sizes listed in Table 3. The average inside diameter of pipe shall not vary more than 1 % or ½ in. [13 mm], whichever is greater, from the

**TABLE 2 Lock Seam Tensile Strength**

Specified Sheet Thickness		Lock Seam Tensile Strength per Unit Width, min	
in.	mm	lbf/in.	kN/M
0.064	1.63	340	60
0.079	2.01	520	91
0.109	2.77	700	122
0.138	3.50	880	154

**TABLE 3 Pipe Sizes**

Nominal Inside Diameter	
in.	mm
24	600
27	675
30	750
33	825
36	900
42	1050
48	1200
54	1350
60	1500
66	1650
72	1800
78	2000
84	2100
90	2250
96	2400
102	2550
108	2700
114	2850
120	3000
126	3150
132	3300
138	3450
144	3600

nominal diameter, measured from the inside of the steel pipe wall.

**7.2 Sheet Thickness**—Sheet thickness shall be specified by the purchaser from the specified sheet thickness listed in Table 4 (see Notes 2 and 3).

**7.3 Polyethylene Liner**—The polyethylene liner shall have a minimum thickness of at least 0.065 in. [1.65 mm]. The polyethylene in the ribs shall be filled with the same polyethylene material simultaneous to liner extrusion. The ribs shall fill at least 90 % of the deltoid shape.

**7.3.1 Adhesion**—There shall be no spalling, cracking, or disbonding of the applied polyethylene liner in accordance with Specification A 742/A 742M.

**7.3.2 Abrasion**—There shall be no disbonding or noticeable loss of thickness of the applied polyethylene liner when tested in accordance with Test Method A 926, except that all test specimen panels shall be 5 ¾ in. [146 mm] wide.

**TABLE 4 Thickness of Metallic Coated Steel Sheet<sup>A</sup>**

Specified Thickness	
in.	mm
0.064	1.63
0.079	2.01
0.109	2.77
0.138	3.51

<sup>A</sup>Sheet thicknesses are referenced in Specification A 742/A 742M. The specified thickness is the thickness of the metallic-coated steel sheet and does not include the thickness of the polymer coating.

**7.3.3 Weatherability**—The applied polyethylene liner shall retain at least 90 % of the original tensile strength and elongation in accordance with Test Method D 638/D 638M after a 180-day sunlight exposure in accordance with Practice D 1435. There shall be no liner delamination.

**7.3.4 Long-term Sunlight Exposure**—The pipe liner shall not be exposed to long-term sunlight. Inlet and outlet design shall provide protection by the use of metal end sections, pipe materials not affected by sunlight at ends of pipe line exposed, headwalls, inlet/outlet structures, set-backs or other methods that minimize sunlight exposure.

NOTE 2—The sheet thicknesses indicated in Table 4 are the thicknesses listed as available in Specification A 742/A 742M which are suitable for use with ribbed steel pipe.

NOTE 3—The purchaser should determine the required thickness of steel sheet for the pipe in accordance with the design criteria in Practice A 796/A 796M or other appropriate guidelines.

## 8. Joint Connectors

**8.1 General Requirements**—Joint connectors for composite ribbed steel pipe precoated and polyethylene lined shall be specified as soil tight, water-resistant, or watertight.

**8.1.1 Soil Tight Joint Connectors**—Joint connectors requiring soil tightness shall meet the requirements of AASHTO Standard Specifications for Highway Bridges, Division II, Section 26.

**8.1.2 Water-Resistant Joint Connectors**—Joint connectors requiring water resistance for storm sewers shall meet the hydrostatic pressure test requirements of Specification D 3212 except that the test shall be conducted at  $2 \pm 0.05$  psi [ $14 \pm 0.4$  kPa], during which the joint leakage shall not exceed 200 gallons per inch of diameter per mile per day [19 L/mm/km/day].

**8.1.3 Watertight Joint Connectors**—Joint connectors requiring watertightness for sanitary sewers and watertight storm sewers shall meet the hydrostatic pressure test requirements of Specification D 3212.

## 9. Workmanship, Finish and Appearance

9.1 The completed pipe shall show careful, finished workmanship in all particulars. Pipe that has been damaged, either during fabrication or in shipping, shall be subject to rejection unless repairs are made that are satisfactory to the purchaser.

## 10. Repair of Damaged Coatings

10.1 Pipe on which either the polyethylene liner or the polymer coating or the underlying metallic coating has been damaged in fabricating or handling shall be repaired. Damage to the metallic coating shall be repaired as described in 10.2 through 10.3. Damage to the polymer coating shall be repaired as described in 10.4. Damage to the polyethylene liner shall be repaired as described in 10.5. The repair shall be done so that the completed pipe shall show careful finished workmanship in all particulars. Pipe which, in the opinion of the purchaser, has not been cleaned or coated satisfactorily shall be rejected. If the purchaser so elects, the repair shall be done in his presence.

10.2 Damage to the metallic coating shall be repaired as provided in Practice A 780, except as described herein. The damaged area shall be cleaned to bright metal by blast

cleaning, power disk sanding, or wire brushing. The cleaned area shall extend at least ½ in. [13 mm] into the undamaged section of the coating. The cleaned area shall be coated within 24 h and before any rusting or soiling.

10.3 *Paints Containing Zinc Dust*—Paints containing zinc dust in accordance with Practice A 780 shall be applied to a dry film thickness of at least 0.005 in. [0.13 mm] over the damaged area.

10.4 Areas of damaged polymer coating shall be repaired with a polymer coating similar and compatible with respect to durability, adhesion, and appearance of the original polymer coating.

10.4.1 The damaged area shall be repaired by first cleaning and removing all rust, dirt, oils, and other contaminants. Acceptable coating materials include ethylene acrylic acid, ethylene methacrylic acid, and other modified poly olefin based materials which display compatibility with ethylene acrylic acid polymers. Application of these coatings shall be performed by using commercial grade flame coating systems or by brush applying manufacturer-approved plural component coatings.

10.5 Areas of damaged polyethylene lining shall be repaired with a polyethylene similar and compatible with respect to durability, adhesion, and appearance of the original polyethylene liner.

10.5.1 The damaged area shall be cleaned and all loose material removed. The pipe manufacturer shall furnish compatible polyethylene in pellet, powder, cord, or sheet form with written repair instructions. The repair procedure shall use thermal bonding as obtained from a hot air blower, hot iron, hand-held extruder, or plastic flame spraying depending on the nature of the repair process.

## 11. Inspection

11.1 The purchaser or his representative shall have free

access to the fabricating plant for inspection, and every facility shall be extended to him for this purpose.

11.2 On a random basis, take samples for chemical analysis and metallic coating measurements for check purposes. These samples shall be secured from fabricated pipe or from sheets or coils of the material used in fabrication of the pipe. Determine the weight [mass] of metallic coating in accordance with Test Method A 90/A 90M. Measure the thickness of the polymer coating in accordance with Test Method D 1005.

## 12. Rejection

12.1 Pipe failing to conform to the specification, or that shows poor workmanship, shall be subject to rejection. This requirement applies not only to the individual pipe, but to any shipment as a whole where a substantial number of pipes are defective. If the average deficiency in length of any shipment of pipe is greater than 1 %, the shipment shall be subject to rejection.

## 13. Certification

13.1 When specified in the purchase order or contract, a manufacturer's or fabricator's certification, or both, shall be furnished to the purchaser stating that samples representing each lot have been tested and inspected in accordance with this specification and have been found to meet the requirements for the material described in the order. When specified in the order, a report of the test results shall be furnished.

## 14. Keywords

14.1 composite ribbed steel pipe; irrigation pipe; liner pipe; polyethylene filled ribs and extruded liner; polyethylene lined steel pipe; polymer coated steel pipe; rehabilitation pipe; sanitary sewer pipe; slip line pipe; storm drain pipe; water transmission pipe

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# Standard Specification for Concrete Pavements and Linings Installed in Corrugated Steel Structures in the Field<sup>1</sup>

This standard is issued under the fixed designation A 979/A 979M; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon ( $\epsilon$ ) indicates an editorial change since the last revision or reapproval.

## 1. Scope\*

1.1 This specification covers the minimum material requirements and describes the procedures for installing concrete pavements and linings in corrugated steel pipes and structural plate structures in the field. Specific designs with additional or greater requirements shall be detailed in the contract documents. This specification is applicable to paving or lining new pipes and for rehabilitating existing structures. The pipe to be paved or lined is described in Specifications A 760/A 760M, A 761/A 761M, and A 762/A 762M.

1.2 This specification covers pipes 48 in. [1 200 mm] and larger for pavements and 24 in. [600 mm] and larger for full linings.

1.3 New pipes are to be designed in accordance with Practice A 796 and installed in accordance with Practice A 798 for factory-made pipes and Practice A 807 for structural plate structures. Structures to be rehabilitated shall be structurally stable.

1.4 Pipes with plant installed concrete pavements and linings are covered under Specification A 849.

1.5 This specification is applicable to product in either inch/pound units as A 979 or in SI units as A 979M. Inch/pound units and SI units are not necessarily equivalent. SI units are shown in brackets in the text for clarity, but they are the applicable values when materials are ordered to A 979M.

1.6 *This standard may involve hazardous materials, operations and equipment. The standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

## 2. Referenced Documents

### 2.1 ASTM Standards:

- A 185 Specification for Steel Welded Wire Fabric, Plain, for Concrete Reinforcement<sup>2</sup>
- A 615 Specification for Deformed and Plain Billet-Steel Bars for Concrete Reinforcement<sup>2</sup>
- A 760/A 760M Specification for Corrugated Steel Pipe, Metallic-Coated for Sewers and Drains<sup>3</sup>
- A 761/A 761M Specification for Corrugated Steel Structural Plate, Zinc-Coated, for Field-Bolted Pipe, Pipe-Arches, and Arches<sup>3</sup>
- A 762/A 762M Specification for Corrugated Steel Pipe, Polymer Precoated for Sewers and Drains<sup>3</sup>
- A 796 Practice for Structural Design of Corrugated Steel Pipe, Pipe-Arches, and Arches for Storm and Sanitary Sewers and Other Buried Applications<sup>3</sup>
- A 798/A 798M Practice for Installing Factory-Made Corrugated Steel Pipe for Sewers and Other Applications<sup>3</sup>
- A 807/A 807M Practice for Installing Corrugated Steel Structural Plate Pipe for Sewers and Other Applications<sup>3</sup>
- A 849 Specification for Post-Applied Coatings, Pavings, and Linings for Corrugated Steel Sewer and Drainage Pipe<sup>3</sup>
- A 902 Terminology Relating to Metallic Coated Steel Products<sup>3</sup>
- C 31/C 31M Practice for Making and Curing Concrete Test Specimens in the Field<sup>4</sup>
- C 33 Specification for Concrete Aggregates<sup>4</sup>
- C 39 Test Method for Compressive Strength of Cylindrical Concrete Specimens<sup>4</sup>
- C 150 Specification for Portland Cement<sup>5</sup>
- C 309 Specification for Liquid Membrane-Forming Compounds for Curing Concrete<sup>4</sup>
- C 595M Specification for Blended Hydraulic Cements<sup>5</sup>
- C 618 Specification for Fly Ash and Raw or Calcined Natural Pozzolan for Use as a Mineral Admixture in Portland Cement Concrete<sup>4</sup>

<sup>1</sup> This specification is under the jurisdiction of ASTM Committee A05 on Metallic Coated Iron and Steel Products and is the direct responsibility of Subcommittee A05.17 on Corrugated Steel Pipe Specifications.

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<sup>2</sup> *Annual Book of ASTM Standards*, Vol 01.04.

<sup>3</sup> *Annual Book of ASTM Standards*, Vol 01.06.

<sup>4</sup> *Annual Book of ASTM Standards*, Vol 04.02.

<sup>5</sup> *Annual Book of ASTM Standards*, Vol 04.01.

\*A Summary of Changes section appears at the end of this standard.

D 3405 Specification for Joint Sealants, Hot-Applied, for Concrete and Asphalt Pavements<sup>6</sup>

2.2 *American Water Works Association Standards:*

AWWA C 602 Standards for Cement-Mortar Lining of Water Pipelines—4 in. (100 mm) and larger-in place<sup>7</sup>

### 3. Terminology

3.1 *Definitions*—For definitions of general terms used in this specification, see Terminology A 902.

3.2 *Definitions of Terms Specific to This Standard:*

3.2.1 *contractor, n*—the installer or applicator of the concrete pavement of lining.

3.2.2 *engineer, n*—the designer of the work and its details.

3.2.3 *fabricator, n*—the producer of the pipe.

3.2.4 *lining, n*—for corrugated metal pipe, a layer of non-metallic material applied uniformly to the interior of a fabricated pipe, of sufficient thickness to fill and cover the corrugations.

3.2.5 *pavement, n*—for corrugated metal pipe, a lining applied only to a portion of the interior circumference, usually located in the lower portion (as the pipe is installed).

3.2.6 *purchaser, n*—the person or agency purchasing the finished product.

### 4. Requirements

4.1 *Concrete Pavements*—Concrete pavements shall be placed after the pipe has been installed. For new pipes, pavements shall be placed after the pipe is backfilled to final grade. If the depth of fill exceeds four feet, the pavement may be placed after four feet of backfill over the pipe has been placed. If the paving is placed prior to completion of the entire fill, any gaps between the pipe and pavement shall be filled with heated joint sealer conforming to Specification D 3405. Special pavement designs, which exceed the minimum requirements of this specification, shall be detailed in the job plans and specifications. In lieu of special designs, pavements shall extend over the area to be protected or rehabilitated. Invert pavements shall cover a minimum of the bottom 25 % of a round pipe's circumference and 40 % of the circumference of a pipe-arch (the invert of the pipe-arch), unless a special design is detailed in the plans and specifications.

4.1.1 The concrete for pavements shall have a minimum 28-day compressive strength of 3250 psi [22.4 MPa] when tested in accordance with Specification C 31 and Test Method C 39. The pavement shall have a minimum 3 in. [75-mm] thickness above the crests of the corrugations or structural plate bolts or nuts as applicable.

4.1.2 A minimum pavement thickness of 1-½ in. [38 mm] above the crests of the corrugations or structural plate bolts or nuts as applicable is required if concrete with a 28-day minimum compressive strength of 5 000 psi [34.5 MPa] when tested in accordance with Specification C 31 and Test Method C 39, is used.

NOTE 1—For rehabilitation applications, greater concrete pavement thicknesses may be required to replace necessary pipe ring compression strength lost due to service conditions.

4.2 *Concrete Linings*—Concrete linings shall be placed after the pipe has been installed and backfilled to final grade. Concrete linings shall cover 100 % of the circumference of round pipes.

4.2.1 The concrete for linings shall have a minimum 28-day compressive strength of 5 000 psi [34.5 MPa] when tested in accordance with Specification C 31 and Test Method C 39. The lining shall have a minimum thickness of ½ in. [3.2 mm] above the crests of the corrugations or structural plate bolts or nuts as applicable.

4.3 *Concrete Materials*—Concrete materials for pavements and linings shall consist of portland cement, fly ash (when used), aggregates and water. Special additives for air entrainment, sulfate resistance, etc., may be included as part of a specific mix design that meets or exceeds the requirements of this specification.

4.3.1 The cement for pavements shall be Type II portland cement conforming to Specification C 150 with an alkali content not more than 0.60 % expressed as Na<sub>2</sub>O.

4.3.2 The cement used for linings shall conform to the requirements of Specification C 150 for Type I or Type II.

4.3.3 Type IP portland Pozzolan cement conforming to Specification C 595 shall be permitted in concrete for pavements or linings, in lieu of the requirements of 4.3.1 or 4.3.2, if no fly ash is used in the mix.

4.3.4 Aggregates shall be clean, hard, and durable conforming to the requirements of Specification C 33 except that for concrete linings, the requirements for grading do not apply. For linings, the aggregates shall be well graded with 100 % passing the No. 16 [1.18 mm] sieve with no more than 5 % passing the No. 100 [150-µm] sieve.

4.3.5 Fly ash shall conform to the requirements of Specification C 618 for Class C or Class F. When used for pavements or linings, fly ash shall not exceed 20 % weight of the total cementitious materials in the mix.

4.3.6 Potable water shall be used.

4.3.7 Steel reinforcement, when required for pavements, shall be billet-steel bars conforming to Specification A 615, Grade 40 minimum or welded wire fabric reinforcement conforming to Specification A 185.

4.4 *Concrete Mix*—The concrete mix shall be uniform and homogeneous. The water content shall be the minimum quantity that produces a workable mixture with full allowance made for condensation forming on the interior of the pipe. The water-cement ratio of the mix shall not exceed 0.50 by weight.

NOTE 2—Guidance as to concrete mix consistency requirements for various types of equipment used to place full concrete linings is provided in the American Water Works Association (AWWA) C 602.

4.5 *Surface Finish:*

4.5.1 Pavements shall have a troweled or untroweled surface finish as specified in the contract documents. Full linings shall have a troweled surface finish.

4.5.1.1 Untroweled pavements shall be uniform and regular in appearance, meeting the requirements of 4.1 unless the plans

<sup>6</sup> Discontinued and replaced by Specification D 6690; see 2001 *Annual Book of ASTM Standards*, Vol 04.03.

<sup>7</sup> Available from American Water Works Association, 6666 West Quincey Avenue, Denver, CO 80235.

and specifications require a specially roughened surface, energy dissipators, etc., to slow or impede flow.

NOTE 3—Concrete pavements including special surface roughening techniques (the placement of concrete bricks, blocks, etc., into the pavement to provide energy dissipating flow checks, etc.) are permitted. Such techniques must be detailed in the plans and specifications.

4.5.2 A troweled surface finish shall be accomplished using metal trowels and floats. The finished surface shall meet the requirements of 7.4.

#### 4.6 *Pipe Repairs:*

4.6.1 When paving or lining new pipes, damaged pipe shall be replaced or repaired in accordance with the pipe Specifications A 760/A 760M, A 761/A 761M, or A 762/A 762M, as applicable.

4.6.2 Damaged or deteriorated pipes to be rehabilitated shall be repaired as directed by the engineer. Repairs are the responsibility of the paving or lining contractor or others as dictated by the contract documents.

## 5. Procedures

### 5.1 *Cleaning and Preparation:*

5.1.1 The interior surface areas of new pipes to be paved or lined shall be free of oil, grease, and accumulated or running water. Dirt and construction debris shall be removed. Brushing, sweeping, or flushing are appropriate cleaning means. Shot or sand blasting shall not be permitted.

5.1.2 For rehabilitating pipes in service, the areas to be paved or lined shall be cleaned by methods specified or approved by the purchaser to remove corrosion, chemical or other products, any loose or deteriorated remains of old coatings, oils, greases, dirt and all other debris, as well as accumulated or running water.

5.1.3 Casual or standing water except for naturally occurring condensation shall be removed from surfaces to be lined or paved. When running water or service flows are present, a bypass system carrying these flows around the portion of the pipeline to be paved or lined shall be provided by the contractor. The bypass system shall be approved by the purchaser and shall carry all the flows. The pavement or lining is to be placed in dry conditions and cured adequately to preclude erosion of the concrete, loss of cement or the formation of excessive laitance.

### 5.2 *Paving Methods:*

5.2.1 Pavements shall be placed by hand or slip forming methods. They must be placed in a full thickness, screeded and finished to the necessary smoothness.

5.2.2 Reinforcement shall be supplied and installed by the pipe fabricator if required by the purchase agreement for the pipe. Otherwise, for new pipe installations and all rehabilitation work the reinforcement shall be supplied and installed by the contractor or others designated in the contract documents.

5.2.3 Reinforcement shall be of the type, size, and spacing as required by the plans and specifications. If the type, size, and spacing of reinforcement are not given in the plans or specifications, a minimum 4×4 W1.4×W1.4 welded wire fabric shall be provided.

5.2.4 Reinforcement shall be securely fastened to the pipe.

NOTE 4—Reinforcement, when required, typically consists of longitu-

dinal No. 3 or larger bars, located to provide a minimum of 0.2 % reinforcement area. Steel welded wire fabric, used in lieu of bars, is selected to provide this minimum, longitudinal steel reinforcement area with a mesh size that accommodates foot traffic during assembly and concrete placement. Specific designs including reinforcement must evaluate reinforcement location and pavement thickness to provide adequate concrete cover over the reinforcement for the intended application.

### 5.3 *Lining Methods:*

5.3.1 The lining for all straight pipe sections shall be placed, in one or more passes, by a machine that progresses uniformly through the pipe and applies concrete against the pipe surface fully filling the corrugation and providing a uniform thickness over the corrugation crests meeting the requirements of 4.2.1. The machine shall not segregate the mix and shall be provided with mechanical trowels to achieve the desired finish.

5.3.2 Linings shall be hand placed in sharp bends, or other areas where machine lining is not practicable. All handwork shall meet the requirements of 4.2. All hand placed lining work shall be completed within 24 h after completion of the machine application portion of the pipeline.

### 5.4 *Curing:*

5.4.1 Curing operations shall begin immediately following the completion of the placement of the pavement or lining in a section of pipeline and shall continue for a minimum period of 72 h or as directed by the engineer. The surface of the concrete shall be kept moist during the cure period. When practical, the pipeline shall be closed with airtight covers and the linings maintained in a moist condition.

5.4.2 Where airtight closures to prevent the evaporation loss are not practicable, proper cure shall be achieved by applying an intermediate water source or a surface membrane to limit evaporation loss from the concrete during cure.

5.4.2.1 Where an intermediate water source is used immediately after the pavement or lining has attained its initial set, it shall be either fully inundated, periodically sprayed, or covered with burlap, etc., that is kept wet for the cure period.

5.4.2.2 Alternatively, a liquid membrane-forming compound conforming to Specification C 309 shall be applied to the entire surface of the pavement or lining.

5.4.2.3 Unless a special mix design is required by the engineer, concrete shall not be placed when the ambient air temperature in the pipe is below 40°F [4°C].

## 6. Additional Considerations

6.1 For installations below existing or perched water tables, appropriate gasketed joints shall be used unless the pavement or lining has been designed to withstand the hydrostatic pressure. The pipe and gasketed coupling system shall be capable of eliminating infiltration under these conditions. If infiltration cannot be eliminated, well pointing or other draw-down methods shall control external hydrostatic head conditions until the pavement or lining is capable of supporting the hydrostatic pressures without blowout or other damage.

### 6.2 *Deflected and Distorted Pipes:*

6.2.1 For lined pipe, where localized distortions are present or the pipe deflection exceeds 1-1/2 % of the diameter, the engineer shall decide if reinforcement of the lining is required.

## 7. Inspection

7.1 The entire procedure shall be open with free access to inspection by the purchaser, but such inspection shall not relieve the contractor of the responsibility to furnish material and provide workmanship in accordance with this specification.

7.2 The contractor shall furnish test specimen to demonstrate the compressive strength of the concrete used as required by the purchase documents.

7.3 Defects in pavements and linings include, but are not limited to, sand pockets, voids, cracked areas which cause loosening of the lining or pavement and spalled areas.

7.4 To determine acceptable smoothness of troweled surface finishes, a predetermined random sampling method shall be agreed to by the purchaser and the contractor. When gaps between a 12-in [300-mm] straight edge laid down the axis of the pipe and the concrete do not exceed ¼-in. [6-mm] in 90 % or more of the tests, the finish is acceptable.

## 8. Repair

8.1 Defective areas shall be repaired such that the repair meets the requirements of the plans and specifications and this specification. All repairs shall require the defective materials to be removed, the exposed pipe to be cleaned, and new concrete to be placed. When suitable repairs are not made, the work shall be rejected by the purchaser.

8.2 Cracks that produce spalls or cause loosening of the pavement or lining shall be repaired to meet the requirements of 8.1.

NOTE 5—Temperature and shrinkage cracks are inherent in concrete pavements and linings. These cracks typically will heal autogenously when the concrete is kept wet.

## 9. Rejection

9.1 Pipe linings or pavement failing to conform to the specific requirements of this specification or that show poor workmanship shall be subject to rejection.

9.2 Defective pipe linings or pavements that are not repaired in accordance with 8.1 shall be rejected.

## 10. Certification

10.1 When specified in the purchase order or contract, a contractor's certification shall be furnished to the purchaser stating that the pavement or lining has been constructed, tested, and inspected in accordance with the requirements of the applicable plans and specifications and this specification.

## 11. Keywords

11.1 concrete linings; concrete linings–corrugated steel pipe; concrete pavements; concrete pavements–corrugated steel pipe; corrugated steel pipe; pipe rehabilitation; steel structural plate

## SUMMARY OF CHANGES

This section identifies the location of selected changes to this specification. For the convenience of the user, Committee A05 has highlighted those changes that may impact the use of this specification. This section may also include descriptions of the changes or reasons for the changes, or both.

A 979/A 979M - 03:

(1) Revised paragraphs 4.1, 5.22, 5.2.3, and 6.1.

(2) Added Specification D 3405.

(3) Deleted paragraph 6.1.

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# Standard Test Method for Measuring Shape Characteristics of Tin Mill Products<sup>1</sup>

This standard is issued under the fixed designation A 987; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last approval. A superscript epsilon ( $\epsilon$ ) indicates an editorial change since the last revision or reapproval.

## 1. Scope

1.1 Shape is a significant quality characteristic for tin mill products. Plate-shape is affected by mill process factors plus the temper, thickness and width of the material supplied. It is the purpose of this test method to define accurately the different plate shape characteristics and to describe the method(s) most commonly used to measure particular characteristics.

1.2 Quantitative limits are not addressed and should be established on an individual producer and user basis, where appropriate.

1.3 *This standard does not purport to address the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and to determine the applicability of regulatory limitations prior to use.*

## 2. Referenced Documents

### 2.1 ASTM Standards:

A 599/A 599M Specification for Tin Mill Products, Electrolytic Tin Coated, Cold-Rolled Sheet<sup>2</sup>

A 623 Specification for Tin Mill Products, General Requirements<sup>2</sup>

A 623M Specification for Tin Mill Products, General Requirements [Metric]<sup>2</sup>

A 624/A 624M Specification for Tin Mill Products, Electrolytic Tin Plate, Single Reduced<sup>2</sup>

A 625/A 625M Specification for Tin Mill Products, Black Plate, Single Reduced<sup>2</sup>

A 626/A 626M Specification for Tin Mill Products, Electrolytic Tin Plate Double Reduced<sup>2</sup>

A 650/A 650M Specification for Tin Mill Products, Black Plate, Double Reduced<sup>2</sup>

A 657/A 657M Specification for Tin Mill Products, Black Plate Electrolytic Chromium-Coated, Single and Double Reduced<sup>2</sup>

<sup>1</sup> This test method is under the jurisdiction of ASTM Committee A01 on Steel, Stainless Steel, and Related Alloys and is the direct responsibility of Subcommittee A01.20 on Tin Mill Products.

Current edition approved Oct. 10, 2000. Published November 2000. Originally published as A 987-98. Last previous edition A 987-98.

<sup>2</sup> *Annual Book of ASTM Standards*, Vol 01.06.

## 3. Classification

3.1 The substrate shall conform to all the requirements of the appropriate specifications as follows: Specifications A 623, A 623M, A 599/A 599M, A 624/A 624M, A 625/A 625M, A 626/A 626M, A 650/A 650M, and A 657.

## 4. Significance and Use

4.1 The definitions and procedures for measuring shape characteristics of tin mill products are provided so that purchasers and suppliers have common measuring procedures and definitions of shape characteristics. These procedures provide definitions and measuring techniques of shape characteristics. The intention of these definitions and measuring methods is not to provide a dimensional specification for shape characteristics, but rather common procedure(s) for quantifying shape anomalies.

## 5. Interferences

5.1 Measurement of shape often has been subjective, at best. Successful measurement of various shape anomalies on quantitative terms requires recognition of several factors that can interfere with accurate measurements.

5.1.1 Flat surfaces are required. Measurement of several anomalies require laying of the sample on a flat surface. A machined flat surface is recommended. Laying a sample on a floor may introduce error due to areas on a floor that are not flat.

5.1.2 Several anomalies are measured by hanging the sheet. Hanging by holding the sample with a hand can introduce error from pressures exerted by fingers. A mechanical single device clamp to help hold these samples is recommended.

5.1.3 Stepblock gages or tapered gages should be checked regularly with a calibrated hand micrometer. Wear or dirt build up could affect accuracy.

5.1.4 The Shapemaster<sup>TM</sup><sup>3</sup> table must be clean and the sensors must be in good condition. The sheet sample must be damage free.

<sup>3</sup> A contact or noncontact flatness measuring instrument, manufactured by SP&C Computer Systems, Inc., 7292 Park Drive, Bath, PA 18014. See Figs. 1 and 2 of the noncontact, laser sensor, Shapemaster TL 1000 shape gage in use. Other instruments of appropriate design also may be used.

## 6. Apparatus

6.1 Appropriate tools to measure shape anomalies are described along with drawings (attached) as required.

6.1.1 *Flat Surfaces*—Accurate measurements of shape anomalies require a flat surface, machined flat preferred.

6.1.2 *Machined Stepblock Gage*—See Fig. 3, typically, steps are in  $\frac{1}{16}$  -in. increments.

6.1.3 *Tapered Gage*—See Fig. 4.

6.1.4 *Standard Ruler or Tape Measure*.

6.1.5 *Hand Micrometer*.

6.1.6 *Shape Test Jig*—Fig. 5, or other shape test jigs of appropriate design.

6.1.7 *Light-Weight Straight-Edge*.

6.1.8 The Shapemaster<sup>TM3</sup> shape gage is a computer-based system designed for flatness measurements on samples of cold rolled sheet products. The system consists of a large steel table, computer-based operator's console, and a motor-driven bridge containing one or more LVDT position sensors to contact the strip or by use of a laser sensor, noncontact measuring system.

## 7. Procedure

### Definitions and Measuring Methods of Shape Anomalies

7.1 *Wavy Edge (See Fig. 6):*

7.1.1 *Definition*—A series of rolling direction edge deviations from a recognized flat surface. When a sample is placed on a recognized flat table, wavy edges will appear as undulations along the edge, having the height ( $A$ ) and a measurable cycle ( $B$ ). This defect can be quantified using the “ $I$ ” unit (see Section 8) or steepness calculations.

7.1.2 *Measuring Methods:*

7.1.2.1 A sample of approximately 3 ft [0.9 m] in length by coil width is placed on a flat table. Measure the height ( $A$ ) at the peak point of each wave from the recognized flat surface with a tapered gage or a stepblock gage. Also measure the cycle length ( $B$ ) from peak to peak of each wave with a ruler or tape measure.

7.1.2.2 Measure using the Shapemaster<sup>TM</sup> or other instrument of appropriate design.

7.2 *Ridge Buckle, Quarter Buckle, Center Buckle (see Fig. 7):*

7.2.1 *Definition*—These buckles are continuous deviations from a recognized flat surface occurring usually in narrow width areas parallel to the rolling direction other than at the sheet edges.

7.2.2 *Measuring Methods:*

7.2.2.1 A sheet sample of approximately 3 ft [0.9 m] by coil width is placed on a flat table. Push material diagonally along the sample to within 4 in. [10 cm] of the selected corner and measure the vertical uplift using a tapered gage or a stepblock gage.

7.2.2.2 Shear through the center line of the shape anomaly and measure as an edge wave using a tapered gage or a stepblock gage.

7.2.2.3 Measure using the Shapemaster<sup>TM</sup> or other instrument of appropriate design.

7.3 *Full Center (see Fig. 8):*

7.3.1 *Definition*—Any overall deviation of a sheet from a recognized flat surface occurring over a major portion of the sheet width parallel to the rolling direction other than at the sheet edges.

7.3.2 *Measuring Methods:*

7.3.2.1 A sheet sample of approximately 3 ft [0.9 m] by coil width is placed on a flat table. Push material diagonally along the sample to within 4 in. [10 cm] of the selected corner and measure the vertical uplift using a tapered gage or a stepblock gage.

7.3.2.2 Shear through the center line of the shape anomaly and measure as an edge wave using a tapered gage or a stepblock gage.

7.3.2.3 Measure using the Shapemaster<sup>TM</sup> or other instrument of appropriate design.

7.4 *Edge Lift (see Fig. 9):*

7.4.1 *Definition*—Any deviation of one sheet edge other than a wavy edge. This edge lift is parallel to the rolling direction and rises when placed on a recognized flat surface.

7.4.2 *Measuring Method*—A sheet sample of approximately 3 ft [0.9 m] by coil width is placed on a flat table. Push material diagonally along the sheet to within 4 in. [10 cm] of the selected edge and measure the vertical distance ( $A$ ) with a tapered gage, a stepblock gage, or a standard ruler.

7.5 *Coil Set and Reverse Coil Set (see Fig. 10):*

7.5.1 *Definition*—A bow condition or deviation in the sheet as measured from a recognized flat surface. The deviation runs parallel with the rolling direction and takes the shape of a coil. Reverse coil set reverses the shape of a coil. The degree of coil set usually is determined in a vertical, free-hanging position when held against a straight-edge. Use of the shape test jig (Fig. 5) is highly recommended for this measurement.

7.5.2 *Measuring Methods:*

7.5.2.1 A sheet sample of approximately 3 ft [0.9 m] by coil width should be held by a clamp or with the thumb and index finger. Hold the sample in the center of the rolling direction dimension. Hold the sample's edges against a recognized straight edge, and measure the deviation ( $A$ ) from the edge to the center of the sample. Use a rule accurate to  $\frac{1}{16}$  in. [or 1 mm].

7.5.2.2 Measure the edge rise ( $A$ ) of the sheet laying on a recognized flat surface.

7.6 *Twist (see Fig. 11):*

7.6.1 *Definition*—A combination of shape anomalies that results in a twisting of the sheet where diagonal corners will bow in opposite directions when the sheet is held in a vertical, free-hanging position.

7.6.2 *Measuring Methods:*

7.6.2.1 A sheet sample of approximately 3 ft [0.9 m] by coil width should be placed on a flat table. Measure the edge lift ( $A$ ) on one side then turn the sheet over and measure the edge lift on the other side of the sample. Measure using a tapered gage or a stepblock gage.

7.6.2.2 A sheet sample of approximately 3 ft [0.9 m] by coil width should be held by a clamp or with the thumb and index finger in the center of the rolling direction dimension. Measure the amount of the twist by the deviation of one of the corners

from a flat surface using a ruler. Flip the sample 180° and measure the deviation from vertical of the other corner, using a ruler.

**7.7 Crossbow (see Fig. 12):**

**7.7.1 Definition**—An edge deviation in the sheet running perpendicular to the rolling direction. Both rolling direction edges are raised measurable amounts (*A*) from a recognized flat surface. The degree of cross bow usually is determined in a vertical, free-hanging position held against a straight edge. Use of the shape test jig (Fig. 5) is highly recommended for this measurement.

**7.7.2 Measuring Methods:**

**7.7.2.1** A sheet sample of approximately 3 ft [0.9 m] by coil width should be held by a clamp or with the thumb and the index finger in the center of sheet dimension that is perpendicular to the rolling direction. In case of dispute, a clamp no more than 2 in. [50.8 mm] wide shall be used to hold the test sample. Hold the sample's edges against a recognized straight edge, and measure the deviation (*A*) from the straight edge to center of the sample. Use a rule accurate to 1/16 in. [or 1 mm].

**7.7.2.2** Measure the edge rise of a sheet lying on a flat surface.

**7.8 Camber (see Fig. 13):**

**7.8.1 Definition**—The greatest deviation of a coil edge from a straight line. The measurement is taken on the concave side and is the perpendicular distance from a straight line to the point of maximum deviation (*A*).

**7.8.2 Methods of Measurement:**

**7.8.2.1** A sample of at least 20 ft [6 m] is laid next to an accurate straight edge. The perpendicular distance (*A*) is measured using a ruler accurate to 1/16 in. [or 1 mm].

**7.8.2.2 Alternate Method of Measurement—Macro Analysis**—Cut two 20-ft [6-m] consecutive sections from master coil. Butt together the sections with similar edges. At a 10-ft [3-m] distance from the end, measure the distance between the two edges. Divide this measurement in half to determine the actual camber.

**7.8.2.3 Alternate Method of Measurement—Micro Analysis**—Obtain consecutive customer sheared sheets equivalent to 20 ft [6 m]. Using a squaring table with a sliding gage set at zero, slide the gages right to left along one slit edge. The reading on the extreme left slit edge of Sheet No. 1 will be the

beginning reading on the extreme right edge of Sheet No. 2. This procedure should be used from consecutive sheet to consecutive sheet until 20 ft [6 m] have been measured. Divide the final measurement in half to determine the actual camber.

**7.9 Lateral Weave (see Fig. 14):**

**7.9.1 Definition**—Weave is defined as oscillation of the coil or sheet edge from a straight line. The measurement is taken on the concave side and is the perpendicular distance from a straight line to the point of maximum deviation (*A*).

**7.9.2 Measuring Methods:**

**7.9.2.1 Macro Analysis**—A sheet sample of at least 20 ft [6 m] in length is laid next to an accurate straight edge. The perpendicular distance (*A*) is measured using a ruler accurate to 1/16 in. [or 1 mm].

**7.9.2.2 Micro Analysis**—Obtain consecutive customer sheared sheets equivalent to 20 ft [6 m]. Using a squaring table with a sliding gage set at zero, slide to gages right to left along one slit edge. The reading on the extreme left slit edge of Sheet No. 1 will be the beginning reading on the extreme right edge of Sheet No. 2. This procedure should be used from consecutive sheet to consecutive sheet until 20 ft [6 m] have been measured. The individual measurements then are plotted, the maximum value being the maximum weave deviation.

**8. I-U Calculation**

**8.1** This calculation assumes that shape irregularities most closely conform to sinusoidal wave forms and uses the shape wave length and height for the calculation. An alternate approach is to use % steepness as a measure of the severity of shape imperfections (see Fig. 15).

**9. Precision and Bias**

**9.1 Precision**—Precision is not specified in these procedures for this test method. The procedures are provided so that purchasers and suppliers have common methodology and definitions of shape characteristics.

**9.2 Bias**—Since there is no accepted reference material suitable for determining the bias of the procedures in this test method, bias has not been determined.

**10. Keywords**

**10.1** coated steel sheet; shape characteristics; tin mill products; tinplate

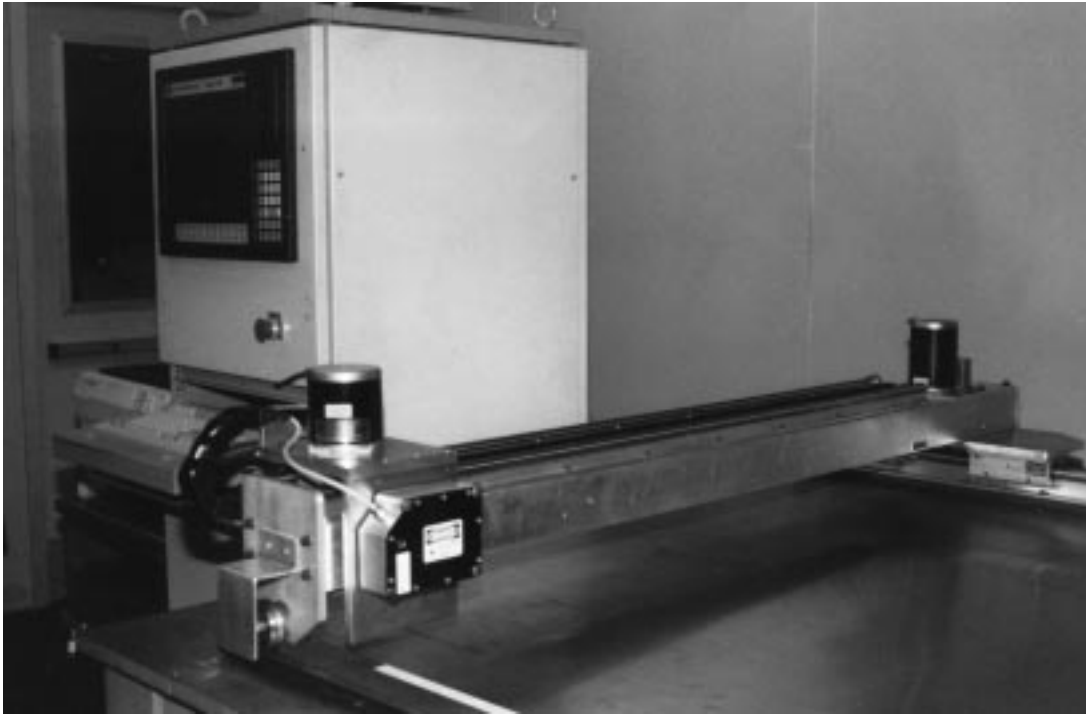
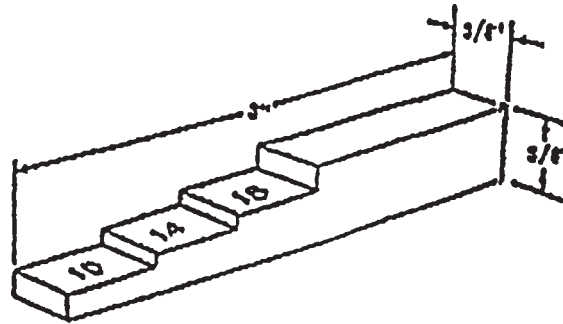


FIG. 1 Shapemaster TL1000 Shape Gage



FIG. 2 Shapemaster TL1000 Shape Gage





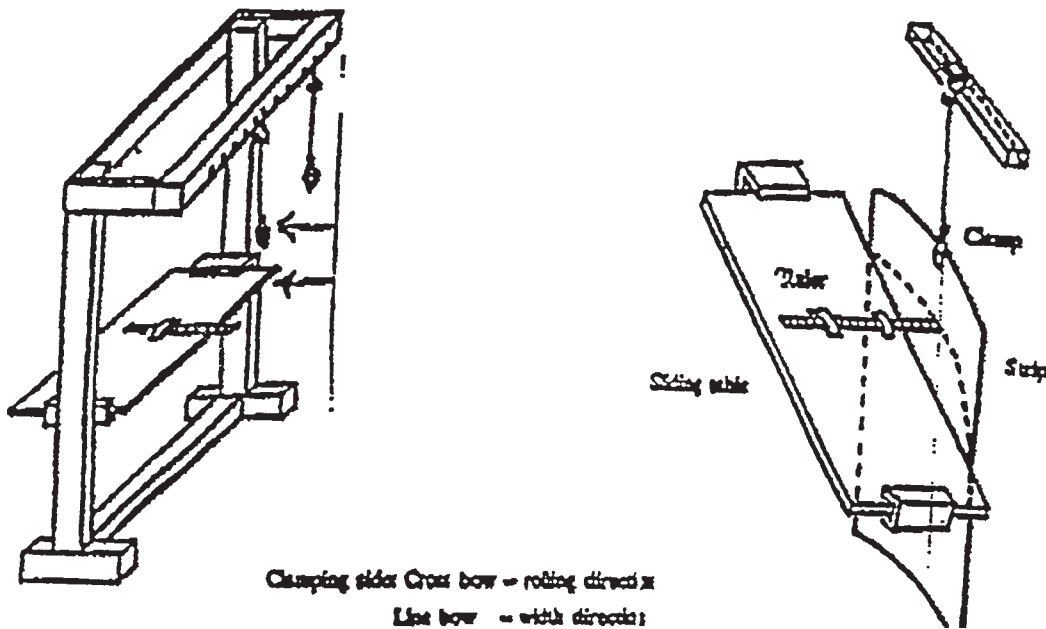
NOTE 1—This is a stepblock gage for all thicknesses and sizes of cut sheets.  
 NOTE 2—Dimensions given are approximate overall dimensions.

FIG. 3 Shape Stepblock Gage



NOTE 1—This is a tapered gage for all thicknesses and sizes of cut sheets.

FIG. 4 Shape Tapered Gage



NOTE 1—To measure line bow (up or down) requires the use of a shape test jig.

FIG. 5 Shape Test Jig

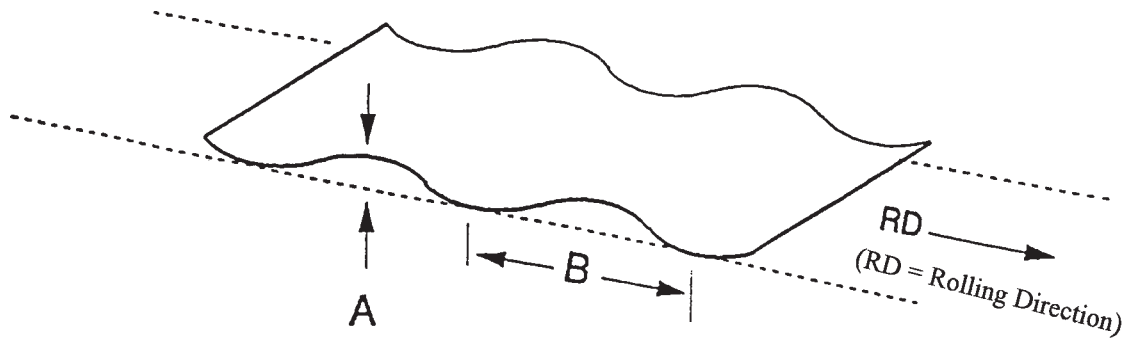


FIG. 6 Wavy Edge

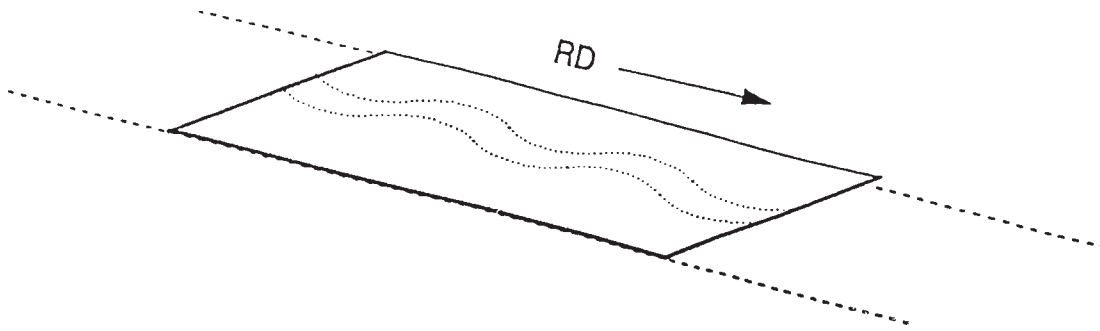


FIG. 7 Ridge Buckle, Quarter Buckle, Center Buckle

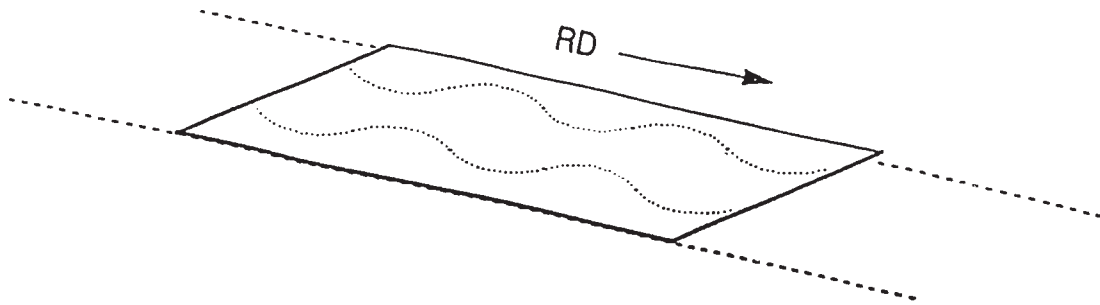


FIG. 8 Full Center

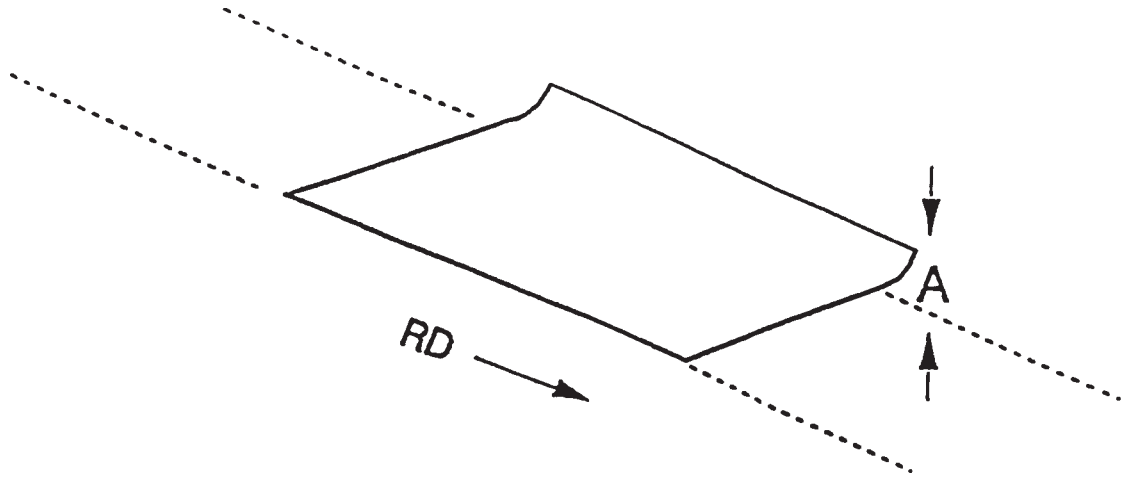


FIG. 9 Edge Lift

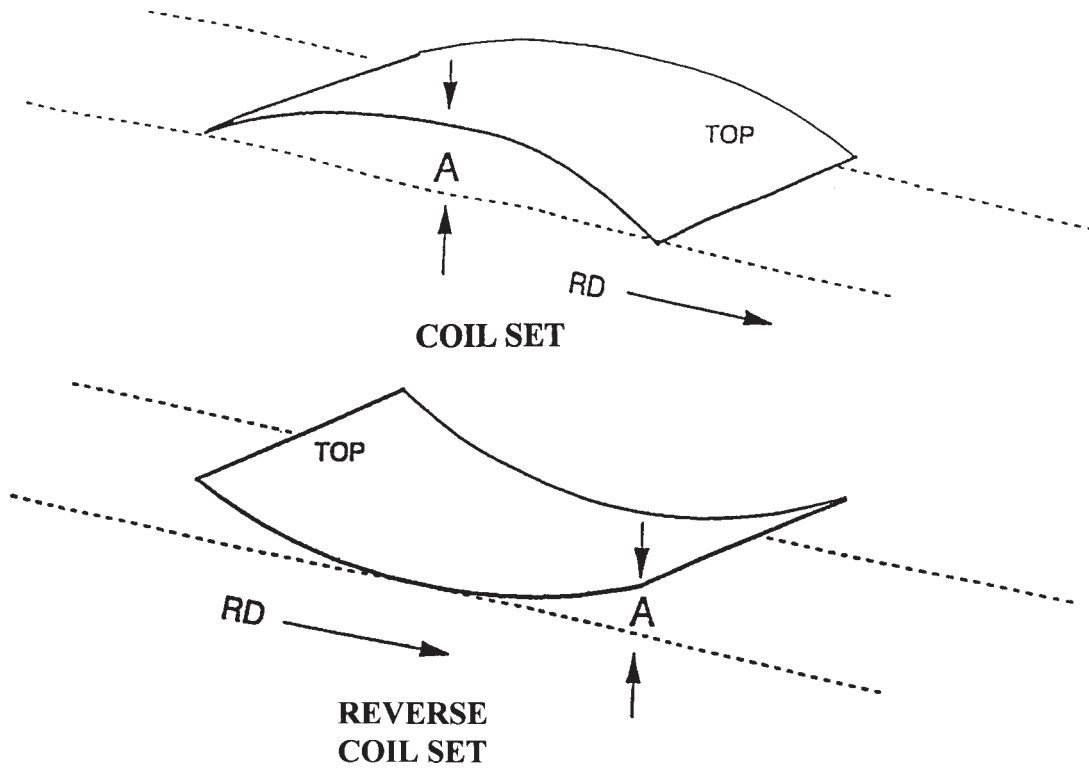


FIG. 10 Coil Set and Reverse Coil Set

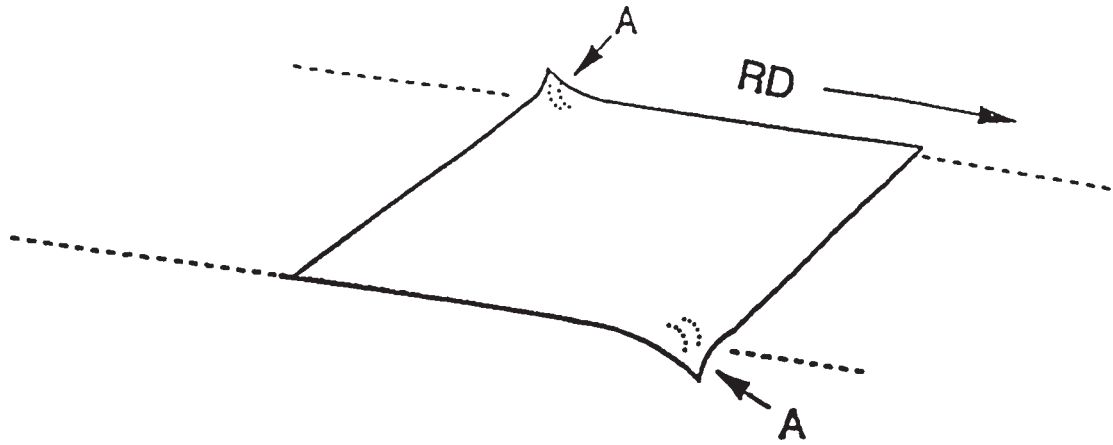


FIG. 11 Twist

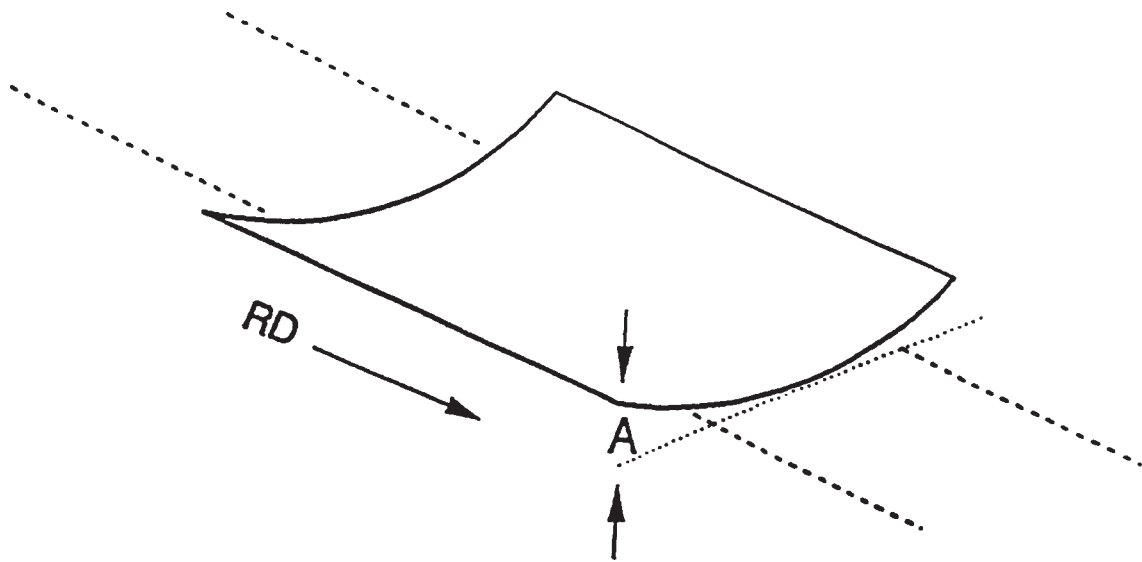


FIG. 12 Crossbow

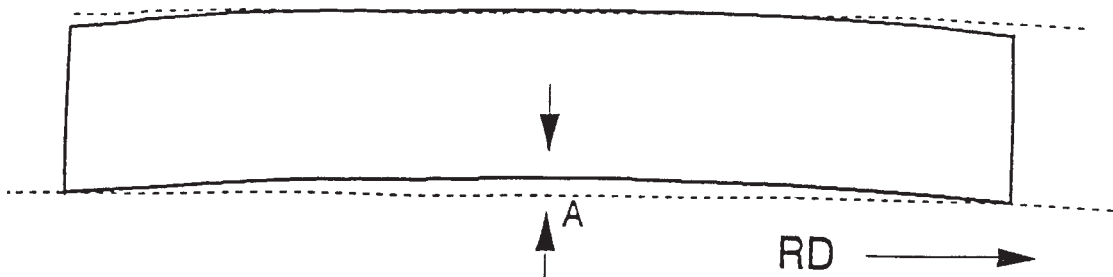


FIG. 13 Camber

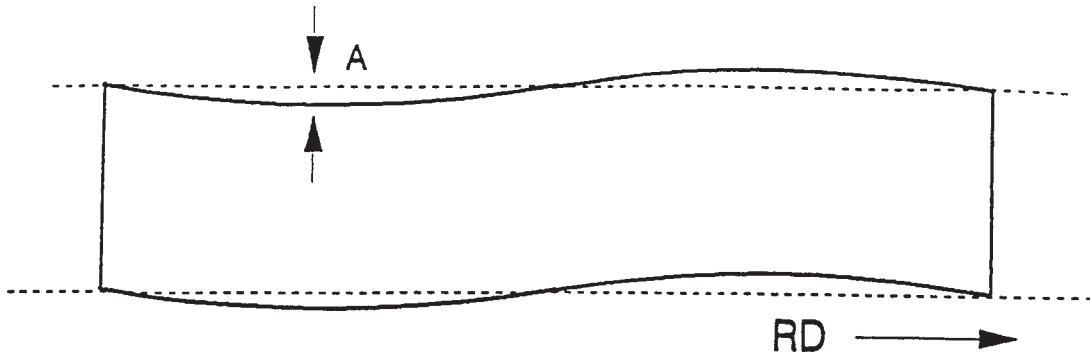
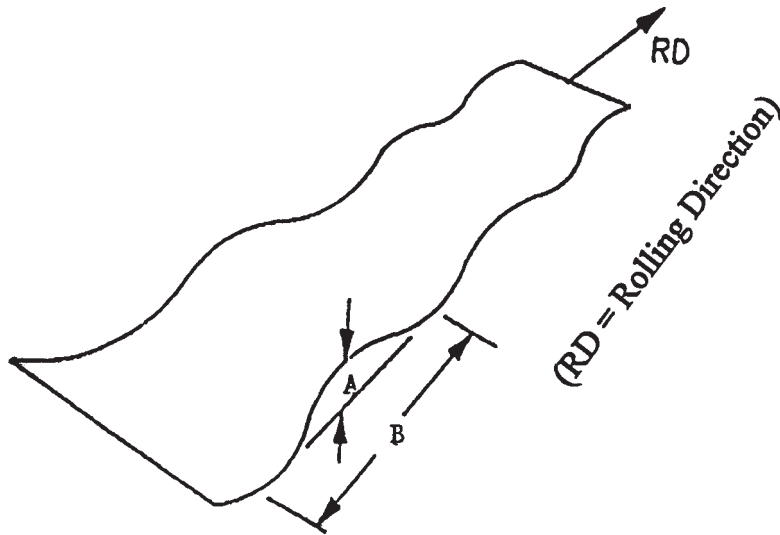


FIG. 14 Lateral Weave



$F = \text{Flatness Index} =$

$$F = KS^2$$

$$F = 2.47 (A/B)^2$$

$$I \text{ Units} = 2.47 S^2 \times 10^6$$

$$\% \text{ Steepness} = A/B \times 100$$

The difference in length between perfect flatness and a sine wave.

$K =$  wave form constant which assumes sine wave shape

$$K = \pi^2/4 = 2.47$$

$S =$  Steepness

$$S = A/B$$

$A =$  wave height

$B =$  wave length

FIG. 15 I-U Calculation

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# Standard Practice for Structural Design of Reinforcements for Fittings in Factory-Made Corrugated Steel Pipe for Sewers and Other Applications<sup>1</sup>

This standard is issued under the fixed designation A 998/A 998M; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reappraisal. A superscript epsilon ( $\epsilon$ ) indicates an editorial change since the last revision or reappraisal.

## 1. Scope

1.1 This practice covers the structural design of reinforcement for fittings in factory-made, round corrugated steel pipe, conforming to Specifications A 760/A 760M or A 762/A 762M, for use as storm and sanitary sewers and other buried applications. This practice is for fittings on pipe installed in a trench or embankment and subjected to earth loads and live loads. It must be recognized that a buried corrugated pipe is a composite structure made up of the steel ring and the soil envelope, and both elements play a vital part. Both main and branch pipe shall be designed in accordance with Practice A 796/A 796M and installed in accordance with Practice A 798/A 798M.

1.2 This practice covers the structural design of reinforcement for fittings such as those for branch pipes. Refer to Section 5 for design limitations.

1.3 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

1.4 The values stated in either inch-pound units or SI units shall be regarded separately as standard. The values stated in each system are not exact equivalents; therefore, each system must be used independently of the other, without combining values in any way. SI units are shown in brackets in the text for clarity, but they are the applicable values when the design is to be performed using SI units.

## 2. Referenced Documents

### 2.1 ASTM Standards:

A 36/A 36M Specification for Carbon Structural Steel<sup>2</sup>

A 153 Specification for Zinc Coating (Hot-Dip) on Iron and Steel Hardware<sup>3</sup>

A 307 Specification for Carbon Steel Bolts and Studs, 60 000 psi Tensile Strength<sup>4</sup>

A 760/A 760M Specification for Corrugated Steel Pipe, Metallic-Coated for Sewers and Drains<sup>3</sup>

A 762/A 762M Specification for Corrugated Steel Pipe, Polymer Precoated for Sewers and Drains<sup>3</sup>

A 796/A 796M Practice for the Structural Design of Corrugated Steel Pipe, Pipe-Arches, and Arches for Storm and Sanitary Sewers and Other Buried Applications<sup>3</sup>

A 798/A 798M Practice for Installing Factory-Made Corrugated Steel Pipe for Sewers and Other Applications<sup>3</sup>

A 902 Terminology Related to Metallic Coated Steel Products<sup>3</sup>

A 929/A 929M Specification for Steel Sheet, Metallic-Coated by the Hot-Dip Process for Corrugated Steel Pipe<sup>3</sup>

F 568M Specification for Carbon and Alloy Steel Externally Threaded Metric Fasteners<sup>3</sup>

### 2.2 AASHTO Standard:

Standard Specifications for Highway Bridges<sup>5</sup>

### 2.3 Society of Automotive Engineers:

J978, Steel Self-Drilling Tapping Screws<sup>6</sup>

## 3. Terminology

3.1 For definitions of general terms used in this standard, refer to Terminology A 902.

### 3.2 Definitions of Terms Specific to This Standard:

3.2.1 *branch pipe*—corrugated pipe with a diameter smaller than or equal to that of the main pipe, carrying a portion of the flow and connected to the main pipe through a fitting welded in place.

3.2.2 *fittings*—sections of main pipe fabricated to accommodate branch pipes or manhole pipes.

3.2.3 *main pipe*—corrugated pipe carrying the primary flow.

3.2.4 *reinforcement*—sheets, bars, or structural members connected to the main pipe to strengthen a fitting.

<sup>1</sup> This practice is under the jurisdiction of ASTM Committee A-5 on Metallic Coated Iron and Steel Products and is the direct responsibility of Subcommittee A05.17 on Corrugated Steel Pipe Specifications.

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<sup>2</sup> *Annual Book of ASTM Standards*, Vol. 01.04.

<sup>3</sup> *Annual Book of ASTM Standards*, Vol. 01.06.

<sup>4</sup> *Annual Book of ASTM Standards*, Vol. 15.08.

<sup>5</sup> Available from American Association of State Highway and Transportation Officials, 444 North Capitol St., N.W., Suite 225, Washington DC, 20001.

<sup>6</sup> Available from Society of Automotive Engineers, 600 Commonwealth Dr., Warrendale, PA.

**4. Symbols**

4.1 The symbols used in this practice have the following significance:

- $a$  = distance of saddle plate extension onto main pipe, in. [mm].
- $A_{li}$  = incremental required min cross section area of each longitudinal reinforcement, in<sup>2</sup>/ft [mm<sup>2</sup>/m].
- $A_{rc}$  = required minimum cross section area of each circumferential reinforcement, in<sup>2</sup> [mm<sup>2</sup>].
- $A_{rcs}$  = cross section area of circumferential reinforcement actually selected, in<sup>2</sup> [mm<sup>2</sup>].
- $A_{rl}$  = required min cross section area of each longitudinal reinforcement, in<sup>2</sup> [mm<sup>2</sup>].
- $A_{rls}$  = cross section area of longitudinal reinforcement actually selected, in<sup>2</sup> [mm<sup>2</sup>].
- $d$  = branch diameter, in. [mm].
- $d_b$  = nominal bolt diameter, in. [mm].
- $d_e$  = effective branch diameter, in. [mm].
- $d_m$  = maximum branch pipe diameter for which no circumferential reinforcement is required in. [mm].
- $d_s$  = nominal screw diameter, in. [mm].
- $D$  = main pipe diameter, in. [mm].
- $H$  = depth of fill above top of pipe, ft [m].
- $H_e$  = equivalent depth of fill, ft [m].
- $H_{nr}$  = fill height for which no longitudinal reinforcement is required, ft [m].
- $L$  = total length of each longitudinal reinforcement, in. [mm].
- $L_w$  = length of weld, in. [mm].
- $LL$  = live load pressure (see Practice A 796/A 796M), lbf/ft<sup>2</sup> [kPa].
- $N_c$  = minimum total number of fasteners required to attach each circumferential reinforcement.
- $N_l$  = minimum total number of fasteners required to attach each longitudinal reinforcement.
- $q$  = allowable load for each fastener, lbf [N].
- $t_{np}$  = bare steel thickness of pipe, in. [mm].
- $t_{nr}$  = bare steel thickness of reinforcement in contact with pipe, in. [mm].
- $t_x$  = bare steel thickness of pipe or reinforcement, whichever is less, in. [mm].
- $w$  = unit force derived from 1 ft<sup>3</sup> [1 m<sup>3</sup>] of fill material above the pipe, lbf/ft<sup>3</sup> [kN/m<sup>3</sup>]. When actual fill material is not known use 120 lbf/ft<sup>3</sup> [19 kN/m<sup>3</sup>].
- $\alpha$  = acute angle between main and branch pipe, degrees.

**5. Basis of Design**

5.1 Reinforcement requirements depend upon pipe diameter, pipe wall profile, pipe wall thickness, density of fill material, height of cover, and live load. Main pipes with intersecting branch pipes shall be investigated in accordance with Section 6 to determine whether reinforcement is required. If reinforcement is required, it shall be designed in accordance with the provisions of Sections 9 and 10, unless one of the alternatives specified in Section 7 is met. Fittings in main pipes with a diameter less than 48 in. [1200 mm], subject to the limitations of 5.2-5.6, do not require reinforcement.

5.2 This practice does not apply to cases where there are two branch pipes on opposite sides of the main pipe, each with a diameter greater than 0.75D, unless the longitudinal distance between the centerlines of the branches measured along the main pipe is greater than D.

5.3 This practice is limited to pipe with a live load that can be described and quantified such as AASHTO H20 or HS20 and AREA E80.

5.4 Reinforcement design shall be based on an equivalent depth of fill ( $H_e$ ) that accounts for both earth load and live load (LL) as follows:

$$H_e = \frac{LL + wH}{120} \left[ H_e = \frac{LL + wH}{19} \right] \quad (1)$$

This practice is limited to pipe with  $H_e \leq 30$  ft [9 m].

5.5 Reinforcement design shall be based on an effective branch diameter ( $d_e$ ) determined for the branch angle ( $\alpha$ ) as follows:

$$d_e = \frac{d}{\sin \alpha} \quad (2)$$

Calculated values of  $d_e$  shall be rounded up to the next 6 in. [150 mm] increment for design calculations. The value of  $d_e$  must not exceed 1.16D.

5.6 This practice is further limited to  $\alpha$  from 30 to 90°, inclusive.

5.7 This practice applies where the branch pipe is welded to the main pipe and has a specified thickness based on the requirements of A 796/A 796M.

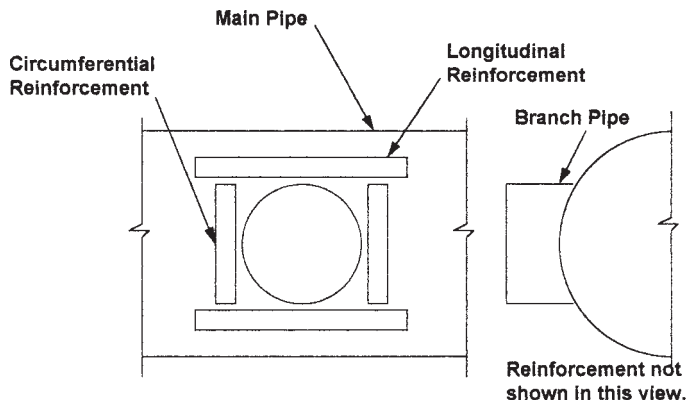
5.8 This practice does not include the possible effects of dragdown loads on vertical risers (manholes) such as caused by settlement of deep fills.

**6. Need for Reinforcement**

6.1 The need for both longitudinal and circumferential reinforcement as illustrated in Fig. 1 shall be considered.

6.2 Longitudinal reinforcement needs shall be determined from Tables 1-48 as applicable for the main pipe diameter and wall profile under consideration.<sup>7</sup> These tables list, for indicated branch pipe diameters, values of fill height,  $H_{nr}$ , for

<sup>7</sup> The diameter-thickness combinations listed in the tables do not necessarily meet the requirements of A 796.



**FIG. 1 Schematic of Reinforcements**





**TABLE 1 Requirements for Longitudinal Reinforcement of Fittings in 48 in. Diameter Main Pipe with 2-2/3 by 1/2 in. Corrugations<sup>A</sup>**

Equivalent Fill Depth for Which No Longitudinal Reinforcement is Required, $H_{nlr}$ and Incremental Longitudinal Reinforcement Area, $A_{lj}$										
Branch Dia., in	0.064 in. Thick Main Pipe		0.079 in. Thick Main Pipe		0.109 in. Thick Main Pipe		0.138 in. Thick Main Pipe		0.168 in. Thick Main Pipe	
	$H_{nlr}$ ft	$A_{lj}$ in. <sup>2</sup> /ft	$H_{nlr}$ ft	$A_{lj}$ in. <sup>2</sup> /ft	$H_{nlr}$ ft	$A_{lj}$ in. <sup>2</sup> /ft	$H_{nlr}$ ft	$A_{lj}$ in. <sup>2</sup> /ft	$H_{nlr}$ ft	$A_{lj}$ in. <sup>2</sup> /ft
24	37.4	0.05	48.2	0.04	69.1	0.04				
30	27.5	0.07	36.3	0.06	53.2	0.05				
36	22.2	0.10	29.6	0.09	39.2	0.07	50.0	0.06		
42	17.9	0.13	21.6	0.11	28.9	0.09	37.0	0.07	45.0	0.06
48	13.8	0.18	16.6	0.15	22.0	0.12	28.0	0.09	34.0	0.07

<sup>A</sup>Branch pipe of any profile with specified thickness as required by A 796/A 796M.

**TABLE 2 Requirements for Longitudinal Reinforcement of Fittings in 1200 mm Diameter Main Pipe with 68 by 13 mm Corrugations<sup>A</sup>**

Equivalent Fill Depth for Which No Longitudinal Reinforcement is Required, $H_{nlr}$ and Incremental Longitudinal Reinforcement Area, $A_{lj}$										
Branch Dia., mm	1.63 mm Thick Main Pipe		2.01 mm Thick Main Pipe		2.77 mm Thick Main Pipe		3.51 mm Thick Main Pipe		4.27 mm Thick Main Pipe	
	$H_{nlr}$ m	$A_{lj}$ mm <sup>2</sup> /m	$H_{nlr}$ m	$A_{lj}$ mm <sup>2</sup> /m	$H_{nlr}$ m	$A_{lj}$ mm <sup>2</sup> /m	$H_{nlr}$ m	$A_{lj}$ mm <sup>2</sup> /m	$H_{nlr}$ m	$A_{lj}$ mm <sup>2</sup> /m
600	11.4	106.	14.7	85.	21.1	85.				
750	8.4	148.	11.1	127.	16.2	106.				
900	6.8	212.	9.0	191.	11.9	148.	15.2	127.	18.6	106.
1050	5.5	275.	6.6	233.	8.8	191.	11.3	148.	13.7	127.
1200	4.2	381.	5.1	318.	6.7	254.	8.5	191.	10.4	148.

<sup>A</sup>Branch pipe of any profile with specified thickness as required by A 796/A 796M.

**TABLE 3 Requirements for Longitudinal Reinforcement of Fittings in 60 in. Diameter Main Pipe with 2-2/3 by 1/2 in. Corrugations<sup>A</sup>**

Equivalent Fill Depth for Which No Longitudinal Reinforcement is Required, $H_{nlr}$ and Incremental Longitudinal Reinforcement Area, $A_{lj}$										
Branch Dia., in	0.064 in. Thick Main Pipe		0.079 in. Thick Main Pipe		0.109 in. Thick Main Pipe		0.138 in. Thick Main Pipe		0.168 in. Thick Main Pipe	
	$H_{nlr}$ ft	$A_{lj}$ in. <sup>2</sup> /ft	$H_{nlr}$ ft	$A_{lj}$ in. <sup>2</sup> /ft	$H_{nlr}$ ft	$A_{lj}$ in. <sup>2</sup> /ft	$H_{nlr}$ ft	$A_{lj}$ in. <sup>2</sup> /ft	$H_{nlr}$ ft	$A_{lj}$ in. <sup>2</sup> /ft
24	29.9	0.06	38.6	0.05	55.3	0.04				
30	22.0	0.09	29.0	0.08	42.6	0.06				
36	17.7	0.12	23.6	0.10	31.4	0.09	40.0	0.08		
42	14.3	0.16	17.3	0.14	23.1	0.11	29.0	0.09	35.0	0.07
48	11.0	0.21	13.3	0.18	17.6	0.14	22.0	0.10	27.0	0.08
54	8.7	0.27	10.5	0.22	14.0	0.17	18.0	0.12	22.0	0.10
60	7.0	0.33	8.5	0.28	11.3	0.21	14.0	0.15	17.0	0.12

<sup>A</sup>Branch pipe of any profile with specified thickness as required by A 796/A 796M.

which no longitudinal reinforcement is required. If  $H_e \leq H_{nlr}$ , no longitudinal reinforcement is required; otherwise, longitudinal reinforcement shall be designed in accordance with Section 9. For main pipe diameters not included in Tables 1-48, interpolation shall be permitted. Fittings for branch pipes with a diameter less than shown in Tables 1-48, subject to the limitations of 5.2-5.6, do not require longitudinal reinforcement.

**TABLE 4 Requirements for Longitudinal Reinforcement of Fittings in 1500 mm Diameter Main Pipe with 68 by 13 mm Corrugations<sup>A</sup>**

Equivalent Fill Depth for Which No Longitudinal Reinforcement is Required, $H_{nlr}$ and Incremental Longitudinal Reinforcement Area, $A_{lj}$										
Branch Dia., mm	1.63 mm Thick Main Pipe		2.01 mm Thick Main Pipe		2.77 mm Thick Main Pipe		3.51 mm Thick Main Pipe		4.27 mm Thick Main Pipe	
	$H_{nlr}$ m	$A_{lj}$ mm <sup>2</sup> /m	$H_{nlr}$ m	$A_{lj}$ mm <sup>2</sup> /m	$H_{nlr}$ m	$A_{lj}$ mm <sup>2</sup> /m	$H_{nlr}$ m	$A_{lj}$ mm <sup>2</sup> /m	$H_{nlr}$ m	$A_{lj}$ mm <sup>2</sup> /m
600	9.1	127	11.8	106	16.9	85				
750	6.7	191	8.8	169	13.0	127				
900	5.4	254	7.2	212	9.6	191	12.2	169		
1050	4.4	339	5.3	296	7.0	233	8.8	191	10.7	148
1200	3.4	445	4.1	381	5.4	296	6.7	212	8.2	169
1350	2.7	572	3.2	466	4.3	360	5.5	254	6.7	212
1500	2.1	699	2.6	593	3.4	445	4.3	318	5.2	254

<sup>A</sup>Branch pipe of any profile with specified thickness as required by A 796/A 796M.

**TABLE 5 Requirements for Longitudinal Reinforcement of Fittings in 72 in. Diameter Main Pipe with 2-2/3 by 1/2 in. Corrugations<sup>A</sup>**

Equivalent Fill Depth for Which No Longitudinal Reinforcement is Required, $H_{nlr}$ and Incremental Longitudinal Reinforcement Area, $A_{lj}$										
Branch Dia., in	0.064 in. Thick Main Pipe		0.079 in. Thick Main Pipe		0.109 in. Thick Main Pipe		0.138 in. Thick Main Pipe		0.168 in. Thick Main Pipe	
	$H_{nlr}$ ft	$A_{lj}$ in. <sup>2</sup> /ft	$H_{nlr}$ ft	$A_{lj}$ in. <sup>2</sup> /ft	$H_{nlr}$ ft	$A_{lj}$ in. <sup>2</sup> /ft	$H_{nlr}$ ft	$A_{lj}$ in. <sup>2</sup> /ft	$H_{nlr}$ ft	$A_{lj}$ in. <sup>2</sup> /ft
24					46.1	0.05				
30					35.5	0.07				
36					26.1	0.10	33.0	0.08		
42					19.2	0.13	24.0	0.10	29.0	0.08
48					14.7	0.16	19.0	0.12	23.0	0.10
54					11.6	0.20	15.0	0.15	18.0	0.12
60					9.4	0.25	12.0	0.20	15.0	0.16
66					7.8	0.29	10.0	0.22	12.0	0.18
72					6.6	0.35	8.0	0.28	10.0	0.22

<sup>A</sup>Branch pipe of any profile with specified thickness as required by A 796/A 796M.

6.3 Circumferential reinforcement needs shall be determined from Tables 49-54 as applicable for the wall profile under consideration.<sup>7</sup> These tables list, for indicated main pipe diameters and wall thicknesses, the maximum branch pipe diameters,  $d_m$ , for which no circumferential reinforcement is required. If  $d_e \leq d_m$ , no circumferential reinforcement is required; otherwise, circumferential reinforcement shall be designed in accordance with Section 10. Branch diameters are listed for equivalent depths of fill ( $H_e$ ) of 10, 20, and 30 ft [3, 6, and 9 m]. Use the 10 ft [3 m] column for  $1 \leq H_e \leq 10$  ft [ $1 \leq H_e \leq 3$  m]. For other  $H_e$  not listed, interpolate between the values listed.

**7. Alternatives to Providing Reinforcement**

7.1 As an alternative to providing required longitudinal or circumferential reinforcement, or both, an increase in the thickness of the main pipe shall be permitted. The increased thickness must be such that the pipe does not require reinforcement when checked in accordance with 6.2, if longitudinal reinforcement is omitted, and 6.3, if circumferential reinforcement is omitted.

**TABLE 6 Requirements for Longitudinal Reinforcement of Fittings in 1800 mm Diameter Main Pipe with 68 by 13 mm Corrugations<sup>A</sup>**

Equivalent Fill Depth for Which No Longitudinal Reinforcement is Required, $H_{nlr}$ and Incremental Longitudinal Reinforcement Area, $A_{ij}$												
		1.63 mm Thick Main Pipe		2.01 mm Thick Main Pipe		2.77 mm Thick Main Pipe		3.51 mm Thick Main Pipe		4.27 mm Thick Main Pipe		
Branch Dia., mm	$H_{nlr}$ m	$A_{ij}$ mm <sup>2</sup> /m	$H_{nlr}$ m	$A_{ij}$ mm <sup>2</sup> /m	$H_{nlr}$ m	$A_{ij}$ mm <sup>2</sup> /m	$H_{nlr}$ m	$A_{ij}$ mm <sup>2</sup> /m	$H_{nlr}$ m	$A_{ij}$ mm <sup>2</sup> /m	$H_{nlr}$ m	$A_{ij}$ mm <sup>2</sup> /m
600					14.1	106						
750					10.8	148						
900					8.0	212	10.1	169				
1050					5.9	275	7.3	212	8.8	169		
1200					4.5	339	5.8	254	7.0	212		
1350					3.5	423	4.6	318	5.5	254		
1500					2.9	529	3.7	423	4.6	339		
1650					2.4	614	3.0	466	3.7	381		
1800					2.0	741	2.4	593	3.0	466		

<sup>A</sup>Branch pipe of any profile with specified thickness as required by A 796/A 796M.

**TABLE 7 Requirements for Longitudinal Reinforcement of Fittings in 84 in. Diameter Main Pipe with 2-2/3 by 1/2 in. Corrugations<sup>A</sup>**

Equivalent Fill Depth for Which No Longitudinal Reinforcement is Required, $H_{nlr}$ and Incremental Longitudinal Reinforcement Area, $A_{ij}$												
		0.064 in. Thick Main Pipe		0.079 in. Thick Main Pipe		0.109 in. Thick Main Pipe		0.138 in. Thick Main Pipe		0.168 in. Thick Main Pipe		
Branch Dia., in.	$H_{nlr}$ ft	$A_{ij}$ in. <sup>2</sup> /ft	$H_{nlr}$ ft	$A_{ij}$ in. <sup>2</sup> /ft	$H_{nlr}$ ft	$A_{ij}$ in. <sup>2</sup> /ft	$H_{nlr}$ ft	$A_{ij}$ in. <sup>2</sup> /ft	$H_{nlr}$ ft	$A_{ij}$ in. <sup>2</sup> /ft	$H_{nlr}$ ft	$A_{ij}$ in. <sup>2</sup> /ft
24					39.5	0.06						
30					30.4	0.09						
36					22.4	0.12	27.6	0.10				
42					16.5	0.15	20.3	0.13	25.0	0.10		
48					12.6	0.19	15.5	0.16	19.0	0.13		
54					10.0	0.23	12.3	0.20	15.0	0.16		
60					8.1	0.28	10.0	0.24	12.0	0.19		
66					6.6	0.33	8.2	0.28	10.0	0.22		
72					5.6	0.39	6.9	0.33	8.0	0.26		
78					4.8	0.46	5.9	0.38	7.0	0.30		
84					4.1	0.54	5.1	0.44	6.0	0.35		

<sup>A</sup>Branch pipe of any profile with specified thickness as required by A 796/A 796M.

7.2 As a second alternative to providing required longitudinal or circumferential reinforcement, or both, it is permissible to provide a saddle plate as illustrated in Fig. 2 with a thickness selected from Tables 55 and 56. Saddle plates that act as reinforcement must be of the same material and wall profile as the main pipe and must extend onto the main pipe on all sides from the branch pipe a distance,  $a$ , of  $d_c/4$  or 6 in. [150 mm], whichever is greater. The saddle plate must be continuously welded to a stub length of the branch pipe. The stub must have a full uncut section at least 12 in. [300 mm] long. The saddle plate must be connected to the main pipe with sufficient

**TABLE 8 Requirements for Longitudinal Reinforcement of Fittings in 2100 mm Diameter Main Pipe with 68 by 13 mm Corrugations<sup>A</sup>**

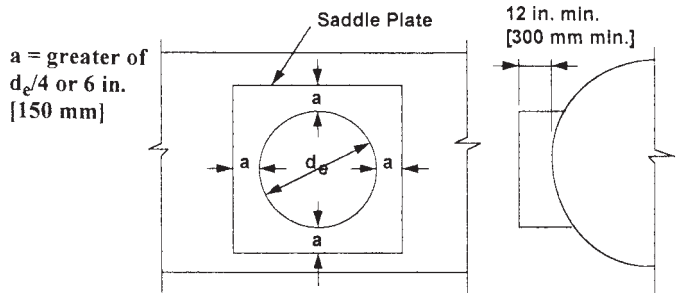
Equivalent Fill Depth for Which No Longitudinal Reinforcement is Required, $H_{nlr}$ and Incremental Longitudinal Reinforcement Area, $A_{ij}$												
		1.63 mm Thick Main Pipe		2.01 mm Thick Main Pipe		2.77 mm Thick Main Pipe		3.51 mm Thick Main Pipe		4.27 mm Thick Main Pipe		
Branch Dia., mm	$H_{nlr}$ m	$A_{ij}$ mm <sup>2</sup> /m	$H_{nlr}$ m	$A_{ij}$ mm <sup>2</sup> /m	$H_{nlr}$ m	$A_{ij}$ mm <sup>2</sup> /m	$H_{nlr}$ m	$A_{ij}$ mm <sup>2</sup> /m	$H_{nlr}$ m	$A_{ij}$ mm <sup>2</sup> /m	$H_{nlr}$ m	$A_{ij}$ mm <sup>2</sup> /m
600							12.0	127				
750							9.3	191				
900							6.8	254	8.4	212		
1050							5.0	318	6.2	275	7.6	212
1200							3.8	402	4.7	339	5.8	275
1350							3.0	487	3.7	423	4.6	339
1500							2.5	593	3.0	508	3.7	402
1650							2.0	699	2.5	593	3.0	466
1800							1.7	826	2.1	699	2.4	550
1950							1.5	974	1.8	804	2.1	635
2100							1.2	1143	1.6	931	1.8	741

<sup>A</sup>Branch pipe of any profile with specified thickness as required by A 796/A 796M.

**TABLE 9 Requirements for Longitudinal Reinforcement of Fittings in 60 in. Diameter Main Pipe with 3 by 1 in. or 5 by 1 in. Corrugations<sup>A</sup>**

Equivalent Fill Depth for Which No Longitudinal Reinforcement is Required, $H_{nlr}$ and Incremental Longitudinal Reinforcement Area, $A_{ij}$												
		0.064 in. Thick Main Pipe		0.079 in. Thick Main Pipe		0.109 in. Thick Main Pipe		0.138 in. Thick Main Pipe		0.168 in. Thick Main Pipe		
Branch Dia., in.	$H_{nlr}$ ft	$A_{ij}$ in. <sup>2</sup> /ft	$H_{nlr}$ ft	$A_{ij}$ in. <sup>2</sup> /ft	$H_{nlr}$ ft	$A_{ij}$ in. <sup>2</sup> /ft	$H_{nlr}$ ft	$A_{ij}$ in. <sup>2</sup> /ft	$H_{nlr}$ ft	$A_{ij}$ in. <sup>2</sup> /ft	$H_{nlr}$ ft	$A_{ij}$ in. <sup>2</sup> /ft
24	25.9	0.06	32.6	0.05	45.3	0.04						
30	18.0	0.09	23.0	0.08	32.6	0.06						
36	13.7	0.12	17.8	0.10	25.7	0.09	33.0	0.08				
42	11.2	0.16	14.7	0.14	21.5	0.11	27.0	0.09	33.0	0.07		
48	9.5	0.21	12.6	0.18	17.6	0.14	22.0	0.10	27.0	0.08		
54	8.7	0.27	10.5	0.22	14.0	0.17	18.0	0.12	18.0	0.10		
60	7.0	0.33	8.5	0.28	11.3	0.21	14.0	0.15	14.0	0.12		

<sup>A</sup>Branch pipe of any profile with specified thickness as required by A 796/A 796M.



**FIG. 2 Schematic of Saddle Plate**

fasteners (welds, bolts, or screws) so that there are no large gaps and so that it will act together with the main pipe.

**TABLE 10 Requirements for Longitudinal Reinforcement of Fittings in 1500 mm Diameter Main Pipe with 75 by 25 mm or 125 by 25 mm Corrugations<sup>A</sup>**

Equivalent Fill Depth for Which No Longitudinal Reinforcement is Required, $H_{nlr}$ and Incremental Longitudinal Reinforcement Area, $A_{lj}$										
Branch Dia., mm	1.63 mm Thick Main Pipe		2.01 mm Thick Main Pipe		2.77 mm Thick Main Pipe		3.51 mm Thick Main Pipe		4.27 mm Thick Main Pipe	
	$H_{nlr}$ m	$A_{lj}$ mm <sup>2</sup> /m	$H_{nlr}$ m	$A_{lj}$ mm <sup>2</sup> /m	$H_{nlr}$ m	$A_{lj}$ mm <sup>2</sup> /m	$H_{nlr}$ m	$A_{lj}$ mm <sup>2</sup> /m	$H_{nlr}$ m	$A_{lj}$ mm <sup>2</sup> /m
600	7.9	127	9.9	106	13.8	85				
750	5.5	191	7.0	169	9.9	127				
900	4.2	254	5.4	212	7.8	191	10.1	169		
1050	3.4	339	4.5	296	6.6	233	8.2	191	10.1	148
1200	2.9	445	3.8	381	5.4	296	6.7	212	8.2	169
1350	2.7	572	3.2	466	4.3	360	5.5	254	5.5	212
1500	2.1	699	2.6	593	3.4	445	4.3	318	4.3	254

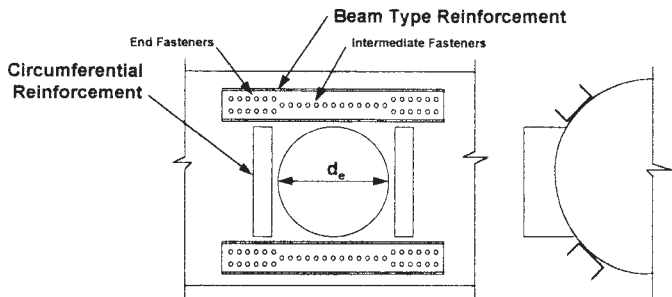
<sup>A</sup>Branch pipe of any profile with specified thickness as required by A 796/A 796M.

**TABLE 11 Requirements for Longitudinal Reinforcement of Fittings in 72 in. Diameter Main Pipe with 3 by 1 in. or 5 by 1 in. Corrugations<sup>A</sup>**

Equivalent Fill Depth for Which No Longitudinal Reinforcement is Required, $H_{nlr}$ and Incremental Longitudinal Reinforcement Area, $A_{lj}$										
Branch Dia., in.	0.064 in. Thick Main Pipe		0.079 in. Thick Main Pipe		0.109 in. Thick Main Pipe		0.138 in. Thick Main Pipe		0.168 in. Thick Main Pipe	
	$H_{nlr}$ ft	$A_{lj}$ in. <sup>2</sup> /ft	$H_{nlr}$ ft	$A_{lj}$ in. <sup>2</sup> /ft	$H_{nlr}$ ft	$A_{lj}$ in. <sup>2</sup> /ft	$H_{nlr}$ ft	$A_{lj}$ in. <sup>2</sup> /ft	$H_{nlr}$ ft	$A_{lj}$ in. <sup>2</sup> /ft
24	21.6	0.07	27.1	0.06	37.7	0.05				
30	15.0	0.10	19.2	0.09	27.2	0.07				
36	11.5	0.14	14.8	0.12	21.4	0.10	27.0	0.08		
42	9.3	0.18	12.2	0.16	17.9	0.13	23.0	0.10	28.0	0.08
48	7.9	0.24	10.5	0.20	14.7	0.16	19.0	0.12	23.0	0.10
54	7.2	0.30	8.7	0.25	11.6	0.20	15.0	0.15	15.0	0.12
60	5.9	0.38	7.1	0.31	9.4	0.25	12.0	0.20	12.0	0.16
66	4.8	0.46	5.9	0.38	7.8	0.29	10.0	0.22	10.0	0.18
72	4.1	0.57	4.9	0.46	6.6	0.35	8.0	0.28	8.0	0.22

<sup>A</sup>Branch pipe of any profile with specified thickness as required by A 796/A 796M.

7.3 As an alternative to providing required longitudinal reinforcement, it is permissible to provide a beam type reinforcement as illustrated in Fig. 3, designed using recognized engineering principles.



**FIG. 3 Schematic of Beam Type Reinforcement**

forcement as illustrated in Fig. 3, designed using recognized engineering principles.

**8. Materials**

8.1 Any reinforcement required shall be a continuous sheet, bar, or structural member. Sheets for longitudinal reinforcement shall be flat sheets, but either flat sheets or circumferentially corrugated sheets are permitted for circumferential reinforcement.

**TABLE 12 Requirements for Longitudinal Reinforcement of Fittings in 1800 mm Diameter Main Pipe with 75 by 25 mm or 125 by 25 mm Corrugations<sup>A</sup>**

Equivalent Fill Depth for Which No Longitudinal Reinforcement is Required, $H_{nlr}$ and Incremental Longitudinal Reinforcement Area, $A_{lj}$										
Branch Dia., mm	1.63 mm Thick Main Pipe		2.01 mm Thick Main Pipe		2.77 mm Thick Main Pipe		3.51 mm Thick Main Pipe		4.27 mm Thick Main Pipe	
	$H_{nlr}$ m	$A_{lj}$ mm <sup>2</sup> /m	$H_{nlr}$ m	$A_{lj}$ mm <sup>2</sup> /m	$H_{nlr}$ m	$A_{lj}$ mm <sup>2</sup> /m	$H_{nlr}$ m	$A_{lj}$ mm <sup>2</sup> /m	$H_{nlr}$ m	$A_{lj}$ mm <sup>2</sup> /m
600	6.6	148	8.3	127	11.5	106				
750	4.6	212	5.9	191	8.3	148				
900	3.5	296	4.5	254	6.5	212	8.2	169		
1050	2.8	381	3.7	339	5.5	275	7.0	212	8.5	169
1200	2.4	508	3.2	423	4.5	339	5.8	254	7.0	212
1350	2.2	635	2.7	529	3.5	423	4.6	318	4.6	254
1500	1.8	804	2.2	656	2.9	529	3.7	423	3.7	339
1650	1.5	974	1.8	804	2.4	614	3.0	466	3.0	381
1800	1.2	1207	1.5	974	2.0	741	2.4	593	2.4	466

<sup>A</sup>Branch pipe of any profile with specified thickness as required by A 796/A 796M.

**TABLE 13 Requirements for Longitudinal Reinforcement of Fittings in 84 in. Diameter Main Pipe with 3 by 1 in. or 5 by 1 in. Corrugations<sup>A</sup>**

Equivalent Fill Depth for Which No Longitudinal Reinforcement is Required, $H_{nlr}$ and Incremental Longitudinal Reinforcement Area, $A_{lj}$										
Branch Dia., in.	0.064 in. Thick Main Pipe		0.079 in. Thick Main Pipe		0.109 in. Thick Main Pipe		0.138 in. Thick Main Pipe		0.168 in. Thick Main Pipe	
	$H_{nlr}$ ft	$A_{lj}$ in. <sup>2</sup> /ft	$H_{nlr}$ ft	$A_{lj}$ in. <sup>2</sup> /ft	$H_{nlr}$ ft	$A_{lj}$ in. <sup>2</sup> /ft	$H_{nlr}$ ft	$A_{lj}$ in. <sup>2</sup> /ft	$H_{nlr}$ ft	$A_{lj}$ in. <sup>2</sup> /ft
24	18.5	0.08	23.3	0.07	32.3	0.06				
30	12.9	0.11	16.4	0.10	23.3	0.09				
36	9.8	0.15	12.7	0.14	18.3	0.12	25.2	0.10		
42	8.0	0.21	10.5	0.18	15.4	0.15	20.3	0.13	25.0	0.10
48	6.8	0.27	9.0	0.23	12.6	0.19	15.5	0.16	19.0	0.13
54	6.2	0.34	7.5	0.29	10.0	0.23	12.3	0.20	15.0	0.16
60	5.0	0.42	6.1	0.35	8.1	0.28	10.0	0.24	12.0	0.19
66	4.1	0.51	5.0	0.43	6.6	0.33	8.2	0.28	10.0	0.22
72	3.5	0.62	4.2	0.51	5.6	0.39	6.9	0.33	8.0	0.26
78	2.9	0.75	3.6	0.61	4.8	0.46	5.9	0.38	7.0	0.30
84	2.5	0.89	3.1	0.72	4.1	0.54	5.1	0.44	6.0	0.35

<sup>A</sup>Branch pipe of any profile with specified thickness as required by A 796/A 796M.

forcement. Sheets for reinforcement shall meet the requirements of A 929/A 929M, having the same metallic coating as the pipe to which the reinforcement is attached. Structural members or bars for reinforcement shall meet the requirements of Specification A 36/A 36M. Reinforcement shall have suitable corrosion protection.

8.2 Mechanical fasteners used to attach reinforcement shall be galvanized in accordance with Specification A 153.

8.3 Welds used to attach reinforcement shall be cleaned and painted or otherwise protected to provide suitable durability.

**9. Design of Longitudinal Reinforcement**

9.1 Longitudinal reinforcement shall be aligned with the longitudinal axis of the main pipe. It shall be attached to the main pipe above and below the branch pipe, and in close proximity thereto. It may be located either inside or outside of the pipe. Each reinforcement shall have the minimum length specified in 9.2 and the minimum cross section area specified

**TABLE 14 Requirements for Longitudinal Reinforcement of Fittings in 2100 mm Diameter Main Pipe with 75 by 25 mm or 125 by 2 mm Corrugations<sup>A</sup>**

Equivalent Fill Depth for Which No Longitudinal Reinforcement is Required, $H_{nlr}$ and Incremental Longitudinal Reinforcement Area, $A_{ji}$										
Branch Dia., mm	1.63 mm Thick Main Pipe		2.01 mm Thick Main Pipe		2.77 mm Thick Main Pipe		3.51 mm Thick Main Pipe		4.27 mm Thick Main Pipe	
	$H_{nlr}$ m	$A_{ji}$ mm <sup>2</sup> /m	$H_{nlr}$ m	$A_{ji}$ mm <sup>2</sup> /m	$H_{nlr}$ m	$A_{ji}$ mm <sup>2</sup> /m	$H_{nlr}$ m	$A_{ji}$ mm <sup>2</sup> /m	$H_{nlr}$ m	$A_{ji}$ mm <sup>2</sup> /m
600	5.6	169	7.1	148	9.8	127				
750	3.9	233	5.0	212	7.1	191				
900	3.0	318	3.9	296	5.6	254	7.7	212		
1050	2.4	445	3.2	381	4.7	318	6.2	275	7.6	212
1200	2.1	572	2.7	487	3.8	402	4.7	339	5.8	275
1350	1.9	720	2.3	614	3.0	487	3.7	423	4.6	339
1500	1.5	889	1.9	741	2.5	593	3.0	508	3.7	402
1650	1.2	1080	1.5	910	2.0	699	2.5	593	3.0	466
1800	1.1	1313	1.3	1080	1.7	826	2.1	699	2.4	550
1950	0.9	1588	1.1	1291	1.5	974	1.8	804	2.1	635
2100	0.8	1884	0.9	1524	1.2	1143	1.6	931	1.8	741

<sup>A</sup>Branch pipe of any profile with specified thickness as required by A 796/A 796M.

**TABLE 15 Requirements for Longitudinal Reinforcement of Fittings in 96 in. Diameter Main Pipe with 3 by 1 in. or 5 by 1 in. Corrugations<sup>A</sup>**

Equivalent Fill Depth for Which No Longitudinal Reinforcement is Required, $H_{nlr}$ and Incremental Longitudinal Reinforcement Area, $A_{ji}$										
Branch Dia., in.	0.064 in. Thick Main Pipe		0.079 in. Thick Main Pipe		0.109 in. Thick Main Pipe		0.138 in. Thick Main Pipe		0.168 in. Thick Main Pipe	
	$H_{nlr}$ ft	$A_{ji}$ in. <sup>2</sup> /ft	$H_{nlr}$ ft	$A_{ji}$ in. <sup>2</sup> /ft	$H_{nlr}$ ft	$A_{ji}$ in. <sup>2</sup> /ft	$H_{nlr}$ ft	$A_{ji}$ in. <sup>2</sup> /ft	$H_{nlr}$ ft	$A_{ji}$ in. <sup>2</sup> /ft
24	16.2	0.08	20.4	0.07	28.3	0.06				
30	11.3	0.12	14.4	0.11	20.4	0.10				
36	8.6	0.17	11.1	0.15	16.1	0.13	22.1	0.11		
42	7.0	0.23	9.2	0.20	13.5	0.17	17.8	0.15	22.0	0.12
48	5.9	0.30	7.9	0.26	11.0	0.21	13.6	0.19	16.0	0.15
54	5.4	0.37	6.6	0.32	8.7	0.26	10.7	0.22	13.0	0.18
60	4.4	0.46	5.3	0.39	7.1	0.31	8.7	0.27	10.0	0.22
66	3.6	0.56	4.4	0.47	5.8	0.37	7.2	0.31	9.0	0.25
72	3.0	0.68	3.7	0.56	4.9	0.44	6.0	0.37	7.0	0.30
78	2.6	0.81	3.1	0.67	4.2	0.51	5.1	0.43	6.0	0.34
84	2.2	0.96	2.7	0.79	3.6	0.60	4.4	0.49	5.0	0.39
90	1.9	1.13	2.4	0.92	3.1	0.69	3.9	0.56	5.0	0.45
96	1.7	1.32	2.1	1.07	2.8	0.79	3.4	0.64	4.0	0.51

<sup>A</sup>Branch pipe of any profile with specified thickness as required by A 796/A 796M.

in 9.3. It shall be attached to the main pipe with fasteners (welds, bolts, or screws) as specified in 9.4.

9.2 The minimum total length ( $L$ ) of each longitudinal reinforcement shall be determined as follows:

$$L = 1.5d_e \quad \text{for } 1 < H_e \leq 10 \quad (3)$$

$$[L = 1.5d_e \quad \text{for } 1 < H_e \leq 3]$$

$$L = 1.5d_e + (H_e - 10)(d_e/20) \quad \text{for } 10 < H_e \leq 30 \quad (4)$$

$$[L = 1.5d_e + (H_e - 3)(d_e/6) \quad \text{for } 3 < H_e \leq 9]$$

9.3 The minimum cross section area ( $A_{rl}$ ) of each longitudinal reinforcement shall be determined as follows:

$$A_{rl} = A_{ji}(H_e - H_{nlr}) \quad (5)$$

where:  $A_{ji}$  is the incremental required minimum cross section area, and  $H_{nlr}$  is the fill height for which no longitudinal

**TABLE 16 Requirements for Longitudinal Reinforcement of Fittings in 2400 mm Diameter Main Pipe with 75 by 25 mm or 125 by 25 mm Corrugations<sup>A</sup>**

Equivalent Fill Depth for Which No Longitudinal Reinforcement is Required, $H_{nlr}$ and Incremental Longitudinal Reinforcement Area, $A_{ji}$										
Branch Dia., mm	1.63 mm Thick Main Pipe		2.01 mm Thick Main Pipe		2.77 mm Thick Main Pipe		3.51 mm Thick Main Pipe		4.27 mm Thick Main Pipe	
	$H_{nlr}$ m	$A_{ji}$ mm <sup>2</sup> /m	$H_{nlr}$ m	$A_{ji}$ mm <sup>2</sup> /m	$H_{nlr}$ m	$A_{ji}$ mm <sup>2</sup> /m	$H_{nlr}$ m	$A_{ji}$ mm <sup>2</sup> /m	$H_{nlr}$ m	$A_{ji}$ mm <sup>2</sup> /m
600	4.9	169	6.2	148	8.6	127				
750	3.4	254	4.4	233	6.2	212				
900	2.6	360	3.4	318	4.9	275	6.7	233		
1050	2.1	487	2.8	423	4.1	360	5.4	318	6.7	254
1200	1.8	635	2.4	550	3.4	445	4.1	402	4.9	318
1350	1.6	783	2.0	677	2.7	550	3.3	466	4.0	381
1500	1.3	974	1.6	826	2.2	656	2.7	572	3.0	466
1650	1.1	1186	1.3	995	1.8	783	2.2	656	2.7	529
1800	0.9	1440	1.1	1186	1.5	931	1.8	783	2.1	635
1950	0.8	1715	0.9	1418	1.3	1080	1.6	910	1.8	720
2100	0.7	2032	0.8	1672	1.1	1270	1.3	1037	1.5	826
2250	0.6	2392	0.7	1948	0.9	1461	1.2	1186	1.5	953
2400	0.5	2794	0.6	2265	0.9	1672	1.0	1355	1.2	1080

<sup>A</sup>Branch pipe of any profile with specified thickness as required by A 796/A 796M.

**TABLE 17 Requirements for Longitudinal Reinforcement of Fittings in 108 in. Diameter Main Pipe with 3 by 1 in. or 5 by 1 in. Corrugations<sup>A</sup>**

Equivalent Fill Depth for Which No Longitudinal Reinforcement is Required, $H_{nlr}$ and Incremental Longitudinal Reinforcement Area, $A_{ji}$										
Branch Dia., in.	0.064 in. Thick Main Pipe		0.079 in. Thick Main Pipe		0.109 in. Thick Main Pipe		0.138 in. Thick Main Pipe		0.168 in. Thick Main Pipe	
	$H_{nlr}$ ft	$A_{ji}$ in. <sup>2</sup> /ft	$H_{nlr}$ ft	$A_{ji}$ in. <sup>2</sup> /ft	$H_{nlr}$ ft	$A_{ji}$ in. <sup>2</sup> /ft	$H_{nlr}$ ft	$A_{ji}$ in. <sup>2</sup> /ft	$H_{nlr}$ ft	$A_{ji}$ in. <sup>2</sup> /ft
24	14.4	0.09	18.1	0.08	25.2	0.07				
30	10.0	0.13	12.8	0.12	18.1	0.10				
36	7.6	0.19	9.9	0.17	14.3	0.14	19.6	0.13		
42	6.2	0.25	8.2	0.22	12.0	0.18	15.8	0.16	19.0	0.13
48	5.3	0.32	7.0	0.28	9.8	0.23	12.1	0.20	15.0	0.16
54	4.8	0.41	5.8	0.35	7.8	0.29	9.6	0.25	12.0	0.20
60	3.9	0.50	4.7	0.43	6.3	0.34	7.8	0.30	9.0	0.24
66	3.2	0.61	3.9	0.51	5.2	0.41	6.4	0.35	8.0	0.28
72	2.7	0.73	3.3	0.61	4.4	0.48	5.4	0.41	7.0	0.33
78	2.3	0.87	2.8	0.72	3.7	0.56	4.6	0.47	6.0	0.38
84	2.0	1.03	2.4	0.85	3.2	0.65	4.0	0.54	5.0	0.43
90	1.7	1.21	2.1	0.99	2.8	0.75	3.5	0.62	4.0	0.50
96	1.5	1.41	1.9	1.15	2.5	0.86	3.0	0.70	4.0	0.56
102	1.4	1.62	1.6	1.32	2.2	0.98	2.7	0.79	3.0	0.64
108	1.2	1.87	1.5	1.51	1.9	1.11	2.4	0.89	3.0	0.72

<sup>A</sup>Branch pipe of any profile with specified thickness as required by A 796/A 796M.

reinforcement is required, both as listed in Tables 1-48, as applicable for the main pipe diameter, wall profile, and wall thickness under consideration.

9.4 Each longitudinal reinforcement shall be attached to the main pipe with a total number of fasteners ( $N_l$ ) not less than that determined as follows:

$$N_l = 50\,000A_{rls}/q \quad [N_l = 0.345A_{rls}/q] \quad (6)$$

where:  $A_{rls}$  is the cross section area of the longitudinal reinforcement actually selected and  $q$  is the allowable load for each fastener as provided in Section 12. The total area of bolt holes, screw holes, or slots for fillet welds on any cross section of the reinforcement shall not exceed 20 % of the cross section area of the reinforcement.



**TABLE 18 Requirements for Longitudinal Reinforcement of Fittings in 2700 mm Diameter Main Pipe with 75 by 25 mm or 125 by 25 mm Corrugations<sup>A</sup>**

Equivalent Fill Depth for Which No Longitudinal Reinforcement is Required, $H_{nlr}$ and Incremental Longitudinal Reinforcement Area, $A_{lj}$										
Branch Dia., mm	1.63 mm Thick Main Pipe		2.01 mm Thick Main Pipe		2.77 mm Thick Main Pipe		3.51 mm Thick Main Pipe		4.27 mm Thick Main Pipe	
	$H_{nlr}$ m	$A_{lj}$ mm <sup>2</sup> /m	$H_{nlr}$ m	$A_{lj}$ mm <sup>2</sup> /m	$H_{nlr}$ m	$A_{lj}$ mm <sup>2</sup> /m	$H_{nlr}$ m	$A_{lj}$ mm <sup>2</sup> /m	$H_{nlr}$ m	$A_{lj}$ mm <sup>2</sup> /m
600	4.4	191	5.5	169	7.7	148				
750	3.0	275	3.9	254	5.5	212				
900	2.3	402	3.0	360	4.4	296	6.0	275		
1050	1.9	529	2.5	466	3.7	381	4.8	339	5.8	275
1200	1.6	677	2.1	593	3.0	487	3.7	423	4.6	339
1350	1.5	868	1.8	741	2.4	614	2.9	529	3.7	423
1500	1.2	1059	1.4	910	1.9	720	2.4	635	2.7	508
1650	1.0	1291	1.2	1080	1.6	868	2.0	741	2.4	593
1800	0.8	1545	1.0	1291	1.3	1016	1.6	868	2.1	699
1950	0.7	1842	0.9	1524	1.1	1186	1.4	995	1.8	804
2100	0.6	2181	0.7	1799	1.0	1376	1.2	1143	1.5	910
2250	0.5	2562	0.6	2096	0.9	1588	1.1	1313	1.2	1059
2400	0.5	2985	0.6	2435	0.8	1821	0.9	1482	1.2	1186
2550	0.4	3430	0.5	2794	0.7	2075	0.8	1672	0.9	1355
2700	0.4	3959	0.5	3197	0.6	2350	0.7	1884	0.9	1524

<sup>A</sup>Branch pipe of any profile with specified thickness as required by A 796/ A 796M.

**TABLE 19 Requirements for Longitudinal Reinforcement of Fittings in 120 in. Diameter Main Pipe with 3 by 1 in. or 5 by 1 in. Corrugations<sup>A</sup>**

Equivalent Fill Depth for Which No Longitudinal Reinforcement is Required, $H_{nlr}$ and Incremental Longitudinal Reinforcement Area, $A_{lj}$										
Branch Dia., in.	0.064 in. Thick Main Pipe		0.079 in. Thick Main Pipe		0.109 in. Thick Main Pipe		0.138 in. Thick Main Pipe		0.168 in. Thick Main Pipe	
	$H_{nlr}$ ft	$A_{lj}$ in. <sup>2</sup> /ft	$H_{nlr}$ ft	$A_{lj}$ in. <sup>2</sup> /ft	$H_{nlr}$ ft	$A_{lj}$ in. <sup>2</sup> /ft	$H_{nlr}$ ft	$A_{lj}$ in. <sup>2</sup> /ft	$H_{nlr}$ ft	$A_{lj}$ in. <sup>2</sup> /ft
24	13.0	0.10	16.3	0.09	22.6	0.08				
30	9.0	0.14	11.5	0.13	16.3	0.11				
36	6.9	0.20	8.9	0.18	12.8	0.15	17.7	0.14		
42	5.6	0.27	7.3	0.24	10.8	0.20	14.2	0.18	16.8	0.16
48	4.7	0.34	6.3	0.30	8.8	0.25	10.9	0.22	12.8	0.20
54	4.3	0.43	5.2	0.38	7.0	0.31	8.6	0.27	10.1	0.24
60	3.5	0.54	4.3	0.46	5.6	0.38	7.0	0.33	8.2	0.29
66	2.9	0.65	3.5	0.56	4.7	0.44	5.7	0.38	6.8	0.34
72	2.4	0.78	3.0	0.66	3.9	0.52	4.8	0.44	5.7	0.39
78	2.1	0.93	2.5	0.78	3.3	0.61	4.1	0.51	4.9	0.45
84	1.8	1.10	2.2	0.91	2.9	0.70	3.6	0.59	4.2	0.51
90	1.6	1.29	1.9	1.06	2.5	0.81	3.1	0.67	3.6	0.58
96	1.4	1.49	1.7	1.22	2.2	0.92	2.7	0.76	3.2	0.66
102	1.2	1.72	1.5	1.40	2.0	1.05	2.4	0.86	2.9	0.74
108	1.1	1.98	1.3	1.60	1.8	1.19	2.2	0.96	2.5	0.82
114	1.0	2.26	1.2	1.82	1.6	1.34	1.9	1.08	2.3	0.92
120	0.9	2.56	1.1	2.06	1.4	1.50	1.8	1.21	2.1	1.02

<sup>A</sup>Branch pipe of any profile with specified thickness as required by A 796/ A 796M.

## 10. Design of Circumferential Reinforcement

10.1 Circumferential reinforcement shall be formed to the approximate radius of the main pipe. However, flat sheet type reinforcement can be hand formed as it is attached. Circumferential reinforcement shall be attached to the main pipe on both sides of the branch pipe, in close proximity thereto, and shall extend around the main pipe approximately the same distance as the opening cut for the branch pipe. It shall have sufficient length to essentially fill the distance between any longitudinal reinforcements present, but need not bear on such

**TABLE 20 Requirements for Longitudinal Reinforcement of Fittings in 3000 mm Diameter Main Pipe with 75 by 25 mm or 125 by 25 mm Corrugations<sup>A</sup>**

Equivalent Fill Depth for Which No Longitudinal Reinforcement is Required, $H_{nlr}$ and Incremental Longitudinal Reinforcement Area, $A_{lj}$										
Branch Dia., mm	1.63 mm Thick Main Pipe		2.01 mm Thick Main Pipe		2.77 mm Thick Main Pipe		3.51 mm Thick Main Pipe		4.27 mm Thick Main Pipe	
	$H_{nlr}$ m	$A_{lj}$ mm <sup>2</sup> /m	$H_{nlr}$ m	$A_{lj}$ mm <sup>2</sup> /m	$H_{nlr}$ m	$A_{lj}$ mm <sup>2</sup> /m	$H_{nlr}$ m	$A_{lj}$ mm <sup>2</sup> /m	$H_{nlr}$ m	$A_{lj}$ mm <sup>2</sup> /m
600	4.0	212	5.0	191	6.9	169				
750	2.7	296	3.5	275	5.0	233				
900	2.1	423	2.7	381	3.9	318	5.4	296		
1050	1.7	572	2.2	508	3.3	423	4.3	381	5.1	339
1200	1.4	720	1.9	635	2.7	529	3.3	466	3.9	423
1350	1.3	910	1.6	804	2.1	656	2.6	572	3.1	508
1500	1.1	1143	1.3	974	1.7	804	2.1	699	2.5	614
1650	0.9	1376	1.1	1186	1.4	931	1.7	804	2.1	720
1800	0.7	1651	0.9	1397	1.2	1101	1.5	931	1.7	826
1950	0.6	1969	0.8	1651	1.0	1291	1.2	1080	1.5	953
2100	0.5	2329	0.7	1926	0.9	1482	1.1	1249	1.3	1080
2250	0.5	2731	0.6	2244	0.8	1715	0.9	1418	1.1	1228
2400	0.4	3154	0.5	2583	0.7	1948	0.8	1609	1.0	1397
2550	0.4	3641	0.5	2964	0.6	2223	0.7	1821	0.9	1567
2700	0.3	4192	0.4	3387	0.5	2519	0.7	2032	0.8	1736
2850	0.3	4784	0.4	3853	0.5	2837	0.6	2286	0.7	1948
3000	0.3	5420	0.3	4361	0.4	3176	0.5	2562	0.6	2159

<sup>A</sup>Branch pipe of any profile with specified thickness as required by A 796/ A 796M.

**TABLE 21 Requirements for Longitudinal Reinforcement of Fittings in 132 in. Diameter Main Pipe with 3 by 1 in. or 5 by 1 in. Corrugations<sup>A</sup>**

Equivalent Fill Depth for Which No Longitudinal Reinforcement is Required, $H_{nlr}$ and Incremental Longitudinal Reinforcement Area, $A_{lj}$										
Branch Dia., in.	0.064 in. Thick Main Pipe		0.079 in. Thick Main Pipe		0.109 in. Thick Main Pipe		0.138 in. Thick Main Pipe		0.168 in. Thick Main Pipe	
	$H_{nlr}$ ft	$A_{lj}$ in. <sup>2</sup> /ft	$H_{nlr}$ ft	$A_{lj}$ in. <sup>2</sup> /ft	$H_{nlr}$ ft	$A_{lj}$ in. <sup>2</sup> /ft	$H_{nlr}$ ft	$A_{lj}$ in. <sup>2</sup> /ft	$H_{nlr}$ ft	$A_{lj}$ in. <sup>2</sup> /ft
24			14.8	0.09	20.6	0.08				
30			10.4	0.14	14.8	0.12				
36			8.1	0.19	11.7	0.16	16.1	0.15		
42			6.7	0.25	9.8	0.21	13.7	0.19	15.3	0.17
48			5.7	0.32	8.0	0.27	9.9	0.24	11.7	0.22
54			4.8	0.40	6.3	0.33	7.8	0.29	9.2	0.26
60			3.9	0.49	5.1	0.40	6.3	0.35	7.5	0.31
66			3.2	0.60	4.2	0.48	5.2	0.42	6.2	0.37
72			2.7	0.71	3.6	0.56	4.4	0.48	5.2	0.43
78			2.3	0.83	3.0	0.65	3.7	0.55	4.4	0.49
84			2.0	0.97	2.6	0.75	3.2	0.63	3.8	0.56
90			1.7	1.13	2.3	0.86	2.8	0.72	3.3	0.63
96			1.5	1.30	2.0	0.98	2.5	0.82	2.9	0.71
102			1.3	1.49	1.8	1.12	2.2	0.92	2.6	0.79
108			1.2	1.70	1.6	1.26	2.0	1.03	2.3	0.89
114			1.1	1.92	1.4	1.42	1.7	1.16	2.1	0.99
120			1.0	2.17	1.3	1.59	1.6	1.29	1.9	1.09
126			0.9	2.44	1.2	1.78	1.4	1.43	1.7	1.21
132			0.8	2.73	1.1	1.98	1.3	1.58	1.5	1.33

<sup>A</sup>Branch pipe of any profile with specified thickness as required by A 796/ A 796M.

reinforcements. Circumferential reinforcement is preferably placed on the outside of the pipe. Each reinforcement shall have the minimum cross section area specified in 10.2. It shall be attached to the main pipe with fasteners (welds, bolts, or screws) as specified in 10.3.

10.2 The minimum cross section area ( $A_{rc}$ ) of each circumferential reinforcement shall be determined as follows:

**TABLE 22 Requirements for Longitudinal Reinforcement of Fittings in 3300 mm Diameter Main Pipe with 75 by 25 mm or 125 by 25 mm Corrugations<sup>A</sup>**

Equivalent Fill Depth for Which No Longitudinal Reinforcement is Required, $H_{nlr}$ and Incremental Longitudinal Reinforcement Area, $A_{ij}$										
Branch Dia., mm	1.63 mm Thick Main Pipe		2.01 mm Thick Main Pipe		2.77 mm Thick Main Pipe		3.51 mm Thick Main Pipe		4.27 mm Thick Main Pipe	
	$H_{nlr}$ m	$A_{ij}$ mm <sup>2</sup> /m	$H_{nlr}$ m	$A_{ij}$ mm <sup>2</sup> /m	$H_{nlr}$ m	$A_{ij}$ mm <sup>2</sup> /m	$H_{nlr}$ m	$A_{ij}$ mm <sup>2</sup> /m	$H_{nlr}$ m	$A_{ij}$ mm <sup>2</sup> /m
600			4.5	191	6.3	169				
750			3.2	296	4.5	254				
900			2.5	402	3.6	339	4.9	318		
1050			2.0	529	3.0	445	4.2	402	4.7	360
1200			1.7	677	2.4	572	3.0	508	3.6	466
1350			1.5	847	1.9	699	2.4	614	2.8	550
1500			1.2	1037	1.6	847	1.9	741	2.3	656
1650			1.0	1270	1.3	1016	1.6	889	1.9	783
1800			0.8	1503	1.1	1186	1.3	1016	1.6	910
1950			0.7	1757	0.9	1376	1.1	1164	1.3	1037
2100			0.6	2053	0.8	1588	1.0	1334	1.2	1186
2250			0.5	2392	0.7	1821	0.9	1524	1.0	1334
2400			0.5	2752	0.6	2075	0.8	1736	0.9	1503
2550			0.4	3154	0.5	2371	0.7	1948	0.8	1672
2700			0.4	3599	0.5	2667	0.6	2181	0.7	1884
2850			0.3	4065	0.4	3006	0.5	2456	0.6	2096
3000			0.3	4594	0.4	3366	0.5	2731	0.6	2308
3150			0.3	5165	0.4	3768	0.4	3027	0.5	2562
3300			0.2	5779	0.3	4192	0.4	3345	0.5	2816

<sup>A</sup>Branch pipe of any profile with specified thickness as required by A 796/A 796M.

**TABLE 23 Requirements for Longitudinal Reinforcement of Fittings in 144 in. Diameter Main Pipe with 3 by 1 in. or 5 by 1 in. Corrugations<sup>A</sup>**

Equivalent Fill Depth for Which No Longitudinal Reinforcement is Required, $H_{nlr}$ and Incremental Longitudinal Reinforcement Area, $A_{ij}$										
Branch Dia., in.	0.064 in. Thick Main Pipe		0.079 in. Thick Main Pipe		0.109 in. Thick Main Pipe		0.138 in. Thick Main Pipe		0.168 in. Thick Main Pipe	
	$H_{nlr}$ ft	$A_{ij}$ in. <sup>2</sup> /ft	$H_{nlr}$ ft	$A_{ij}$ in. <sup>2</sup> /ft	$H_{nlr}$ ft	$A_{ij}$ in. <sup>2</sup> /ft	$H_{nlr}$ ft	$A_{ij}$ in. <sup>2</sup> /ft	$H_{nlr}$ ft	$A_{ij}$ in. <sup>2</sup> /ft
24					18.9	0.08				
30					13.6	0.13				
36					10.7	0.17	14.7	0.16		
42					9.0	0.23	12.6	0.20	14.0	0.19
48					7.3	0.29	9.1	0.26	10.7	0.23
54					5.8	0.35	7.2	0.31	8.4	0.28
60					4.7	0.43	5.8	0.37	6.8	0.34
66					3.9	0.51	4.8	0.44	5.7	0.40
72					3.3	0.60	4.0	0.52	4.7	0.46
78					2.8	0.70	3.4	0.60	4.0	0.53
84					2.4	0.81	3.0	0.68	3.5	0.60
90					2.1	0.92	2.6	0.77	3.1	0.68
96					1.9	1.05	2.3	0.87	2.7	0.76
102					1.6	1.19	2.0	0.98	2.4	0.85
108					1.5	1.34	1.8	1.10	2.1	0.95
114					1.3	1.51	1.6	1.23	1.9	1.05
120					1.2	1.68	1.4	1.37	1.7	1.17
126					1.1	1.88	1.3	1.52	1.5	1.29
132					1.0	2.09	1.2	1.68	1.4	1.42
138					0.9	2.31	1.1	1.85	1.3	1.56
144					0.8	2.55	1.0	2.03	1.2	1.70

<sup>A</sup>Branch pipe of any profile with specified thickness as required by A 796/A 796M.

$$A_{rc} = \left( \frac{H_e D d_e}{96\,000} \right) \left( \frac{d_e - d_m}{d_e} \right) \left[ A_{rc} = \left( \frac{H_e D d_e}{29\,260} \right) \left( \frac{d_e - d_m}{d_e} \right) \right] \quad (7)$$

where:  
D is the main pipe diameter, and

**TABLE 24 Requirements for Longitudinal Reinforcement of Fittings in 3600 mm Diameter Main Pipe with 75 by 25 mm or 125 by 25 mm Corrugations<sup>A</sup>**

Equivalent Fill Depth for Which No Longitudinal Reinforcement is Required, $H_{nlr}$ and Incremental Longitudinal Reinforcement Area, $A_{ij}$										
Branch Dia., mm	1.63 mm Thick Main Pipe		2.01 mm Thick Main Pipe		2.77 mm Thick Main Pipe		3.51 mm Thick Main Pipe		4.27 mm Thick Main Pipe	
	$H_{nlr}$ m	$A_{ij}$ mm <sup>2</sup> /m	$H_{nlr}$ m	$A_{ij}$ mm <sup>2</sup> /m	$H_{nlr}$ m	$A_{ij}$ mm <sup>2</sup> /m	$H_{nlr}$ m	$A_{ij}$ mm <sup>2</sup> /m	$H_{nlr}$ m	$A_{ij}$ mm <sup>2</sup> /m
600							5.8	169		
750							4.1	275		
900							3.3	360	4.5	339
1050							2.7	487	3.8	423
1200							2.2	614	2.8	550
1350							1.8	741	2.2	656
1500							1.4	910	1.8	783
1650							1.2	1080	1.5	931
1800							1.0	1270	1.2	1101
1950							0.9	1482	1.0	1270
2100							0.7	1715	0.9	1440
2250							0.6	1948	0.8	1630
2400							0.6	2223	0.7	1842
2550							0.5	2519	0.6	2075
2700							0.5	2837	0.5	2329
2850							0.4	3197	0.5	2604
3000							0.4	3557	0.4	2900
3150							0.3	3980	0.4	3218
3300							0.3	4425	0.4	3557
3450							0.3	4890	0.3	3916
3600							0.2	5398	0.3	4298

<sup>A</sup>Branch pipe of any profile with specified thickness as required by A 796/A 796M.

**TABLE 25 Requirements for Longitudinal Reinforcement of Fittings in 48 in. Diameter Main Pipe with ¾ by ¾ by 7-½ in. Ribs<sup>A</sup>**

Equivalent Fill Depth for Which No Longitudinal Reinforcement is Required, $H_{nlr}$ and Incremental Longitudinal Reinforcement Area, $A_{ij}$										
Branch Dia., in.	0.064 in. Thick Main Pipe		0.079 in. Thick Main Pipe		0.109 in. Thick Main Pipe		0.138 in. Thick Main Pipe		0.168 in. Thick Main Pipe	
	$H_{nlr}$ ft	$A_{ij}$ in. <sup>2</sup> /ft	$H_{nlr}$ ft	$A_{ij}$ in. <sup>2</sup> /ft	$H_{nlr}$ ft	$A_{ij}$ in. <sup>2</sup> /ft	$H_{nlr}$ ft	$A_{ij}$ in. <sup>2</sup> /ft	$H_{nlr}$ ft	$A_{ij}$ in. <sup>2</sup> /ft
24	30.4	0.07	37.7	0.05						
30	20.5	0.10	25.8	0.08						
36	15.2	0.10	19.3	0.12						
42	11.9	0.18	15.3	0.14	21.9	0.10				
48	9.9	0.25	12.8	0.20	18.5	0.13				

<sup>A</sup>Branch pipe of any profile with specified thickness as required by A 796/A 796M.

$d_m$  is the maximum branch diameter for which no circumferential reinforcement is required, as listed in Tables 49-54 as applicable for the main pipe diameter, wall profile, and wall thickness under consideration.

10.3 Each circumferential reinforcement shall be attached to the main pipe with a total number of fasteners ( $N_c$ ) not less than that determined as follows:

$$N_c = 40\,000 A_{rcs}/q \quad [N_c = 0.276 A_{rcs}/q] \quad (8)$$

where:  $A_{rcs}$  is the cross section area of the circumferential reinforcement actually selected, and

$q$  is the allowable load for each fastener as provided in Section 12. The spacing between fasteners in a row shall not exceed 12 in. [25 mm]; additionally, for flat material, the



**TABLE 26 Requirements for Longitudinal Reinforcement of Fittings in 1200 mm Diameter Main Pipe with 19 by 19 by 190 mm Ribs<sup>A</sup>**

Equivalent Fill Depth for Which No Longitudinal Reinforcement is Required, $H_{nlr}$ and Incremental Longitudinal Reinforcement Area, $A_{lj}$										
	1.63 mm Thick Main Pipe		2.01 mm Thick Main Pipe		2.77 mm Thick Main Pipe		3.51 mm Thick Main Pipe		4.27 mm Thick Main Pipe	
Branch Dia., mm	$H_{nlr}$ m	$A_{lj}$ mm <sup>2</sup> /m	$H_{nlr}$ m	$A_{lj}$ mm <sup>2</sup> /m	$H_{nlr}$ m	$A_{lj}$ mm <sup>2</sup> /m	$H_{nlr}$ m	$A_{lj}$ mm <sup>2</sup> /m	$H_{nlr}$ m	$A_{lj}$ mm <sup>2</sup> /m
600	9.3	148	11.5	106						
750	6.2	212	7.9	169						
900	4.6	212	5.9	254						
1050	3.6	381	4.7	296	6.7	212				
1200	3.0	529	3.9	423	5.6	275				

<sup>A</sup>Branch pipe of any profile with specified thickness as required by A 796/A 796M.

**TABLE 27 Requirements for Longitudinal Reinforcement of Fittings in 60 in. Diameter Main Pipe with ¾ by ¾ by 7-½ in. Ribs<sup>A</sup>**

Equivalent Fill Depth for Which No Longitudinal Reinforcement is Required, $H_{nlr}$ and Incremental Longitudinal Reinforcement Area, $A_{lj}$										
	0.064 in. Thick Main Pipe		0.079 in. Thick Main Pipe		0.109 in. Thick Main Pipe		0.138 in. Thick Main Pipe		0.168 in. Thick Main Pipe	
Branch Dia., in.	$H_{nlr}$ ft	$A_{lj}$ in. <sup>2</sup> /ft	$H_{nlr}$ ft	$A_{lj}$ in. <sup>2</sup> /ft	$H_{nlr}$ ft	$A_{lj}$ in. <sup>2</sup> /ft	$H_{nlr}$ ft	$A_{lj}$ in. <sup>2</sup> /ft	$H_{nlr}$ ft	$A_{lj}$ in. <sup>2</sup> /ft
24	24.3	0.08	30.2	0.06						
30	16.4	0.13	20.6	0.10						
36	12.1	0.17	15.4	0.13						
42	9.6	0.16	12.3	0.18	17.5	0.12				
48	7.9	0.22	10.2	0.23	14.8	0.15				
54	6.7	0.38	8.8	0.29	13.0	0.19				
60	5.9	0.46	7.9	0.36	11.3	0.23				

<sup>A</sup>Branch pipe of any profile with specified thickness as required by A 796/A 796M.

spacing shall not exceed 44 times the sheet thickness. Flat material shall have a minimum of two rows of fasteners.

### 11. Multiple Reinforcements

11.1 Fig. 4 illustrates the use of reinforcements for multiple branches. Where two or more branches in a row are encountered, the longitudinal reinforcement above and below the branch shall be either a continuous member or multiple members with splices that develop the full tensile strength of the reinforcement. The reinforcement for the first and last branch in the row shall extend, from the centerline of the branch to the end, a distance equal to one-half the reinforcement length specified in 9.2. Likewise, over each of these half

**TABLE 28 Requirements for Longitudinal Reinforcement of Fittings in 1500 mm Diameter Main Pipe with 19 by 19 by 190 mm Ribs<sup>A</sup>**

Equivalent Fill Depth for Which No Longitudinal Reinforcement is Required, $H_{nlr}$ and Incremental Longitudinal Reinforcement Area, $A_{lj}$										
	1.63 mm Thick Main Pipe		2.01 mm Thick Main Pipe		2.77 mm Thick Main Pipe		3.51 mm Thick Main Pipe		4.27 mm Thick Main Pipe	
Branch Dia., mm	$H_{nlr}$ m	$A_{lj}$ mm <sup>2</sup> /m	$H_{nlr}$ m	$A_{lj}$ mm <sup>2</sup> /m	$H_{nlr}$ m	$A_{lj}$ mm <sup>2</sup> /m	$H_{nlr}$ m	$A_{lj}$ mm <sup>2</sup> /m	$H_{nlr}$ m	$A_{lj}$ mm <sup>2</sup> /m
600	7.4	169	9.2	127						
750	5.0	275	6.3	212						
900	3.7	360	4.7	275						
1050	2.9	339	3.7	381	5.3	254				
1200	2.4	466	3.1	487	4.5	318				
1350	2.0	804	2.7	614	4.0	402				
1500	1.8	974	2.4	762	3.4	487				

<sup>A</sup>Branch pipe of any profile with specified thickness as required by A 796/A 796M.

**TABLE 29 Requirements for Longitudinal Reinforcement of Fittings in 72 in. Diameter Main Pipe with ¾ by ¾ by 7-½ in. Ribs<sup>A</sup>**

Equivalent Fill Depth for Which No Longitudinal Reinforcement is Required, $H_{nlr}$ and Incremental Longitudinal Reinforcement Area, $A_{lj}$										
	0.064 in. Thick Main Pipe		0.079 in. Thick Main Pipe		0.109 in. Thick Main Pipe		0.138 in. Thick Main Pipe		0.168 in. Thick Main Pipe	
Branch Dia., in.	$H_{nlr}$ ft	$A_{lj}$ in. <sup>2</sup> /ft	$H_{nlr}$ ft	$A_{lj}$ in. <sup>2</sup> /ft	$H_{nlr}$ ft	$A_{lj}$ in. <sup>2</sup> /ft	$H_{nlr}$ ft	$A_{lj}$ in. <sup>2</sup> /ft	$H_{nlr}$ ft	$A_{lj}$ in. <sup>2</sup> /ft
24			24.4	0.08						
30			16.4	0.12						
36			12.1	0.16						
42			9.5	0.21	13.3	0.14				
48			7.8	0.26	11.1	0.18				
54			6.6	0.32	9.5	0.22				
60			5.8	0.40	8.4	0.28				
66			5.2	0.49	7.6	0.32				
72			4.7	0.60	6.6	0.38				

<sup>A</sup>Branch pipe of any profile with specified thickness as required by A 796/A 796M.

lengths, use half the total number of fasteners specified in 9.4 and maintain the same fastener pattern and spacing throughout the entire length of the reinforcement. Circumferential reinforcement placement and attachment remains the same for single or multiple branches.

### 12. Allowable Loads and Locations for Fasteners

#### 12.1 Welds:

12.1.1 Welds shall be fillet welds with a leg size equal to the thickness of the pipe or the reinforcement, whichever is less.

**TABLE 30 Requirements for Longitudinal Reinforcement of Fittings in 1800 mm Diameter Main Pipe with 19 by 19 by 190 mm Ribs<sup>A</sup>**

Equivalent Fill Depth for Which No Longitudinal Reinforcement is Required, $H_{nlr}$ and Incremental Longitudinal Reinforcement Area, $A_{ij}$												
		1.63 mm Thick Main Pipe		2.01 mm Thick Main Pipe		2.77 mm Thick Main Pipe		3.51 mm Thick Main Pipe		4.27 mm Thick Main Pipe		
Branch Dia., mm	$H_{nlr}$ m	$A_{ij}$ mm <sup>2</sup> /m	$H_{nlr}$ m	$A_{ij}$ mm <sup>2</sup> /m	$H_{nlr}$ m	$A_{ij}$ mm <sup>2</sup> /m	$H_{nlr}$ m	$A_{ij}$ mm <sup>2</sup> /m	$H_{nlr}$ m	$A_{ij}$ mm <sup>2</sup> /m	$H_{nlr}$ m	$A_{ij}$ mm <sup>2</sup> /m
600			7.4	169								
750			5.0	254								
900			3.7	339								
1050			2.9	445	4.1	296						
1200			2.4	550	3.4	381						
1350			2.0	677	2.9	466						
1500			1.8	847	2.6	593						
1650			1.6	1037	2.3	677						
1800			1.4	1270	2.0	804						

<sup>A</sup>Branch pipe of any profile with specified thickness as required by A 796/A 796M.

**TABLE 31 Requirements for Longitudinal Reinforcement of Fittings in 84 in. Diameter Main Pipe with ¾ by ¾ by 7-½ in. Ribs<sup>A</sup>**

Equivalent Fill Depth for Which No Longitudinal Reinforcement is Required, $H_{nlr}$ and Incremental Longitudinal Reinforcement Area, $A_{ij}$												
		0.064 in. Thick Main Pipe		0.079 in. Thick Main Pipe		0.109 in. Thick Main Pipe		0.138 in. Thick Main Pipe		0.168 in. Thick Main Pipe		
Branch Dia., in.	$H_{nlr}$ ft	$A_{ij}$ in. <sup>2</sup> /ft	$H_{nlr}$ ft	$A_{ij}$ in. <sup>2</sup> /ft	$H_{nlr}$ ft	$A_{ij}$ in. <sup>2</sup> /ft	$H_{nlr}$ ft	$A_{ij}$ in. <sup>2</sup> /ft	$H_{nlr}$ ft	$A_{ij}$ in. <sup>2</sup> /ft	$H_{nlr}$ ft	$A_{ij}$ in. <sup>2</sup> /ft
24			20.9	0.09								
30			14.1	0.13								
36			10.4	0.18								
42			8.1	0.25	11.4	0.16						
48			6.7	0.30	9.5	0.21						
54			5.7	0.38	8.2	0.25						
60			5.0	0.45	7.2	0.31						
66			4.5	0.56	6.5	0.36						
72			4.1	0.66	5.6	0.43	6.9	0.33				
78			3.6	0.79	4.8	0.51	5.9	0.38				
84			3.1	0.94	4.1	0.59	5.1	0.44				

<sup>A</sup>Branch pipe of any profile with specified thickness as required by A 796/A 796M.

Any gap between the reinforcement and the pipe within the design length of the weld shall be built up with weld metal and shall not be included in the leg size.

12.1.2 The allowable load per weld ( $q$ ) shall be calculated as follows:

$$q = (18\,000t_x - 67)L_w [q - (0.124t_x - 0.12)L_w] \quad (9)$$

where:

$t_x$  is the bare steel thickness of the pipe or the reinforcement, whichever is less, and

$L_w$  is the length of the weld. For structural members, the thickness of the reinforcement is the thickness of the part of the cross section in contact with the pipe. For pipe and for reinforcement made from pipe stock,  $t_x$  shall be taken as the specified minimum thickness less 0.004 in. [0.10 mm].

12.1.3 Welds to corrugated pipe shall be located on corrugation crests. Welds to ribbed pipe shall be located in the flat portion of the cross section, approximately 1 in. [25 mm] from the ribs, for inside reinforcement, or on top of the ribs, for

**TABLE 32 Requirements for Longitudinal Reinforcement of Fittings in 2100 mm Diameter Main Pipe with 19 by 19 by 190 mm Ribs<sup>A</sup>**

Equivalent Fill Depth for Which No Longitudinal Reinforcement is Required, $H_{nlr}$ and Incremental Longitudinal Reinforcement Area, $A_{ij}$												
		1.63 mm Thick Main Pipe		2.01 mm Thick Main Pipe		2.77 mm Thick Main Pipe		3.51 mm Thick Main Pipe		4.27 mm Thick Main Pipe		
Branch Dia., mm	$H_{nlr}$ m	$A_{ij}$ mm <sup>2</sup> /m	$H_{nlr}$ m	$A_{ij}$ mm <sup>2</sup> /m	$H_{nlr}$ m	$A_{ij}$ mm <sup>2</sup> /m	$H_{nlr}$ m	$A_{ij}$ mm <sup>2</sup> /m	$H_{nlr}$ m	$A_{ij}$ mm <sup>2</sup> /m	$H_{nlr}$ m	$A_{ij}$ mm <sup>2</sup> /m
600			6.4	191								
750			4.3	275								
900			3.2	381								
1050			2.5	529	3.5	339						
1200			2.0	635	2.9	445						
1350			1.7	804	2.5	529						
1500			1.5	953	2.2	656						
1650			1.4	1186	2.0	762						
1800			1.2	1397	1.7	910	2.1	699				
1950			1.1	1672	1.5	1080	1.8	804				
2100			0.9	1990	1.2	1249	1.6	931				

<sup>A</sup>Branch pipe of any profile with specified thickness as required by A 796/A 796M.

**TABLE 33 Requirements for Longitudinal Reinforcement of Fittings in 96 in. Diameter Main Pipe with ¾ by ¾ by 7-½ in. Ribs<sup>A</sup>**

Equivalent Fill Depth for Which No Longitudinal Reinforcement is Required, $H_{nlr}$ and Incremental Longitudinal Reinforcement Area, $A_{ij}$												
		0.064 in. Thick Main Pipe		0.079 in. Thick Main Pipe		0.109 in. Thick Main Pipe		0.138 in. Thick Main Pipe		0.168 in. Thick Main Pipe		
Branch Dia., in.	$H_{nlr}$ ft	$A_{ij}$ in. <sup>2</sup> /ft	$H_{nlr}$ ft	$A_{ij}$ in. <sup>2</sup> /ft	$H_{nlr}$ ft	$A_{ij}$ in. <sup>2</sup> /ft	$H_{nlr}$ ft	$A_{ij}$ in. <sup>2</sup> /ft	$H_{nlr}$ ft	$A_{ij}$ in. <sup>2</sup> /ft	$H_{nlr}$ ft	$A_{ij}$ in. <sup>2</sup> /ft
42							10.0	0.19				
48							8.3	0.23				
54							7.2	0.29				
60							6.3	0.34				
66							5.7	0.41				
72							4.9	0.48	6.0	0.37		
78							4.2	0.56	5.1	0.43		
84							3.6	0.66	4.4	0.49		
90							3.1	0.76	3.9	0.56		
96							2.8	0.87	3.4	0.64		

<sup>A</sup>Branch pipe of any profile with specified thickness as required by A 796/A 796M.

outside reinforcement. Welds shall be placed along the edges of the reinforcement or in slots cut in the reinforcement.

**12.2 Bolts:**

12.2.1 Bolts shall conform to the requirements of Specification A 307, or Specification F 568M, Class 4.6.

12.2.2 The allowable load per bolt ( $q$ ) shall be taken as the least of the following equations:

$$q = 54,000t_x d_b [q = 0.372t_x d_b] \quad (10)$$

$$q = 7850(d_b)^2 [q = 0.0541(d_b)^2] \quad (11)$$

where:  $d_b$  is the nominal bolt diameter.

12.2.3 Bolts shall be located on corrugation crests. Bolts to corrugated pipe shall be located on corrugation crests. Bolts to ribbed pipe shall be located in the flat portion of the cross section, approximately 1 in. [25 mm] from the ribs, for inside reinforcement, or on top of the ribs, for outside reinforcement. If more than one row of bolts is required, the bolts shall be





**TABLE 34 Requirements for Longitudinal Reinforcement of Fittings in 2400 mm Diameter Main Pipe with 19 by 19 by 190 mm Ribs<sup>A</sup>**

Equivalent Fill Depth for Which No Longitudinal Reinforcement is Required, $H_{nlr}$ and Incremental Longitudinal Reinforcement Area, $A_{lj}$											
		1.63 mm Thick Main Pipe		2.01 mm Thick Main Pipe		2.77 mm Thick Main Pipe		3.51 mm Thick Main Pipe		4.27 mm Thick Main Pipe	
Branch Dia., mm	$H_{nlr}$ m	$A_{lj}$ mm <sup>2</sup> /m	$H_{nlr}$ m	$A_{lj}$ mm <sup>2</sup> /m	$H_{nlr}$ m	$A_{lj}$ mm <sup>2</sup> /m	$H_{nlr}$ m	$A_{lj}$ mm <sup>2</sup> /m	$H_{nlr}$ m	$A_{lj}$ mm <sup>2</sup> /m	
1050					3.0	402					
1200					2.5	487					
1350					2.2	614					
1500					1.9	720					
1650					1.7	868					
1800					1.5	1016	1.8	783			
1950					1.3	1186	1.6	910			
2100					1.1	1397	1.3	1037			
2250					0.9	1609	1.2	1186			
2400					0.9	1842	1.0	1355			

<sup>A</sup>Branch pipe of any profile with specified thickness as required by A 796/A 796M.

**TABLE 35 Requirements for Longitudinal Reinforcement of Fittings in 108 in. Diameter Main Pipe with ¾ by ¾ by 7-½ in. Ribs<sup>A</sup>**

Equivalent Fill Depth for Which No Longitudinal Reinforcement is Required, $H_{nlr}$ and Incremental Longitudinal Reinforcement Area, $A_{lj}$											
		0.064 in. Thick Main Pipe		0.079 in. Thick Main Pipe		0.109 in. Thick Main Pipe		0.138 in. Thick Main Pipe		0.168 in. Thick Main Pipe	
Branch Dia., in.	$H_{nlr}$ ft	$A_{lj}$ in. <sup>2</sup> /ft	$H_{nlr}$ ft	$A_{lj}$ in. <sup>2</sup> /ft	$H_{nlr}$ ft	$A_{lj}$ in. <sup>2</sup> /ft	$H_{nlr}$ ft	$A_{lj}$ in. <sup>2</sup> /ft	$H_{nlr}$ ft	$A_{lj}$ in. <sup>2</sup> /ft	
42					9.7	0.20					
48					8.2	0.25					
54					7.2	0.31					
60					6.3	0.37					
66					5.2	0.45					
72					4.4	0.53	5.4	0.41			
78					3.7	0.62	4.6	0.47			
84					3.2	0.72	4.0	0.54			
90					2.8	0.83	3.5	0.62			
96					2.5	0.95	3.0	0.70			
102					2.2	1.08	2.7	0.79			
108					1.9	1.22	2.4	0.89			

<sup>A</sup>Branch pipe of any profile with specified thickness as required by A 796/A 796M.

placed in rows spaced at least  $3d_b$  apart. The center of the first and last bolts in each row shall be at least  $1.5d_b$  from the end of the reinforcement. The minimum distance from the center of bolts to the longitudinal edges of the reinforcement shall be  $4/3$  times the bolt diameter for sheet material and  $5/3$  times the bolt diameter for structural members.

12.3 Screws:

12.3.1 Screws shall be self tapping and shall meet the minimum mechanical and quality requirements for tapping screws in accordance with SAE J978. Screw nominal diameters shall be ¼ in. [6.3 mm], No. 12, or No. 10.

12.3.2 The allowable load per screw ( $q$ ) shall not exceed 1000 lbf [4.45 kN] for a ¼ in. diameter [6.3 mm] screw, 770 lbf [3.42 kN] for a No. 12 screw, or 547 lbf [2.43 kN] for a No. 10 screw. In addition, the allowable load per screw shall not exceed the least of Eq 12-14, as applicable, depending on the

**TABLE 36 Requirements for Longitudinal Reinforcement of Fittings in 2700 mm Diameter Main Pipe with 19 by 19 by 190 mm Ribs<sup>A</sup>**

Equivalent Fill Depth for Which No Longitudinal Reinforcement is Required, $H_{nlr}$ and Incremental Longitudinal Reinforcement Area, $A_{lj}$											
		1.63 mm Thick Main Pipe		2.01 mm Thick Main Pipe		2.77 mm Thick Main Pipe		3.51 mm Thick Main Pipe		4.27 mm Thick Main Pipe	
Branch Dia., mm	$H_{nlr}$ m	$A_{lj}$ mm <sup>2</sup> /m	$H_{nlr}$ m	$A_{lj}$ mm <sup>2</sup> /m	$H_{nlr}$ m	$A_{lj}$ mm <sup>2</sup> /m	$H_{nlr}$ m	$A_{lj}$ mm <sup>2</sup> /m	$H_{nlr}$ m	$A_{lj}$ mm <sup>2</sup> /m	
1050							3.0	423			
1200							2.5	529			
1350							2.2	656			
1500							1.9	783			
1650							1.6	953			
1800							1.3	1122	1.6	868	
1950							1.1	1313	1.4	995	
2100							1.0	1524	1.2	1143	
2250							0.9	1757	1.1	1313	
2400							0.8	2011	0.9	1482	
2550							0.7	2286	0.8	1672	
2700							0.6	2583	0.7	1884	

<sup>A</sup>Branch pipe of any profile with specified thickness as required by A 796/A 796M.

**TABLE 37 Requirements for Longitudinal Reinforcement of Fittings in 48 in. Diameter Main Pipe with ¾ by 11-½ in. Ribs<sup>A</sup>**

Equivalent Fill Depth for Which No Longitudinal Reinforcement is Required, $H_{nlr}$ and Incremental Longitudinal Reinforcement Area, $A_{lj}$											
		0.064 in. Thick Main Pipe		0.079 in. Thick Main Pipe		0.109 in. Thick Main Pipe		0.138 in. Thick Main Pipe		0.168 in. Thick Main Pipe	
Branch Dia., in.	$H_{nlr}$ ft	$A_{lj}$ in. <sup>2</sup> /ft	$H_{nlr}$ ft	$A_{lj}$ in. <sup>2</sup> /ft	$H_{nlr}$ ft	$A_{lj}$ in. <sup>2</sup> /ft	$H_{nlr}$ ft	$A_{lj}$ in. <sup>2</sup> /ft	$H_{nlr}$ ft	$A_{lj}$ in. <sup>2</sup> /ft	
24	29.7	0.10	36.6	0.07	49.7	0.06					
30	19.8	0.11	24.7	0.10	33.8	0.07					
36	14.4	0.19	18.2	0.15	25.2	0.10					
42	11.2	0.25	14.2	0.19	20.0	0.13					
48	9.1	0.34	11.7	0.26	16.6	0.17					

<sup>A</sup>Branch pipe of any profile with specified thickness as required by A 796/A 796M.

**TABLE 38 Requirements for Longitudinal Reinforcement of Fittings in 1200 mm Diameter Main Pipe with 19 by 25 by 292 mm Ribs<sup>A</sup>**

Equivalent Fill Depth for Which No Longitudinal Reinforcement is Required, $H_{nlr}$ and Incremental Longitudinal Reinforcement Area, $A_{lj}$											
		1.63 mm Thick Main Pipe		2.01 mm Thick Main Pipe		2.77 mm Thick Main Pipe		3.51 mm Thick Main Pipe		4.27 mm Thick Main Pipe	
Branch Dia., mm	$H_{nlr}$ m	$A_{lj}$ mm <sup>2</sup> /m	$H_{nlr}$ m	$A_{lj}$ mm <sup>2</sup> /m	$H_{nlr}$ m	$A_{lj}$ mm <sup>2</sup> /m	$H_{nlr}$ m	$A_{lj}$ mm <sup>2</sup> /m	$H_{nlr}$ m	$A_{lj}$ mm <sup>2</sup> /m	
600	9.1	212	11.2	148	15.1	127					
750	6.0	233	7.5	212	10.3	148					
900	4.4	402	5.5	318	7.7	212					
1050	3.4	529	4.3	402	6.1	275					
1200	2.8	720	3.6	550	5.1	360					

<sup>A</sup>Branch pipe of any profile with specified thickness as required by A 796/A 796M.

ratio of the bare steel thickness of the pipe to that of the reinforcement in contact with the pipe ( $t_{np}/t_{nr}$ ).

$$\text{When } t_{np}/t_{nr} \leq 1$$

$$q = 85,500 \sqrt{t_{np}^3 d_s} \quad [q = 0.590 \sqrt{t_{np}^3 d_s}] \quad (12)$$

**TABLE 39 Requirements for Longitudinal Reinforcement of Fittings in 60 in. Diameter Main Pipe with ¾ by 11-½ in. Ribs<sup>A</sup>**

Equivalent Fill Depth for Which No Longitudinal Reinforcement is Required, $H_{nlr}$ and Incremental Longitudinal Reinforcement Area, $A_{ij}$											
		0.064 in. Thick Main Pipe		0.079 in. Thick Main Pipe		0.109 in. Thick Main Pipe		0.138 in. Thick Main Pipe		0.168 in. Thick Main Pipe	
Branch Dia., in.	$H_{nlr}$ ft	$A_{ij}$ in. <sup>2</sup> /ft	$H_{nlr}$ ft	$A_{ij}$ in. <sup>2</sup> /ft	$H_{nlr}$ ft	$A_{ij}$ in. <sup>2</sup> /ft	$H_{nlr}$ ft	$A_{ij}$ in. <sup>2</sup> /ft	$H_{nlr}$ ft	$A_{ij}$ in. <sup>2</sup> /ft	
24	23.7	0.11	29.3	0.08	39.8	0.06					
30	15.8	0.17	19.7	0.14	27.1	0.08					
36	11.5	0.23	14.5	0.17	20.2	0.13					
42	9.0	0.30	11.4	0.24	16.0	0.15					
48	7.3	0.40	9.4	0.31	13.3	0.20					
54	6.1	0.51	8.0	0.37	11.5	0.24					
60	5.3	0.63	7.0	0.48	10.1	0.29					

<sup>A</sup>Branch pipe of any profile with specified thickness as required by A 796/ A 796M.

**TABLE 40 Requirements for Longitudinal Reinforcement of Fittings in 1500 mm Diameter Main Pipe with 19 by 25 by 292 mm Ribs<sup>A</sup>**

Equivalent Fill Depth for Which No Longitudinal Reinforcement is Required, $H_{nlr}$ and Incremental Longitudinal Reinforcement Area, $A_{ij}$											
		1.63 mm Thick Main Pipe		2.01 mm Thick Main Pipe		2.77 mm Thick Main Pipe		3.51 mm Thick Main Pipe		4.27 mm Thick Main Pipe	
Branch Dia., mm	$H_{nlr}$ m	$A_{ij}$ mm <sup>2</sup> /m	$H_{nlr}$ m	$A_{ij}$ mm <sup>2</sup> /m	$H_{nlr}$ m	$A_{ij}$ mm <sup>2</sup> /m	$H_{nlr}$ m	$A_{ij}$ mm <sup>2</sup> /m	$H_{nlr}$ m	$A_{ij}$ mm <sup>2</sup> /m	
600	7.2	233	8.9	169	12.1	127	0.0	0	0.0	0	
750	4.8	360	6.0	296	8.3	169	0.0	0	0.0	0	
900	3.5	487	4.4	360	6.2	275	0.0	0	0.0	0	
1050	2.7	635	3.5	508	4.9	318	0.0	0	0.0	0	
1200	2.2	847	2.9	656	4.1	423	0.0	0	0.0	0	
1350	1.9	1080	2.4	783	3.5	508	0.0	0	0.0	0	
1500	1.6	1334	2.1	1016	3.1	614	0.0	0	0.0	0	

<sup>A</sup>Branch pipe of any profile with specified thickness as required by A 796/ A 796M.

**TABLE 41 Requirements for Longitudinal Reinforcement of Fittings in 72 in. Diameter Main Pipe with ¾ by 1 by 11-½ in. Ribs<sup>A</sup>**

Equivalent Fill Depth for Which No Longitudinal Reinforcement is Required, $H_{nlr}$ and Incremental Longitudinal Reinforcement Area, $A_{ij}$											
		0.064 in. Thick Main Pipe		0.079 in. Thick Main Pipe		0.109 in. Thick Main Pipe		0.138 in. Thick Main Pipe		0.168 in. Thick Main Pipe	
Branch Dia., in.	$H_{nlr}$ ft	$A_{ij}$ in. <sup>2</sup> /ft	$H_{nlr}$ ft	$A_{ij}$ in. <sup>2</sup> /ft	$H_{nlr}$ ft	$A_{ij}$ in. <sup>2</sup> /ft	$H_{nlr}$ ft	$A_{ij}$ in. <sup>2</sup> /ft	$H_{nlr}$ ft	$A_{ij}$ in. <sup>2</sup> /ft	
24	20.3	0.13	25.1	0.10	34.4	0.07					
30	13.7	0.19	17.2	0.15	23.8	0.10					
36	10.1	0.27	12.8	0.20	18.1	0.14					
42	8.0	0.34	10.2	0.27	14.6	0.18					
48	6.6	0.46	8.5	0.34	12.4	0.22					
54	5.6	0.57	7.4	0.42	10.8	0.28					
60	4.9	0.72	6.5	0.53	9.4	0.35					
66	4.4	0.87	5.9	0.65	7.8	0.41					
72	4.0	1.08	4.9	0.78	6.6	0.49					

<sup>A</sup>Branch pipe of any profile with specified thickness as required by A 796/ A 796M.

$$q = 54,000t_{np}d_s \quad [q = 0.372t_{np}d_s] \quad (13)$$

When  $t_{np}/t_{nr} \geq 2.5$

$$q = 54,000t_{nr}d_s \quad [q = 0.372t_{nr}d_s] \quad (14)$$

where  $d_s$  is the nominal screw diameter taken as follows: ¼ in. nominal dia. - 0.250 [6.3 mm]; No. 12 - 0.216 in. [5.49

**TABLE 42 Requirements for Longitudinal Reinforcement of Fittings in 1800 mm Diameter Main Pipe with 19 by 25 by 292 mm Ribs<sup>A</sup>**

Equivalent Fill Depth for Which No Longitudinal Reinforcement is Required, $H_{nlr}$ and Incremental Longitudinal Reinforcement Area, $A_{ij}$											
		1.63 mm Thick Main Pipe		2.01 mm Thick Main Pipe		2.77 mm Thick Main Pipe		3.51 mm Thick Main Pipe		4.27 mm Thick Main Pipe	
Branch Dia., mm	$H_{nlr}$ m	$A_{ij}$ mm <sup>2</sup> /m	$H_{nlr}$ m	$A_{ij}$ mm <sup>2</sup> /m	$H_{nlr}$ m	$A_{ij}$ mm <sup>2</sup> /m	$H_{nlr}$ m	$A_{ij}$ mm <sup>2</sup> /m	$H_{nlr}$ m	$A_{ij}$ mm <sup>2</sup> /m	
600	6.2	275	7.7	212	10.5	148					
750	4.2	402	5.2	318	7.3	212					
900	3.1	572	3.9	423	5.5	296					
1050	2.4	720	3.1	572	4.5	381					
1200	2.0	974	2.6	720	3.8	466					
1350	1.7	1207	2.3	889	3.3	593					
1500	1.5	1524	2.0	1122	2.9	741					
1650	1.3	1842	1.8	1376	2.4	868					
1800	1.2	2286	1.5	1651	2.0	1037					

<sup>A</sup>Branch pipe of any profile with specified thickness as required by A 796/ A 796M.

**TABLE 43 Requirements for Longitudinal Reinforcement of Fittings in 84 in. Diameter Main Pipe with ¾ by 1 by 11-½ in. Ribs<sup>A</sup>**

Equivalent Fill Depth for Which No Longitudinal Reinforcement is Required, $H_{nlr}$ and Incremental Longitudinal Reinforcement Area, $A_{ij}$											
		0.064 in. Thick Main Pipe		0.079 in. Thick Main Pipe		0.109 in. Thick Main Pipe		0.138 in. Thick Main Pipe		0.168 in. Thick Main Pipe	
Branch Dia., in.	$H_{nlr}$ ft	$A_{ij}$ in. <sup>2</sup> /ft	$H_{nlr}$ ft	$A_{ij}$ in. <sup>2</sup> /ft	$H_{nlr}$ ft	$A_{ij}$ in. <sup>2</sup> /ft	$H_{nlr}$ ft	$A_{ij}$ in. <sup>2</sup> /ft	$H_{nlr}$ ft	$A_{ij}$ in. <sup>2</sup> /ft	
24			21.5	0.12	29.5	0.08	37.9	0.06			
30			14.7	0.17	20.4	0.13	26.8	0.10			
36			11.0	0.24	15.5	0.17	20.7	0.13			
42			8.8	0.31	12.5	0.21	17.0	0.17			
48			7.3	0.39	10.6	0.27	14.6	0.21			
54			6.3	0.29	9.3	0.32	12.3	0.26			
60			5.6	0.60	8.1	0.39	10.0	0.31			
66			5.0	0.73	6.6	0.46	8.2	0.36			
72			4.2	0.87	5.6	0.55	6.9	0.43			
78			3.6	1.04	4.8	0.64	5.9	0.49			
84			3.1	1.22	4.1	0.76	5.1	0.57			

<sup>A</sup>Branch pipe of any profile with specified thickness as required by A 796/ A 796M.

mm], or No. 10 - 0.190 in. [4.83 mm]. For values of  $1 < (t_{np}/t_{nr}) < 2.5$ , interpolation shall be used.

12.3.3 Screws to corrugated pipe shall be located on corrugation crests. Screws to ribbed pipe shall be located in the flat portion of the cross section, approximately 1 in. [25 mm] from the ribs, for inside reinforcement, or on top of the ribs, for outside reinforcement. If more than one row of screws is required, the screws shall be placed in rows spaced at least 1 in. [25 mm] apart. The center of the first and last screws in each row shall be at least ¾ in. [19 mm] from the end of the reinforcement. The minimum distance from the center of screws to the longitudinal edges of the reinforcement shall be ½ in. [12 mm].

**13. Keywords**

13.1 buried applications; corrugated steel pipe; pipe fittings; reinforcement; steel pipe structural design



**TABLE 44 Requirements for Longitudinal Reinforcement of Fittings in 2100 mm Diameter Main Pipe with 19 by 25 by 292 mm Ribs<sup>A</sup>**

Equivalent Fill Depth for Which No Longitudinal Reinforcement is Required, $H_{nlr}$ and Incremental Longitudinal Reinforcement Area, $A_{lj}$										
Branch Dia., mm	1.63 mm Thick Main Pipe		2.01 mm Thick Main Pipe		2.77 mm Thick Main Pipe		3.51 mm Thick Main Pipe		4.27 mm Thick Main Pipe	
	$H_{nlr}$ m	$A_{lj}$ mm <sup>2</sup> /m	$H_{nlr}$ m	$A_{lj}$ mm <sup>2</sup> /m	$H_{nlr}$ m	$A_{lj}$ mm <sup>2</sup> /m	$H_{nlr}$ m	$A_{lj}$ mm <sup>2</sup> /m	$H_{nlr}$ m	$A_{lj}$ mm <sup>2</sup> /m
600			6.6	254	9.0	169				
750			4.5	360	6.2	275				
900			3.4	508	4.7	360				
1050			2.7	656	3.8	445				
1200			2.2	826	3.2	572				
1350			1.9	614	2.8	677				
1500			1.7	1270	2.5	826				
1650			1.5	1545	2.0	974				
1800			1.3	1842	1.7	1164				
1950			1.1	2202	1.5	1355				
2100			0.9	2583	1.2	1609				

<sup>A</sup>Branch pipe of any profile with specified thickness as required by A 796/A 796M.

**TABLE 45 Requirements for Longitudinal Reinforcement of Fittings in 96 in. Diameter Main Pipe with ¾ by 1 by 11-½ in. Ribs<sup>A</sup>**

Equivalent Fill Depth for Which No Longitudinal Reinforcement is Required, $H_{nlr}$ and Incremental Longitudinal Reinforcement Area, $A_{lj}$										
Branch Dia., in.	0.064 in. Thick Main Pipe		0.079 in. Thick Main Pipe		0.109 in. Thick Main Pipe		0.138 in. Thick Main Pipe		0.168 in. Thick Main Pipe	
	$H_{nlr}$ ft	$A_{lj}$ in. <sup>2</sup> /ft	$H_{nlr}$ ft	$A_{lj}$ in. <sup>2</sup> /ft	$H_{nlr}$ ft	$A_{lj}$ in. <sup>2</sup> /ft	$H_{nlr}$ ft	$A_{lj}$ in. <sup>2</sup> /ft	$H_{nlr}$ ft	$A_{lj}$ in. <sup>2</sup> /ft
24					25.8	0.08	33.2	0.08		
30					17.9	0.14	23.4	0.12		
36					13.6	0.18	18.1	0.14		
42					11.0	0.24	14.9	0.20		
48					9.3	0.29	12.8	0.25		
54					8.1	0.36	10.7	0.29		
60					7.1	0.43	8.7	0.35		
66					5.8	0.52	7.2	0.40		
72					4.9	0.62	6.0	0.48		
78					4.2	0.71	5.1	0.56		
84					3.6	0.84	4.4	0.64		
90					3.1	0.97	3.9	0.73		
96					2.8	1.11	3.4	0.83		

<sup>A</sup>Branch pipe of any profile with specified thickness as required by A 796/A 796M.

**TABLE 46 Requirements for Longitudinal Reinforcement of Fittings in 2400 mm Diameter Main Pipe with 19 by 25 by 292 mm Ribs<sup>A</sup>**

Equivalent Fill Depth for Which No Longitudinal Reinforcement is Required, $H_{nlr}$ and Incremental Longitudinal Reinforcement Area, $A_{lj}$										
Branch Dia., mm	1.63 mm Thick Main Pipe		2.01 mm Thick Main Pipe		2.77 mm Thick Main Pipe		3.51 mm Thick Main Pipe		4.27 mm Thick Main Pipe	
	$H_{nlr}$ m	$A_{lj}$ mm <sup>2</sup> /m	$H_{nlr}$ m	$A_{lj}$ mm <sup>2</sup> /m	$H_{nlr}$ m	$A_{lj}$ mm <sup>2</sup> /m	$H_{nlr}$ m	$A_{lj}$ mm <sup>2</sup> /m	$H_{nlr}$ m	$A_{lj}$ mm <sup>2</sup> /m
600					7.9	169	10.1	262		
750					5.5	296	7.1	254		
900					4.1	381	5.5	296		
1050					3.4	508	4.5	423		
1200					2.8	614	3.9	529		
1350					2.5	762	3.3	614		
1500					2.2	910	2.7	741		
1650					1.8	1101	2.2	847		
1800					1.5	1313	1.8	1016		
1950					1.3	1503	1.6	1185		
2100					1.1	1778	1.3	1355		
2250					0.9	2053	1.2	1545		
2400					0.9	2350	1.0	1757		

<sup>A</sup>Branch pipe of any profile with specified thickness as required by A 796/A 796M.

**TABLE 47 Requirements for Longitudinal Reinforcement of Fittings in 108 in. Diameter Main Pipe with ¾ by 1 by 11-½ in. Ribs<sup>A</sup>**

Equivalent Fill Depth for Which No Longitudinal Reinforcement is Required, $H_{nlr}$ and Incremental Longitudinal Reinforcement Area, $A_{lj}$										
Branch Dia., in.	0.064 in. Thick Main Pipe		0.079 in. Thick Main Pipe		0.109 in. Thick Main Pipe		0.138 in. Thick Main Pipe		0.168 in. Thick Main Pipe	
	$H_{nlr}$ ft	$A_{lj}$ in. <sup>2</sup> /ft	$H_{nlr}$ ft	$A_{lj}$ in. <sup>2</sup> /ft	$H_{nlr}$ ft	$A_{lj}$ in. <sup>2</sup> /ft	$H_{nlr}$ ft	$A_{lj}$ in. <sup>2</sup> /ft	$H_{nlr}$ ft	$A_{lj}$ in. <sup>2</sup> /ft
24					22.1	0.10	28.2	0.08		
30					15.0	0.14	19.5	0.12		
36					11.2	0.20	14.7	0.17		
42					8.9	0.25	11.9	0.21		
48					7.4	0.32	10.0	0.26		
54					6.4	0.41	8.8	0.32		
60					5.6	0.48	7.8	0.39		
66					5.1	0.57	6.4	0.46		
72					4.4	0.67	5.4	0.53		
78					3.7	0.78	4.6	0.61		
84					3.2	0.91	4.0	0.70		
90					2.8	1.05	3.5	0.81		
96					2.5	1.20	3.0	0.91		
102					2.2	1.37	2.7	1.03		
108					1.9	1.55	2.4	1.16		

<sup>A</sup>Branch pipe of any profile with specified thickness as required by A 796/A 796M.

**TABLE 48 Requirements for Longitudinal Reinforcement of Fittings in 2700 mm Diameter Main Pipe with 19 by 25 by 292 mm Ribs<sup>A</sup>**

Equivalent Fill Depth for Which No Longitudinal Reinforcement is Required, $H_{nlr}$ and Incremental Longitudinal Reinforcement Area, $A_{lf}$										
<div style="display: flex; justify-content: space-around;"> <div style="text-align: center;">1.63 mm Thick Main Pipe</div> <div style="text-align: center;">2.01 mm Thick Main Pipe</div> <div style="text-align: center;">2.77 mm Thick Main Pipe</div> <div style="text-align: center;">3.51 mm Thick Main Pipe</div> <div style="text-align: center;">4.27 mm Thick Main Pipe</div> </div>										
Branch Dia., mm	$H_{nlr}$ m	$A_{lf}$ mm <sup>2</sup> /m	$H_{nlr}$ m	$A_{lf}$ mm <sup>2</sup> /m	$H_{nlr}$ m	$A_{lf}$ mm <sup>2</sup> /m	$H_{nlr}$ m	$A_{lf}$ mm <sup>2</sup> /m	$H_{nlr}$ m	$A_{lf}$ mm <sup>2</sup> /m
600				6.7	212	8.6	262			
750				4.6	296	5.9	254			
900				3.4	423	4.5	360			
1050				2.7	529	3.6	444			
1200				2.3	677	3.0	550			
1350				2.0	868	2.7	677			
1500				1.7	1016	2.4	825			
1650				1.6	1207	2.0	974			
1800				1.3	1418	1.6	1122			
1950				1.1	1651	1.4	1291			
2100				1.0	1926	1.2	1482			
2250				0.9	2223	1.1	1714			
2400				0.8	2540	0.9	1926			
2550				0.7	2900	0.8	2180			
2700				0.6	3281	0.7	2455			

<sup>A</sup>Branch pipe of any profile with specified thickness as required by A 796/A 796M.



**TABLE 49 Requirements for Circumferential Reinforcement of Fittings in Main Pipe with 2-2/3 by 1/2 in., 3 by 1 in., or 5 by 1 in. Corrugations<sup>A</sup>**

Maximum Branch Diameter for Which No Circumferential Reinforcement is Required, $d_m$ (in.)																
0.064 in. Thick Main Pipe			0.079 in. Thick Main Pipe			0.109 in. Thick Main Pipe			0.138 in. Thick Main Pipe			0.168 in. Thick Main Pipe				
Main Pipe Dia., in	He = 10 ft	He = 20 ft	He = 30 ft	He = 10 ft	He = 20 ft	He = 30 ft	He = 10 ft	He = 20 ft	He = 30 ft	He = 10 ft	He = 20 ft	He = 30 ft	He = 10 ft	He = 20 ft	He = 30 ft	
48	48	30	18	48	48	30	48	48	48	48	48	48	48	48	48	
54	48	30	18	54	42	30	54	54	48	54	54	54	54	54	54	
60	48	30	18	60	42	24	60	60	48	60	60	60	60	60	60	
66	48	30	18	66	42	24	66	60	42	66	66	60	66	66	66	
72	48	24	18	66	42	18	72	60	42	72	72	60	72	72	72	
78	48	24	18	66	36	18	78	60	42	78	78	60	78	78	72	
84	48	18	18	60	36	18	84	60	36	84	78	60	84	84	72	
90	48	18	18	60	30	18	90	60	36	90	78	54	90	90	66	
96	48	18	18	60	30	18	90	54	30	96	78	54	96	96	66	
102	48	18	18	60	24	18	90	54	30	102	78	54	102	96	66	
108	42	18	18	60	24	18	90	54	24	108	78	48	108	96	66	
114	42	18	18	60	24	18	90	48	24	114	78	48	114	96	66	
120	42	18	18	60	18	18	90	48	18	114	72	42	120	96	66	
126				60	18	18	90	48	18	114	72	42	126	96	66	
132				60	18	18	90	42	18	114	72	36	132	96	60	
138				54	18	18	90	42	18	114	66	30	138	96	60	
144							90	36	18	114	66	30	144	90	54	

<sup>A</sup>Branch pipe of any profile with specified thickness as required by A 796/A 796M.

**TABLE 50 Requirements for Circumferential Reinforcement of Fittings in Main Pipe with 68 by 13 mm, 75 by 25 mm, or 125 by 25 mm Corrugations<sup>A</sup>**

Maximum Branch Diameter for Which No Circumferential Reinforcement is Required, $d_m$ (mm)																
1.63 mm Thick Main Pipe			2.01 mm Thick Main Pipe			2.77 mm Thick Main Pipe			3.51 mm Thick Main Pipe			4.27 mm Thick Main Pipe				
Main Pipe Dia., mm	He = 3 m	He = 6 m	He = 9 m	He = 3 m	He = 6 m	He = 9 m	He = 3 m	He = 6 m	He = 9 m	He = 3 m	He = 6 m	He = 9 m	He = 3 m	He = 6 m	He = 9 m	
1200	1200	750	450	1200	1200	750	1200	1200	1200	1200	1200	1200	1200	1200	1200	
1350	1200	750	450	1350	1050	750	1350	1350	1200	1350	1350	1350	1350	1350	1350	
1500	1200	750	450	1500	1050	600	1500	1500	1200	1500	1500	1500	1500	1500	1500	
1650	1200	750	450	1650	1050	600	1650	1500	1050	1650	1650	1500	1650	1650	1650	
1800	1200	600	450	1650	1050	450	1800	1500	1050	1800	1800	1500	1800	1800	1800	
1950	1200	600	450	1650	900	450	1950	1500	1050	1950	1950	1500	1950	1950	1800	
2100	1200	450	450	1500	900	450	2100	1500	900	2100	1950	1500	2100	2100	1800	
2250	1200	450	450	1500	750	450	2250	1500	900	2250	1950	1350	2250	2250	1650	
2400	1200	450	450	1500	750	450	2250	1350	750	2400	1950	1350	2400	2400	1650	
2550	1200	450	450	1500	600	450	2250	1350	750	2550	1950	1350	2550	2400	1650	
2700	1050	450	450	1500	600	450	2250	1350	600	2700	1950	1200	2700	2400	1650	
2850	1050	450	450	1500	600	450	2250	1200	600	2850	1950	1200	2850	2400	1650	
3000	1050	450	450	1500	450	450	2250	1200	450	2850	1800	1050	3000	2400	1650	
3150				1500	450	450	2250	1200	450	2850	1800	1050	3150	2400	1650	
3300				1500	450	450	2250	1050	450	2850	1800	900	3300	2400	1500	
3450				1350	450	450	2250	1050	450	2850	1650	750	3450	2400	1500	
3600							2250	900	450	2850	1650	750	3600	2250	1350	

<sup>A</sup>Branch pipe of any profile with specified thickness as required by A 796/A 796M.

**TABLE 51 Requirements for Circumferential Reinforcement of Fittings in Main Pipe with ¾ by ¾ by 7-½ in. Ribs<sup>A</sup>**

Maximum Branch Diameter for Which No Circumferential Reinforcement is Required, $d_m$ (in.)																
		0.064 in. Thick Main Pipe			0.079 in. Thick Main Pipe			0.109 in. Thick Main Pipe			0.138 in. Thick Main Pipe			0.168 in. Thick Main Pipe		
Main Pipe Dia., in	$He = 10$ ft	$He = 20$ ft	$He = 30$ ft	$He = 10$ ft	$He = 20$ ft	$He = 30$ ft	$He = 10$ ft	$He = 20$ ft	$He = 30$ ft	$He = 10$ ft	$He = 20$ ft	$He = 30$ ft	$He = 10$ ft	$He = 20$ ft	$He = 30$ ft	
48	30	18	12	42	30	18	48	48	42							
54	30	18	12	42	24	18	54	54	36							
60	30	18	12	42	24	18	60	54	36							
66				42	24	18	66	54	36							
72				42	18	18	72	48	30							
78				42	18	18	78	48	30	78	78	60				
84							78	48	24	84	78	60				
90							78	48	24	90	78	54				
96							78	42	18	96	78	54				
102							78	42	18	102	78	54				
108										108	78	48				

<sup>A</sup>Branch pipe of any profile with specified thickness as required by A 796/A 796M.

**TABLE 52 Requirements for Circumferential Reinforcement of Fittings in Main Pipe with 19 by 19 by 190 mm Ribs<sup>A</sup>**

Maximum Branch Diameter for Which No Circumferential Reinforcement is Required, $d_m$ (mm)																
		1.63 mm Thick Main Pipe			2.01 mm Thick Main Pipe			2.77 mm Thick Main Pipe			3.51 mm Thick Main Pipe			4.27 mm Thick Main Pipe		
Main Pipe Dia., mm	$He = 3$ m	$He = 6$ m	$He = 9$ m	$He = 3$ m	$He = 6$ m	$He = 9$ m	$He = 3$ m	$He = 6$ m	$He = 9$ m	$He = 3$ m	$He = 6$ m	$He = 9$ m	$He = 3$ m	$He = 6$ m	$He = 9$ m	
1200	750	450	300	1050	750	450	1200	1200	1050							
1350	750	450	300	1050	600	450	1350	1350	900							
1500	750	450	300	1050	600	450	1500	1350	900							
1650				1050	600	450	1650	1350	900							
1800				1050	450	450	1800	1200	750							
1950				1050	450	450	1950	1200	750	1950	1950	1500				
2100							1950	1200	600	2100	1950	1500				
2250							1950	1200	600	2250	1950	1350				
2400							1950	1050	450	2400	1950	1350				
2550							1950	1050	450	2550	1950	1350				
2700										2700	1950	1200				

<sup>A</sup>Branch pipe of any profile with specified thickness as required by A 796/A 796M.

**TABLE 53 Requirements for Circumferential Reinforcement of Fittings in Main Pipe with ¾ by 1 by 11-½ in. Ribs<sup>A</sup>**

Maximum Branch Diameter for Which No Circumferential Reinforcement is Required, $d_m$ (in.)																
		0.064 in. Thick Main Pipe			0.079 in. Thick Main Pipe			0.109 in. Thick Main Pipe			0.138 in. Thick Main Pipe			0.168 in. Thick Main Pipe		
Main Pipe Dia., in	$He = 10$ ft	$He = 20$ ft	$He = 30$ ft	$He = 10$ ft	$He = 20$ ft	$He = 30$ ft	$He = 10$ ft	$He = 20$ ft	$He = 30$ ft	$He = 10$ ft	$He = 20$ ft	$He = 30$ ft	$He = 10$ ft	$He = 20$ ft	$He = 30$ ft	
48	18	12	12	30	18	18	48	36	24							
54	18	12	12	30	18	18	54	36	24							
60	18	12	12	30	18	12	54	36	18							
66	18	12		30	18	12	54	36	18							
72				30	18	12	54	30	18							
78				30	18	12	54	30	18							
84				24	18		54	24	18							
90							54	24	12							
96							54	24	12							
102							54	18	12							
108							54	18	12							

<sup>A</sup>Branch pipe of any profile with specified thickness as required by A 796/A 796M.



**TABLE 54 Requirements for Circumferential Reinforcement of Fittings in Main Pipe with 19 by 25 by 292 mm Ribs<sup>A</sup>**

Maximum Branch Diameter for Which No Circumferential Reinforcement is Required, $d_m$ (mm)																
Main Pipe Dia., mm	1.63 mm Thick Main Pipe			2.01 mm Thick Main Pipe			2.77 mm Thick Main Pipe			3.51 mm Thick Main Pipe			4.27 mm Thick Main Pipe			
	$H_e = 3$ m	$H_e = 6$ m	$H_e = 9$ m	$H_e = 3$ m	$H_e = 6$ m	$H_e = 9$ m	$H_e = 3$ m	$H_e = 6$ m	$H_e = 9$ m	$H_e = 3$ m	$H_e = 6$ m	$H_e = 9$ m	$H_e = 3$ m	$H_e = 6$ m	$H_e = 9$ m	
1200	450	300	300	750	450	450	1200	900	600							
1350	450	300	300	750	450	450	1350	900	600							
1500	450	300	300	750	450	300	1350	900	450							
1650	450			750	450	300	1350	900	450							
1800				750	450	300	1350	750	450							
1950				750	450	300	1350	750	450							
2100				600	450		1350	600	450							
2250							1350	600	300							
2400							1350	600	300							
2550							1350	450	300							
2700							1350	450	300							

<sup>A</sup>Branch pipe of any profile with specified thickness as required by A 796/A 796M.

**TABLE 55 Required Saddle Plate Thickness (in.)<sup>A</sup>**

Increased Main Pipe Thickness (in.) to Avoid Both Longitudinal and Circumferential Reinforcement Per 6.2 and 6.3	Original Main Pipe Thickness (in.) Per A 796			
	0.064	0.079	0.109	0.138
	Required Saddle Plate Thickness (in.)			
0.079	0.064	-	-	-
0.109	0.079	0.064	-	-
0.138	0.138	0.109	0.079	-
0.168	0.168	0.138	0.138	0.079

<sup>A</sup>Branch pipe of any profile with specified thickness as required by A 796/A 796M.

**TABLE 56 Required Saddle Plate Thickness (mm)<sup>A</sup>**

Increased Main Pipe Thickness (mm.) to Avoid Both Longitudinal and Circumferential Reinforcement Per 6.2 and 6.3	Original Main Pipe Thickness (mm) Per A 796			
	1.63	2.01	2.77	3.51
	Required Saddle Plate Thickness (mm)			
2.01	1.63	-	-	-
2.77	2.01	1.63	-	-
3.51	3.51	2.77	2.01	-
4.27	4.27	3.51	3.51	2.01

<sup>A</sup>Branch pipe of any profile with specified thickness as required by A 796/A 796M.

## APPENDIX

### (Nonmandatory Information)

#### X1. Background Information

X1.1 This practice is based mainly on the results of three dimensional finite element analyses<sup>8</sup> of main pipes with openings cut for branch pipes. The longitudinal reinforcements at the top and bottom of the branch pipe reduce the longitudinal

tension stresses that concentrate in the main pipe at these locations. The circumferential reinforcements at the sides of the branch pipe reduce the circumferential ring compression stresses that concentrate in the main pipe. For the identified cases where the concentrations are not excessive, no reinforcement is required. The strength contribution of the branch pipe stub, fully welded to the main pipe, with an assumed thickness of 0.064 in. was considered.

<sup>8</sup> Brockenbrough, R.L., "Fittings Reinforcement in Corrugated Steel Pipe," paper presented at A2C06 Session on Latest Advances in Metal Culvert Design and Construction, Transportation Research Board, 1999 Annual Meeting, Washington, DC.

Single reinforcement with twice the cross section area can be used in lieu of the two reinforcements shown between branch pipes.

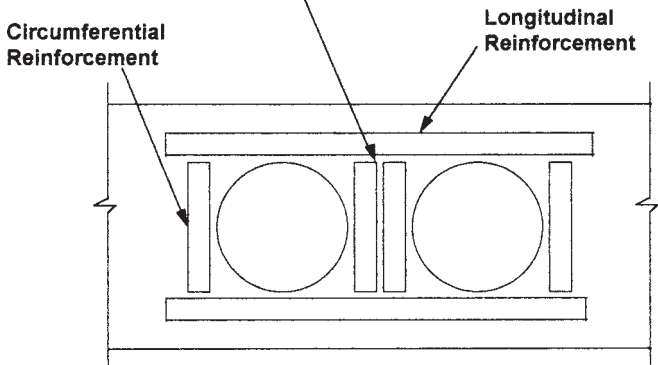


FIG. 4 Schematic of Multiple Reinforcements

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Designation: A 1003/A 1003M – 02a

## Standard Specification for Steel Sheet, Carbon, Metallic- and Nonmetallic-Coated for Cold-Formed Framing Members<sup>1</sup>

This standard is issued under the fixed designation A 1003/A 1003M; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon ( $\epsilon$ ) indicates an editorial change since the last revision or reapproval.

<sup>1</sup> This specification is under the jurisdiction of ASTM Committee A05 on Metallic-Coated Iron and Steel Products and is the direct responsibility of Subcommittee A05.11 on Sheet Specifications.

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### 1. Scope

1.1 This specification covers coated steel sheet used in the manufacture of cold-formed framing members, such as, but not limited to, studs, joists, purlins, girts, and track.

1.2 The steel sheet used for cold-formed framing members includes metallic-coated, painted metallic-coated, or painted nonmetallic-coated.

1.3 The values stated in either inch-pound or SI units shall be regarded separately as standard. Within the text, SI units are shown in brackets. The values stated in each system are not exact equivalents; therefore, each system shall be used independently of the other.

1.4 Unless the order specifies the “M” designation [SI units], the product shall be furnished to inch-pound units.

1.5 The text of this specification references notes and footnotes, which provide explanatory material. These notes and footnotes, excluding those in tables and figures, shall not be considered as requirements of this specification.

### 2. Referenced Documents

#### 2.1 ASTM Standards:

A 463/A 463M Specification for Steel Sheet, Aluminum-Coated, by the Hot-Dip Process<sup>2</sup>

A 568/A 568M Specification for Steel Sheet, Carbon, and High-Strength Low-Alloy, Hot-Rolled and Cold-Rolled, General Requirements for<sup>3</sup>

A 653/A 653M Specification for Steel Sheet, Zinc-Coated (Galvanized) or Zinc-Iron Alloy-Coated (Galvannealed) by the Hot-Dip Process<sup>2</sup>

A 755/A 755M Specification for Steel Sheet, Metallic-Coated by the Hot-Dip Process and Prepainted by the Coil-Coating Process for Exterior Exposed Building Products<sup>2</sup>

A 792/A 792M Specification for Steel Sheet, 55 % Aluminum-Zinc Alloy-Coated by the Hot-Dip Products<sup>2</sup>

A 875/A 875M Specification for Steel Sheet, Zinc-5 % Aluminum Alloy-Coated by the Hot-Dip Process<sup>2</sup>

A 879 Specification for Steel Sheet, Zinc Coated by the Electrolytic Process for Applications Requiring Designation of the Coating Mass on Each Surface<sup>2</sup>

A 902 Terminology Relating to Metallic-Coated Steel Products<sup>2</sup>

A 924/A 924M Specification for General Requirements for Steel Sheet, Metallic-Coated by the Hot-Dip Process<sup>2</sup>

A 941 Terminology Relating to Steel, Stainless Steel, Related Alloys, and Ferroalloys<sup>4</sup>

A 1004/A 1004M Practice for Establishing Conformance to the Minimum Expected Corrosion Characteristics of Metallic, Painted-Metallic, and Nonmetallic-Coated Steel Sheet Intended for Use as Cold-Formed Framing Members<sup>2</sup>

C 645 Specification for Nonstructural Framing Members

C 955 Specification for Load-Bearing (Transverse and Axial) Steel Studs, Runners (Tracks), and Bracing or Bridging for Screw Application of Gypsum Board and Metal Plaster Bases<sup>5</sup>

D 714 Test Method for Evaluating Degree of Blistering of Paints<sup>6</sup>

<sup>2</sup> Annual Book of ASTM Standards, Vol 01.06.

<sup>3</sup> Annual Book of ASTM Standards, Vol 01.03.

<sup>4</sup> Annual Book of ASTM Standards, Vol 01.01.

<sup>5</sup> Annual Book of ASTM Standards, Vol 04.01.

<sup>6</sup> Annual Book of ASTM Standards, Vol 06.01.

- D 1005 Test Methods for Measurement of Dry-Film Thickness of Organic Coatings Using Micrometers<sup>6</sup>  
D 1654 Test Method for Evaluation of Painted or Coated Specimens Subjected to Corrosive Environments<sup>6</sup>  
D 4138 Test Method for Measurement of Dry-Film Thickness of Protective Coating Systems by Destructive Means<sup>7</sup>  
D 4145 Test Method for Coating Flexibility of Prepainted Sheet<sup>7</sup>

2.2 *ISO Standard:*

ISO 9223 Corrosion of Metals and Alloys—Corrosivity of Atmospheres-Classification<sup>8</sup>

2.3 *AISI Standard:*

Specification for the Design of Cold-Formed Steel Structural Members<sup>9</sup>

### 3. Terminology

3.1 *Definitions*—See Terminology A 902 for definitions of general terminology relating to metallic-coated steel products, and Terminology A 941 for definitions of general terminology relating to uncoated steel sheet products.

3.2 *Definitions of Terms Specific to This Standard:*

3.2.1 *coating sequence, n*—the unbroken or uninterrupted manufacture of coils of the same coating designation.

3.2.2 *coil coater, n*—the organization that applies paint film coatings to coils of steel sheet on continuous paint lines.

3.2.3 *producer, n*—the organization that produces the steel sheet coil product from which the cold-formed members are fabricated.

3.2.4 *purlins and girts, n*—horizontal structural members that support roof deck or panel covering with loads applied principally by bending.

3.2.5 *resample, n*—additional tests made when the original test results do not satisfy the specification requirements.

3.2.6 *retest, n*—additional test, or tests, made when the original test results do not satisfy the specification requirements and the failure is due to a mechanical condition of the test specimen.

3.2.7 *roll former, n*—the organization that produces the cold-formed members.

3.2.8 *zinc-iron alloy, n*—a dull grey coating with no spangle pattern that is produced on hot-dip zinc-coated steel sheet.

3.2.8.1 *Discussion*—Zinc-iron alloy-coating is normally dull gray in appearance when produced by the manufacture of the coated sheet. Typically, the coating contains between 8 and 12 % iron, which is the result of a diffusion reaction between the steel sheet and the zinc coating during the coating process. In most applications, this product is intended to be painted. The coating offers excellent paint adhesion. When the product is exposed to the environment without a paint coating, there is a tendency for the development of a rust-colored stain on the surface. This is caused by the presence of iron in the coating. This stain may be aesthetically objectionable to some users of cold formed framing members.

3.2.9 *aluminum coating type 1, n*—a coating of aluminum and silicon alloy on steel sheet.

3.2.9.1 *Discussion*—Aluminum-coated steel sheet type 1 provides protection from corrosion primarily through the barrier action of the coating. The aluminum-silicon alloy coating provides galvanic corrosion only in marine environments. Because this coating does not generally provide galvanic protection, rust staining may be evident at area where the base metal is exposed to the environment, such as at punch-outs, cut or sheared edges of members, and at scratches.

3.2.10 *aluminum coating type 2, n*—a coating of commercially pure aluminum on steel sheet.

3.2.10.1 *Discussion*—Aluminum-coated steel sheet type 2 provides protection from corrosion primarily through the barrier action of the coating. The aluminum coating provides galvanic corrosion only in marine environments. Because this coating does not generally provide galvanic protection, rust staining may be evident at areas where the base metal is exposed to the environment such as at punch-outs, cut or sheared edges of members, and at scratches.

3.3 *Suffixes:*

*H, adj*—high ductility.

*L, adj*—low ductility.

*NS, adj*—nonstructural.

3.3.1 These designations are associated with aspects of the end uses of the steel products; *H* and *L* are associated with structural or load-bearing applications, and *NS* with nonstructural or nonload-bearing applications.

### 4. Classification

4.1 The steel sheet is available in the following designations:

4.1.1 Structural Grade 50 Type H (ST50H), Structural Grade 340 Type H [ST340H].

4.1.2 Structural Grade 40 Type H (ST40H), Structural Grade 275 Type H [ST275H].

4.1.3 Structural Grade 37 Type H (ST37H), Structural Grade 255 Type H [ST255H].

4.1.4 Structural Grade 33 Type H (ST33H), Structural Grade 230 Type H [ST230H].

4.1.5 Structural Grade 50 Type L (ST50L), Structural Grade 340 Type L [ST340L].

<sup>7</sup> Annual Book of ASTM Standards, Vol 06.02.

<sup>8</sup> Available from American National Standards Institute, 25 W. 43rd St., 4th Floor, New York, NY 10036 .

<sup>9</sup> Available from American Iron and Steel Institute, 1101 17th St., NW, Suite 1300, Washington, DC 20036.

- 4.1.6 Structural Grade 40 Type L (ST40L), Structural Grade 275 Type L [ST275L].
- 4.1.7 Structural Grade 37 Type L (ST37L), Structural Grade 255 Type L [ST255L].
- 4.1.8 Structural Grade 33 Type L (ST33L), Structural Grade 230 Type L [ST230L].
- 4.1.9 Nonstructural Grade 33 (NS33), Nonstructural Grade 230 [NS230]).

NOTE 1—Abbreviated designations are shown in parenthesis or brackets.

4.2 Use of Type L steels is limited to purlins and girts (see 3.2.4).

## 5. Ordering Information

5.1 Steel sheet in coils or cut lengths shall be ordered to base metal thickness requirements expressed in increments of 0.0001 in. [0.001 mm].

5.2 Orders for product to this specification shall include the following information, as necessary to adequately describe the desired product.

5.2.1 ASTM specification number and year of issue (A 1003 – \_\_\_ for inch-pound units and A 1003M – \_\_\_ for SI units),

5.2.2 Name of the material (metallic-coated steel sheet), (painted metallic-coated steel sheet), or (painted nonmetallic-coated steel sheet), and designation (see 4.1).

5.2.2.1 See Specification A 755/A 755M for additional ordering requirements for the painted-metallic-coated steel sheet.

5.2.3 Type of coating (metallic-coated; zinc, zinc-iron alloy, 55 % aluminum-zinc alloy, zinc-5 % aluminum alloy, aluminum-coated Type 1, and aluminum-coated Type 2, electrolytic zinc-coated), (painted-metallic-coated; metallic-coating and nonmetallic-coating type), (painted nonmetallic coated: nonmetallic-coating type).

5.2.3.1 Metallic coating weight [mass] designation (see Table 1), (see 9.1).

5.2.3.2 Nonmetallic coating thickness (see 9.2 or 9.3).

5.2.4 Chemically-treated or not chemically-treated (metallic-coated only).

5.2.5 Oiled or not-oiled,

5.2.6 Dimensions (show thickness, width, and flatness requirements and length, if cut lengths). Specify the applicable table of thickness tolerances of Specification A 924/A 924M, for metallic-coated, or A 568/A 568M for nonmetallic-coated sheet that applies to the order, that is, the table of thickness tolerances for  $\frac{3}{8}$ -in. [10-mm] edge distance, or the table of thickness tolerances for 1-in. [25-mm] edge distance.

5.2.7 Coil size requirements (specify maximum outside diameter (OD) acceptable inside diameter (ID), and maximum weight [mass]).

5.2.8 Packaging (specify requirements for banding, paper wrapping and other special packaging requirements).

5.2.9 Certification, if required (heat analysis, metallic coating weight or nonmetallic coating thickness and mechanical properties report).

5.2.10 Special Requirements, if any.

NOTE 2—Typical ordering descriptions are as follows: Steel sheet, zinc-coated, Structural Grade 50 Type H (ST50H), ASTM A 1003, Coating Designation G60, chemically-treated, not oiled, 0.035 by 48 in. by coil, thickness tolerance Table 2, 24-in ID, 30 000 lb maximum for steel studs, or

Steel sheet, zinc-coated, Structural Grade 230 Type L [ST230L], ASTM A 1003M, Coating Designation Z180, chemically-treated, not oiled, 1.00 mm by 920 mm by coil, thickness tolerance Table 2, 600 mm ID, 10 000 kg maximum for purlins.

NOTE 3—Electrolytic zinc-coated steel sheet designations indicate the coating on one surface only; therefore, the coating requirement must be specified for each side of the steel sheet as indicated in Table 1. Also, the electrolytic zinc-coated steel sheet is only available in SI values.

## 6. Materials and Manufacture

6.1 The ordered thickness shall be the base metal thickness.

NOTE 4—This requirement differs from the normal ordering practice for hot dip metallic-coated products where the ordered thickness includes the base

**TABLE 1 Coating Weight [Mass] Requirements  
(Metallic Coatings)**

Product Designation	Coating Designation
Type H and Type L	G60 [Z180] <sup>A</sup> A60 [Z180] <sup>B</sup> AZ50 [AZ150] <sup>C</sup> GF30 [ZGF90] <sup>D</sup> T1–25 [T1M 75] <sup>E</sup> T2–100 [T2M 300] <sup>F</sup> [90G/90G] <sup>F</sup>
Type NS	G40 [Z120] <sup>A</sup> A40 [Z120] <sup>B</sup> AZ50 [AZ150] <sup>C</sup> GF30 [ZGF90] <sup>D</sup> T1–25 [T1M 75] <sup>E</sup> T2–100 [T2M 300] <sup>F</sup> [60G/60G] <sup>F</sup>

<sup>A</sup>Zinc-coated steel sheet as described in Specification A 653/A 653M.

<sup>B</sup>Zinc-iron alloy-coated steel sheet as described in Specification A 653/A 653M.

<sup>C</sup>55 % aluminum-zinc alloy-coated as described in Specification A 792/A 792M.

<sup>D</sup>Zinc-5 % aluminum alloy-coated steel sheet as described in Specification A 875/A 875M.

<sup>E</sup>Aluminum-coated Type 1 and Type 2 steel sheet as described in Specification A 463/A 463M.

<sup>F</sup>Zinc-coated steel sheet as described in Specification A 879



**TABLE 2 Mechanical Properties, Base Metal**

NOTE 1—All values are minimum requirements in the longitudinal direction.

Designation	Yield Strength, ksi [MPa]	Tensile Strength, ksi [MPa]	Elongation <sup>A</sup> in ½ in. [13 mm]	Elongation in 2 in. [50 mm]
ST50H [ST340H]	50 [340] <sup>B</sup>	65 [450]	C	10 %
ST40H [ST275H]	40 [275] <sup>B</sup>	55 [380]	C	10 %
ST37H [ST255H]	37 [255] <sup>B</sup>	52 [360]	C	10 %
ST33H [ST255H]	33 [230] <sup>B</sup>	45 [310]	C	10 %
ST50L [ST340L] <sup>D</sup>	50 [340]		20 % <sup>E</sup>	3 % <sup>F</sup>
ST40L [ST275L] <sup>D</sup>	40 [275]		20 % <sup>E</sup>	3 % <sup>F</sup>
ST37L [ST255L] <sup>D</sup>	37 [255]		20 % <sup>E</sup>	3 % <sup>F</sup>
ST33L [ST230L] <sup>D</sup>	33 [230]		20 % <sup>E</sup>	3 % <sup>F</sup>
NS 33	33 [230]		... <sup>G</sup>	... <sup>G</sup>

<sup>A</sup>The procedure for determining the local and uniform elongation can be found in the *AISI Cold Formed Design Manual*, "Standard Methods for Determination of Uniform and Local Ductility."

<sup>B</sup>Ratio of tensile strength to yield strength for the Type H steels shall not be less than 1.08.

<sup>C</sup>Elongation in ½-in. [13-mm] is not required.

<sup>D</sup>The use of Type L steels shall be limited to purlins and girts (see 3.2.4).

<sup>E</sup>Local elongation in a ½-in. [13-mm] gage length across the fracture.

<sup>F</sup>Uniform elongation outside of the fracture.

<sup>G</sup>Where an ellipsis appears there is no requirement.

metal and the coating but is similar to the ordering practice for heavy coating mass electrolytic coated product.

**7. Chemical Composition**

7.1 *Base Metal:*

7.1.1 The chemical composition of the steel sheet shall conform to the requirements of Table 3.

7.1.2 All tests shall be conducted in accordance with the requirements for chemical composition as described in Specification A 924/A 924M for products with metallic coatings and Specification A 568/A 568M for nonmetallic coated products.

7.1.3 An analysis of each heat of steel shall be made by the producer to determine the percentage of elements specified in Table 3.

7.1.4 In those cases where the heat analysis is not available a product analysis test shall be performed to determine conformance with the requirements of Table 3.

**TABLE 3 Chemical Composition Heat and Product Analysis, Max %**

Element	Heat Analysis	Product Analysis
Carbon	0.25	<sup>A</sup>
Manganese	1.15	<sup>A</sup>
Phosphorus	0.20	<sup>A</sup>
Sulfur	0.04	<sup>A</sup>
Copper	0.20 <sup>B</sup>	0.23
Nickel	0.20 <sup>B</sup>	0.23
Chromium	0.15 <sup>B,C</sup>	0.19
Molybdenum	0.06 <sup>B</sup>	0.07
Vanadium	0.008 <sup>D</sup>	0.018 <sup>D</sup>
Columbium	0.008 <sup>D</sup>	0.018 <sup>D</sup>
Titanium	0.008 <sup>D</sup>	0.018 <sup>D</sup>

<sup>A</sup>Product analysis tolerances for these elements are found in Table 1 of Specification A 924/A 924M.

<sup>B</sup>The sum of copper, chromium, nickel, and molybdenum shall not exceed 0.50 %. When one or more of these elements are specified, the sum does not apply. If this occurs, only the individual limits on the remaining elements shall apply.

<sup>C</sup>Chromium is permitted, at producer's option, to 0.25 % maximum when the carbon content is less than or equal to 0.05 %. In this case, the limit on the sum of the four elements in footnote<sup>B</sup> does not apply.

<sup>D</sup>The limits for steels whose carbon content is 0.02 % or less are as follows:

Element	Heat Analysis	Product Analysis
Vanadium	0.10	0.11
Columbium	0.045	0.055
Titanium	0.30	0.33

7.1.5 Each of the elements listed in Table 3 shall be included in the report of heat or product analysis. When the amount of copper, nickel, chromium, or molybdenum is less than 0.02 %, report the analysis as <0.02 % or the actual determined value. When the amount of vanadium, columbium, or titanium is less than 0.008 %, report the analysis as <0.008 % or the actual determined value.

## 8. Mechanical Properties

8.1 The mechanical properties of the steel sheet shall conform to the requirements shown in Table 2.

8.2 Tests for mechanical properties of the “H” and “NS” steel designations shall be conducted in accordance with the tests for mechanical properties described in Specification A 924/A 924M for metallic-coated steel sheet and A 568/A 568M for nonmetallic coated steel sheet.

8.3 Tests for elongation in ½ in. [13 mm] of the “L” steel designations shall be conducted in accordance with the procedure found in the *AISI Cold Formed Design Manual*, “Standard Methods for Determination of Uniform and Local Ductility.”

## 9. Coating Properties

9.1 *Metallic Coating*—The minimum metallic coating weight [mass] requirements shall be as shown in Table 1.

9.1.1 Not all coatings will react the same under a given set of environmental conditions. These minimum coating designations assume normal exposure conditions and construction practices. When more severe exposure conditions are probable, for example, in coastal areas, consideration should be given to specifying heavier coating weight [mass].

9.1.2 Other metallic coatings shall be considered for inclusion to Table 1 provided they satisfy the minimum expected corrosion characteristics as indicated by laboratory testing conducted in accordance with Practice A 1004/A 1004M.

9.1.3 The minimum expected corrosion characteristics as indicated by laboratory testing for metallic coated sheet steels are as follows:

9.1.3.1 *Corrosion Standard*—No more than 10 % loss of coating from the surface of the laboratory test sample at the end of the prescribed test duration.

9.1.3.2 *Test Duration*—Minimum exposure for Type H and Type L steels is 100 h. Minimum exposure for Type NS steels is 75 h.

NOTE 5—The 10 % standard is intended to be used for laboratory evaluation only and not for assessing rust condition of installed cold formed members.

9.1.4 All tests for coating weight [mass] shall be conducted in accordance with the coating properties of Specifications A 653/A 653M, A 792/A 792M, and A 875/A 875M.

9.2 *Painted-Metallic Coatings*:

9.2.1 Painted-metallic-coated steel sheet shall consist of a metallic-coated substrate and a paint film.

9.2.2 The metallic-coated substrate shall meet the coating weight [mass] requirements of Table 1.

9.2.3 The paint film shall have a minimum thickness of 0.5 mil per side (primer plus topcoat) with a minimum primer thickness of 0.1 mil per side.

9.2.4 The paint film thickness shall be determined according to the requirements of Test Methods D 1005 and D 4138.

9.2.5 The flexibility and adhesion of the paint film shall be determined according to the requirements of Test Method D 4145.

9.2.6 The minimum expected corrosion characteristics as indicated by laboratory testing for painted metallic-coated steel sheet are as follows:

9.2.6.1 *Corrosion Standard*—Mean creepage from a scribe shall satisfy a rating number of 6 (¼ in. [2 mm] to ⅜ in. [3 mm]) (in accordance with Test Method D 1654) and no resistance to blistering shall satisfy the requirement of “no more than a few scattered number 8 blisters” on the surface of the test specimens at the end of the prescribed test duration. See Test Method D 714 for a description including photographic standards of the term “few.”

9.2.6.2 *Test Duration*—Minimum exposure of 500 h.

9.2.7 The laboratory procedure for determining conformance to the minimum expected corrosion characteristics is described in Practice A 1004/A 1004M.

9.3 *Nonmetallic Coatings*:

9.3.1 Nonmetallic-coated (painted) steel sheet is intended to be used in environments where the rate of corrosion is low. Typically, these environments include very dry atmospheres, such as areas of low rainfall and low humidity, and the interior of buildings that are climate-controlled. The application of painted product shall be restricted to applications defined as Category 1 or 2 of Table A1.1. These categories are described in ISO 9223.

9.3.2 Nonmetallic-coated steel which is painted after roll forming shall have a minimum paint thickness of 1.0 mil on all surfaces including the edges.

9.3.3 The minimum expected corrosion characteristics as indicated by laboratory testing for nonmetallic-coated painted sheet steel are as follows:

9.3.3.1 *Corrosion Standard*—Mean creepage from a scribe shall satisfy a rating number of 6 (¼ in. [2 mm] to ⅜ in. [3 mm]) (in accordance with Test Method D 1654) and resistance to blistering shall satisfy the requirement of “no more than a few scattered number 8 blisters” on the surface of the test specimens at the end of the prescribed test duration. See Test Method D 714 for a description including photographic standards of the term “few.”

9.3.3.2 *Test Duration*—Minimum exposure 250 h.

9.3.4 The laboratory procedure for determining conformance to the minimum expected corrosion characteristics is described in Practice A 1004/A 1004M.

## 10. Number of Tests

10.1 The producer, coil coater, and rollformer shall be responsible for conducting a sufficient number of tests to certify all of the material to the applicable requirements of this specification.

10.2 *Producer*—Each coating sequence and heat shall be tested by the producer to indicate conformance to the requirements of this specification. At least one test per coating sequence shall be performed to assess coating weight conformance.

### 10.3 *Coil Coater*:

10.3.1 The certified test results of the producer shall be used to certify conformance of the substrate to the requirements of this specification.

10.3.2 If certified test results are not available from the producer, the coil coater shall test the product to verify conformance of the substrate to the requirements of this specification.

10.3.2.1 *Type H and Type L Steels*—All coils shall be tested to determine conformance with applicable requirements of this specification. This requirement applies to all coils segments that have been joined to form larger coils.

10.3.2.2 *Type NS Steels*—The number of tests taken to certify the material shall be appropriate to the specific condition and processing history of the material.

10.3.3 The coil coater shall test each coil to assure conformance with the requirements of the nonmetallic coating(s).

### 10.4 *Roll Former*:

10.4.1 The certified result of tests for mechanical properties and coating weight from the producer or coil coater, shall be used to certify the conformance of the material used for the manufacture of the cold formed framing members.

10.4.2 If certified test results are not available from the producer or coil coater, and a certified test report is required on the purchase order, the roll former shall test in accordance with the following requirements.

10.4.2.1 *Type H and Type L Steels*—As a minimum, all coils shall be tested in order to determine conformance with the applicable requirements of this specification. This requirement applies to each of the coil segments joined together to form larger coils and after all processing of the flat sheet has taken place. Sufficient testing shall be done to assure that all of the cold formed framing members associated with a certified report satisfy the applicable requirements.

10.4.2.2 *NS Steels*—The number of tests taken to certify the material shall be appropriate to the specific condition and processing history of the material.

10.4.3 Testing by the roll former for those characteristics that are unchanged by additional processing, such as chemical composition, is not required when certified reports of test are available from the producer or coil coater.

10.4.4 Testing shall be performed by the roll former after all processing, such as cold rolling, has occurred, which alters the mechanical properties of the flat-steel sheet.

## 11. Retests and Resamples

### 11.1 *Retests*:

11.1.1 If any test specimen shows defective machining or other flaws, it must be discarded and another specimen substituted.

11.1.2 If the results on an original tensile test are within 2000 psi [14 MPa] of the required yield strength, or within two percentage points of the required elongation, a retest shall be permitted for which one random specimen from the heat or test lot shall be used. If the result on this retest specimen satisfy the specified mechanical requirements, the lot shall be accepted.

### 11.2 *Resamples*:

11.2.1 If the results of the original tensile test are below the required yield strength or more than two percentage points below the required elongation, resamples shall be permitted providing material represented by the original test specimen is discarded.

11.2.2 Resampling requires two test specimens be taken to qualify the heat or test lot. The first test shall be taken adjacent to the material discarded from the lot and the second from another location within the lot to be qualified. The results of both test shall satisfy the specification requirements.

11.2.3 A maximum of two resamples shall be permitted. If the resampled material does not satisfy the requirements, the coil or coils shall be rejected.

## 12. Certification

12.1 When required by the purchaser as indicated on the purchase order, a certificate of compliance or a test report, or both, shall be furnished to the purchaser.

12.2 The certificate of compliance shall include a certification that the product has been manufactured and tested in accordance with the requirements of the specification, and that the test results conform to the requirements of that specification.

12.3 The test report shall show the results of all tests required by the specification and the order.

12.4 The documents shall provide information necessary to identify the product represented; for example, the manufacturer's name or brand, ASTM specification, name of the material, product designation, heat number, metallic coating weight, nonmetallic-coating type and thickness, ordered thickness, width, length, and section, unit identification (coil number, heat number, invoice number, etc.).

12.5 A signature is not required on the test report; however, the document shall identify clearly the organization submitting the report. Notwithstanding the absence of a signature, the organization submitting the report is responsible for the content of the report.

12.6 A material test report, certificate of inspection, or similar document printed from or used in electronic form from an electronic data interchange (EDI) transmission shall be regarded as having the same validity as a counterpart printed in the certifier’s facility. The content of the EDI transmitted document must meet the requirements of the invoked ASTM standard and conform to any existing EDI agreement between the purchaser and the supplier. Notwithstanding the absence of a signature, the organization submitting the EDI transmission is responsible for the content of the report.

12.7 The furnishing of a certificate of compliance or test report, or both, shall not restrict the right of the purchaser to sample and test the material furnished.

12.8 When specified in the purchase order or contract, an independent third party shall be used to certify that a producer, coil coater or roll former maintains an adequate quality assurance program.

### 13. Product Marking

13.1 Coils from the producer and coil coater purchased according to this specification, as a minimum, shall be identified with the producer’s name or brand, ASTM specification, product designation, coating designation, size, unit weight, purchaser’s order number, and unit identification, that is, ticket number, coil number, etc. legibly shown on a tag attached to each coil or shipping unit.

13.2 Except for the products described in Specifications C 645 and C 955 all cold-formed products manufactured from material purchased or certified to this specification, shall be marked legibly to indicate conformance with the following: minimum steel sheet thickness, metallic-coating designation, nonmetallic-coating thickness, nonmetallic-coating type, minimum yield strength, product designation, and name of manufacturer.

### 14. Keywords

14.1 metallic-coated steel sheet; steel framing members—cold-formed; steel products—metallic-coated; steel sheet

## ANNEX

### (Mandatory Information)

#### A1. CATEGORIES OF ATMOSPHERES

Category	Description of Categories <sup>A</sup>
1	Interior climates with climate controlled conditions
2	Properly ventilated interior climates without climate controlled conditions in dry temperature locations [Exceptions — locations (1) with average to high humidity, (2) with substantial air pollution, and/or (3) close to the seacoast.] Exterior climates that are (1) very dry and (2) very warm or dry and very cold.
3	Exterior climates that are dry and warm or cold. Properly ventilated interior climates in (1) dry, warm or cold locations, and (2) temperate locations, both without climate control.
4	All temperate, average humidity exterior climates. Properly ventilated interior climates in humid locations. Unventilated buildings in temperate climates; no climate control.
5	All damp exterior climates. Unventilated buildings in humid climates.

<sup>A</sup>See ISO 9223, First Edition 1992–02–15.

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# Standard Practice for Establishing Conformance to the Minimum Expected Corrosion Characteristics of Metallic, Painted-Metallic, and Nonmetallic-Coated Steel Sheet Intended for Use as Cold Formed Framing Members<sup>1</sup>

This standard is issued under the fixed designation A 1004/A 1004M; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reappraisal. A superscript epsilon ( $\epsilon$ ) indicates an editorial change since the last revision or reappraisal.

## 1. Scope

1.1 This practice covers procedures for establishing the acceptability of metallic-coated steel sheet, painted metallic-coated steel sheet and painted nonmetallic-coated steel sheet for use as cold formed framing members.

1.2 This practice shall be used to assess the corrosion resistance of different coatings on steel sheet in a laboratory test. It shall not be used as an application performance standard for the cold formed framing members.

1.3 The practice shall be used to evaluate coatings under consideration for addition to Specification A 1003/A 1003M.

1.4 The values stated in either inch-pound or SI units are to be regarded separately as standard. Within the text, the SI units are shown in brackets. The values stated in each system are not exact equivalents; therefore, each system must be used independently of the other.

1.5 The text of this standard references notes and footnotes that provide explanatory material. These notes and footnotes, excluding those in tables and figures, shall not be considered as requirements of the standard.

## 2. Referenced Documents

### 2.1 ASTM Standards:

A 902 Terminology Relating to Metallic Coated Steel Products<sup>2</sup>

A 1003/A 1003M Specification for Steel Sheet, Carbon, Metallic and Non-Metallic Coated for Cold Formed Framing Members<sup>2</sup>

B 117 Practice for Operating Salt Spray (Fog) Testing Apparatus<sup>3</sup>

D 714 Test Method for Evaluating Degree of Blistering of Paints<sup>4</sup>

D 1654 Test Method for Evaluation of Painted or Coated Specimens Subjected to Corrosive Environments<sup>4</sup>

<sup>1</sup> This practice is under the jurisdiction of Committee A-5 on Metallic-Coated Iron and Steel Products and is the direct responsibility of Subcommittee A05.11 on Sheet Specifications.

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<sup>2</sup> Annual Book of ASTM Standards, Vol 01.06.

<sup>3</sup> Annual Book of ASTM Standards, Vol 03.02.

<sup>4</sup> Annual Book of ASTM Standards, Vol 06.01.

## 3. Terminology

3.1 For definitions of terms related to metallic-coated steel products, see Terminology A 902.

### 3.2 Definitions of Terms Specific to This Standard:

3.2.1 *red rust, n*—the oxide formed when iron combines chemically with oxygen.

3.2.2 *red rust stains, n*—the discoloration of the surface of a coated steel sheet caused by the bleeding of red rust from adjacent areas.

## 4. Summary of Practice

4.1 This practice involves exposing flat and formed samples of metallic-coated, painted metallic-coated and painted nonmetallic-coated steel sheet to a controlled saline environment using Practice B 117 and measuring the extent of corrosion after a predetermined time of exposure in the accelerated test.

4.2 The samples exposed to the saline environment are prepared according to Test Method D 1654.

4.3 The maximum acceptable amount of corrosion allowed for each material is described in Specification A 1003/A 1003M.

## 5. Significance and Use

5.1 This practice is intended solely for the evaluation of metallic-coated, painted metallic-coated, and painted nonmetallic-coated materials used for the manufacture of cold formed framing members.

5.2 Correlation and extrapolation of corrosion performance based on exposure to the test environment provided by Practice B 117 are not always predictable. Correlation and extrapolation should be considered only in cases where appropriate corroborating long-term atmospheric exposures have been conducted.

5.3 This practice assesses whether coated materials not currently in Specification A 1003/A 1003M satisfy the required minimum corrosion characteristics.

## 6. Procedure

### 6.1 General Requirements:

6.1.1 Select test panels from routine production material ensuring that the samples are representative of the material.



Test panels with the normally applied surface coatings such as chemical treatment or oil, or both.

6.1.2 The size of flat test panels shall be 4 by 12 in. [100 by 300 mm]. Formed panels shall be 4 by 12 in. [100 by 300 mm] or the actual production width, if smaller than the 4-in. [100-mm] width requirement.

6.1.3 Orient test panels in the salt spray cabinet with the 12-in. [300-mm] dimension in the vertical position.

6.2 *Metallic-Coated Products:*

6.2.1 Use Practice B 117 to evaluate conformance with the minimum expected corrosion characteristics.

6.2.2 Test at least three samples from three different production runs of a candidate product.

6.2.3 Protect the edges of all test panels from exposure to the salt solution.

6.2.4 Metallic-coated materials shall satisfy the minimum corrosion characteristics of G60 [Z180] for the Type H and Type L steels and G40 [Z120] for the Type NS steels.

6.2.5 Test for 100 h for Type H and Type L materials or 75 h for Type NS material.

6.2.6 Loss of coating is indicated by the appearance of red rust in areas devoid of any metallic coating. The products of oxidation combined with the salt solution have a tendency to coat the test sample with a red rust stain. Remove the red rust stain before evaluating the test panel.

NOTE 1—The test criteria for metallic-coated products are listed in Specification A 1003/A 1003M.

6.3 *Painted Metallic-Coated:*

6.3.1 Use Practice B 117 to establish the minimum expected corrosion characteristics.

6.3.2 Test at least three samples from three different production runs of a candidate product.

6.3.3 The metallic-coated substrate of the painted metallic-coated steel sheet shall satisfy the test requirements described in 6.2

6.3.4 Painted metallic-coated test panels shall have a scribe that penetrates the nonmetallic coating only. The scribe shall be at an angle of 30° to the longest panel (12 in. [300 mm]) dimension.

6.3.5 Protect the edges of all test panels from exposure to the salt solution.

6.3.6 Test for 500 h to establish conformance to the minimum expected corrosion characteristics of the nonmetallic coating.

NOTE 2—The test criteria for painted metallic-coated product are listed in Specification A 1003/A 1003M.

6.3.7 Evaluate the mean creepage in accordance with Test Method D 1654.

6.3.8 Evaluate the blisters in accordance with Test Method D 714.

6.4 *Painted Nonmetallic-Coated Products:*

6.4.1 Use Practice B 117 to establish the minimum expected corrosion characteristics.

6.4.2 Test at least three samples from three different production lots of a candidate material.

6.4.3 Painted nonmetallic-coated test panels shall have a scribe that penetrates the nonmetallic coating only. The scribe shall be at an angle of 30° to the longest panel (12 in. [300 mm]) dimension.

6.4.4 Protect the edges of all test panels from exposure to the salt solution.

6.4.5 Test for 250 h to establish conformance to requirements.

NOTE 3—The test criteria for painted nonmetallic-coated product are listed in Specification A 1003/A 1003M.

6.4.6 Evaluate the mean creepage in accordance with Test Method D 1654.

6.4.7 Evaluate the blisters in accordance with Test Method D 714.

## 7. Report

7.1 Subcommittee A05.11 will consider the addition of coating systems not currently referenced in Specification A 1003/A 1003M through the review of results of tests conducted according to this practice.

## 8. Keywords

8.1 Corrosion; metallic-coated sheet; painted metallic-coated sheet; painted nonmetallic-coated sheet; salt spray; sheet steel


## APPENDIX

### (Nonmandatory Information)

#### X1. GENERAL INFORMATION ON THE SIGNIFICANCE AND USE OF SALT SPRAY TESTING

X1.1 Practice B 117, salt spray (fog) testing, is commonly used to assess the relative corrosion resistance of a coated steel product through the use of a controlled corrosive environment. The practice, however, is sometimes mistakenly considered to be a guide for the evaluation of corrosion resistance of coated products. As stated in that standard Practice B 117 describes the apparatus, procedure, and conditions required to create and maintain the salt spray (fog) test environment. The practice

does not prescribe the type of test specimen or exposure periods to be used for a specific product, nor the interpretation to be given to the results. The practice provides a controlled corrosive environment that has been utilized to produce relative corrosion resistance information for specimens of metals and coated metals in any particular test chamber. Consequently, users of Practice B 117 must describe specific information on the test specimens such as size, degree of exposed surface

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(edges protected or not), and localization of corrosion with a scribe through the coating. The users must also define the “end of test” criteria. Examples of these criteria include: onset of first rust, degree of delamination of protective film, or loss of coating to rust. Development of these criteria must consider the corrosion resistance mechanism of the product under test, for example, galvanic protection or barrier protection.

X1.2 Industry experience with Practice B 117 has resulted in a body of knowledge of the testing protocols and test criteria

for specific products. The requirements contained in Annexes A1.1, A2.1 and A2.2 of Practice B 117 reflect this experience.

X1.3 While the limitations of salt spray testing are widely recognized, the test remains in use, especially as a quality control tool. Because of its limitations, salt spray testing should not be used to predict service performance, nor should it be used to rank dissimilar materials. Its use should be limited to process qualification and quality control.

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## Standard Specification for Closed Rib Steel Pipe with Diameter of 36 in. [900 mm] or Less, Polymer Precoated for Sewers and Drains<sup>1</sup>

This standard is issued under the fixed designation A 1019/A 1019M; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon ( $\epsilon$ ) indicates an editorial change since the last revision or reapproval.

### 1. Scope

1.1 This specification covers polymer precoated, closed rib steel pipe, intended for use for storm water drainage, under-drains, the construction of culverts, and similar uses. Pipe covered by this specification is not normally used for the conveyance of sanitary or industrial wastes. The steel sheet used in fabrication of the pipe has a polymer protective coating over a metallic coating of zinc.

1.2 The polymer precoating provides extra protection of the base metal against corrosion or abrasion, or both, in addition to that provided by the metallic coating. Severe environments are likely to cause corrosion problems to accessory items such as coupling band hardware that does not have a polymer coating unless supplemental protection is provided. Additional protection for polymer precoated steel pipe is available by use of coatings applied after fabrication of the pipe as described in Specification A 849.

1.3 This specification does not include requirements for bedding, backfill, or the relationship between earth cover load and sheet thickness of the pipe. Experience with drainage products has shown that successful performance depends upon the proper selection of rib depth, sheet thickness, type of bedding and backfill, controlled manufacture in the plant, and care in installation. The installation procedure is described in Practice A 798/A 798M.

1.4 This specification is applicable to orders in either inch-pound units as A 1019, or in SI units as A 1019M. Inch-pound units and SI units are not necessarily equivalent. SI units are shown in brackets in the text for clarity, but they are the applicable values when the material is ordered to A 1019M.

1.5 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

### 2. Referenced Documents

#### 2.1 ASTM Standards:

- A 90/A90M Test Method for Weight [Mass] of Coating on Iron and Steel Articles With Zinc or Zinc-Alloy Coatings<sup>2</sup>
- A 153/A153M Specification for Zinc Coating (Hot-Dip) on Iron and Steel Hardware<sup>2,3</sup>
- A 307 Specification for Carbon Steel Bolts and Studs, 60,000 psi Tensile Strength<sup>3</sup>
- A 563 Specification for Carbon and Alloy Steel Nuts<sup>3</sup>
- A 563M Specification for Carbon and Alloy Steel Nuts [Metric]<sup>3</sup>
- A 653/A653M Specification for Steel Sheet, Zinc-Coated (Galvanized) or Zinc-Iron Alloy-Coated (Galvannealed) by the Hot-Dip Process<sup>2</sup>
- A 742/A742M Specification for Steel Sheet, Metallic Coated, and Polymer Precoated for Corrugated Steel Pipe<sup>2</sup>
- A 780 Practice for Repair of Damaged Hot-Dip Galvanized Coatings<sup>2</sup>
- A 796/A796M Practice for Structural Design of Corrugated Steel Pipe, Pipe-Arches, and Arches for Storm and Sanitary Sewers and Other Buried Applications<sup>2</sup>
- A 798/A798M Practice for Installing Factory-Made Corrugated Steel Pipe for Sewers and Other Applications<sup>2</sup>
- A 849 Specification for Post-Applied Coatings, Pavings, and Linings for Corrugated Steel Sewer and Drainage Pipe<sup>2</sup>
- A 902 Terminology Relating to Metallic Coated Steel Products<sup>2</sup>
- A 924/A924M Specification for General Requirements for Steel Sheet, Metallic-Coated by the Hot-Dip Process<sup>2</sup>
- B 633 Specification for Electrodeposited Coatings of Zinc on Iron and Steel<sup>3</sup>
- B 695 Specification for Coatings of Zinc Mechanically Deposited on Iron and Steel<sup>4</sup>
- C 443 Specification for Joints for Circular Concrete Sewer and Culvert Pipe, Using Rubber Gaskets<sup>5</sup>
- D 1005 Test Methods for Measurement of Dry-Film Thickness of Organic Coatings Using Micrometers<sup>6</sup>
- D 1056 Specification for Flexible Cellular Materials,

<sup>1</sup> This specification is under the jurisdiction of ASTM Committee A05 on Metallic Coated Iron and Steel Products and is the direct responsibility of Subcommittee A05.17 on Corrugated Steel Pipe Specifications.

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<sup>2</sup> *Annual Book of ASTM Standards*, Vol 01.06.

<sup>3</sup> *Annual Book of ASTM Standards*, Vol 15.08.

<sup>4</sup> *Annual Book of ASTM Standards*, Vol 02.05.

<sup>5</sup> *Annual Book of ASTM Standards*, Vol 04.05.

<sup>6</sup> *Annual Book of ASTM Standards*, Vol 06.01.

Sponge or Expanded Rubber<sup>7</sup>

E 29 Practice for Using Significant Digits in Test Data to Determine Conformance with Specifications<sup>8</sup>

F 568 Specification for Carbon and Alloy Steel Externally Threaded Metric Fasteners<sup>3</sup>

2.2 AASHTO Standard:

T 249M Test for Helical Lock Seam Corrugated Pipe<sup>9</sup>

### 3. Terminology

3.1 *General Definitions*—For definitions of general terms used in this standard, refer to Terminology A 902.

3.2 *Definitions of Terms Specific to This Standard:*

3.2.1 *fabricator*—the producer of the pipe.

3.2.2 *manufacturer*—the producer of the sheet.

3.2.3 *purchaser*—the purchaser of the finished product.

### 4. Classification

4.1 The closed rib steel pipe covered by this specification is of the following type:

4.1.1 *Type ICR*—This pipe shall have a full circular cross section with a single thickness of smooth sheet, fabricated with closed helical ribs projecting outwardly.

### 5. Ordering Information

5.1 Orders for material to this specification shall include the following information as necessary, to adequately describe the desired product.

5.1.1 Name of material (polymer-coated closed rib steel pipe),

5.1.2 ASTM designation and year of issue, as A 1019 - XX for inch-pound units or as A 1019M - XX for SI units,

5.1.3 Diameter of circular pipe (Table 1),

5.1.6 Sheet thickness (8.2),

5.1.7 Coupling bands, number, and type (9.1) if special type is required,

5.1.8 Gaskets for coupling bands, if required (9.2.5),

5.1.9 Certification, if required (14.1), and

5.1.10 Special requirements.

### 6. Materials and Manufacture

6.1 *Steel Sheet for Pipe*—All pipe fabricated under this specification shall be formed from polymer precoated sheet conforming to Annex A1 of this specification.

6.1.1 The polymer coating shall be applied to steel sheet having a metallic coating of zinc.

6.2 *Steel Sheet for Coupling Bands*—The sheet used in fabricating coupling bands shall be the same as that specified for fabrication of the pipe furnished under the order, with the same polymer coating and same metallic coating.

6.3 *Hardware for Coupling Bands*—Bolts and nuts for coupling bands shall conform to the following requirements:

	Bolts	Nuts
For A 1019 pipe	A 307	A 563, Grade A
[For A 1019M pipe]	[F 568, Class 4.6]	[A 563M, Class 5]

6.3.1 Bolts, nuts, and other threaded items used with coupling bands shall be zinc coated by one of the following processes: hot-dip process as provided in Specification A 153; electroplating process as provided in Specification B 633, Class Fe/Zn 8; or mechanical process as provided in Specification B 695, Class 8. Other hardware items used with coupling bands shall be zinc coated by one of the following processes: hot-dip process as provided in Specification A 153; electroplating process as provided in Specification B 633, Class Fe/Zn 25; or mechanical process as provided in Specification B 695, Class 25.

6.4 *Gaskets*—If gaskets are used in couplings, they shall be a band of expanded rubber that meets the requirements of Specification D 1056 for the “RE” closed cell grades, O-rings meeting the requirements of Specification C 443, or other material approved by the purchaser.

### 7. Fabrication

7.1 *General Requirements*—Pipe shall be fabricated in full circular cross section.

7.1.1 The pipe shall be fabricated with essentially closed helical ribs projecting outward, with a continuous lock seam extending from end to end of each length of pipe.

7.2 *Wall Profile*—The dimensions and spacing of the ribs shall be in accordance with Table 2 for the nominal size indicated on the order. The ribs shall be spaced such that, after every third rib, a wider spacing is provided to accommodate the lock seam.

7.2.1 The maximum spacing of the lock seam, measured perpendicular to the lock seam, shall be 5-3/4 in. [146 mm].

NOTE 1—The nominal dimensions and properties for pipe wall profiles are given in Practice A 796/A 796M.

7.3 *Helical Lock Seams*—The lock seam shall be formed in the flat zone of the pipe wall midway between each pair of ribs having the wider spacing described in 7.2.

7.3.1 The edges of the sheets within the cross section of the lock seam shall lap at least 3/32 in. [4.0 mm] with an occasional

**TABLE 1 Pipe Sizes**

Nominal Inside Diameter		Closed Rib Profile Sizes <sup>A</sup>		
in.	mm	1/4 by 5-7/16 [6 by 138 mm]	3/8 by 5-7/16 [9.5 by 138 mm]	1/2 by 5-7/16 [13 by 138 mm]
6	150	x		
8	200	x		
10	250	x		
12	300	x	x	
15	375		x	
18	450		x	
21	500		x	
24	600			x
27	675			x
30	750			x
33	825			x
36	900			x

<sup>A</sup> An “x” indicates standard closed rib profile sizes for each nominal diameter of pipe.

5.1.4 Length, either total length or length of each piece and number of pieces,

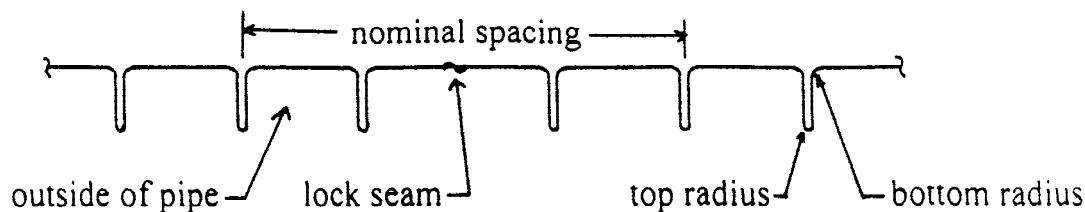
5.1.5 Description of wall profile (7.2),

<sup>7</sup> Annual Book of ASTM Standards, Vol 09.02.

<sup>8</sup> Annual Book of ASTM Standards, Vol 14.02.

<sup>9</sup> Available from American Association of State Highway and Transportation Officials, 444 N. Capital, Washington, DC 20001.

TABLE 2 Rib Requirements



Nominal Size <sup>A</sup>	Rib Width, <sup>B</sup> max	Rib Depth, <sup>C</sup> min	Rib Spacing, <sup>D</sup> max	Bottom Outside Radius, min	Bottom Outside Radius, <sup>E</sup> max avg	Top Outside Radius, min	Top Outside Radius, max
A1019, in.							
¼ × 5-7/16	0.12	0.24	1.25	0.06	0.15	0.04	0.06
⅜ × 5-7/16	0.12	0.36	1.25	0.06	0.15	0.04	0.06
½ × 5-7/16	0.12	0.48	1.25	0.06	0.15	0.04	0.06
A1019M, mm							
6 × 138	3.0	6.1	32	1.5	3.8	1.0	1.5
9.5 × 138	3.0	9.1	32	1.5	3.8	1.0	1.5
13 × 138	3.0	12.2	32	1.5	3.8	1.0	1.5

<sup>A</sup> Nominal size is the nominal rib depth times the repetitive spacing of three-rib clusters. Spacing of individual ribs varies.

<sup>B</sup> Width is measured on the outside of the pipe (outside of the rib).

<sup>C</sup> Depth is an average of the three ribs within one sheet width measured from the outside by placing a straight edge across adjacent ribs and measuring to the flat between ribs, adjacent to a rib.

<sup>D</sup> Spacing is an average of two adjacent rib spacings, exclusive of the spacing that includes the lock seam. For the spacing that includes the lock seam, the maximum spacing shall be 3-1/8 in. [79 mm], and the lock seam shall be approximately at the midwidth of this spacing.

<sup>E</sup> The average of the two bottom radii shall be within the minimum and maximum tolerances. The term "outside" refers to the outside surface of the pipe.

tolerance of -10 % of lap width allowable. The lapped surfaces shall be in tight contact. The profile of the sheet shall include a retaining offset adjacent to the 180° fold (as described in AASHTO T 249) of one sheet thickness on one side of the lock seam, or one-half sheet thickness on both sides of the lock seam, at the fabricator's option. There shall be no visible cracks in the metal, loss of metal-to-metal contact, or excessive angularity on the interior of the 180° fold of metal at the completion of forming the lock seam. Damage to the polymer coating or the underlying metallic coating is subject to repair in conformance with Section 11.

7.3.2 Specimens cut from production pipe normal to and across the lock seam shall develop the tensile strength listed in Table 3, when tested in accordance with AASHTO T 249M.

## 8. Pipe Requirements

8.1 *Pipe Dimensions*—The nominal diameter of the pipe shall be as stated in the order, selected from the sizes listed in Table 1. The size of closed rib profiles that are standard for each size of pipe are also shown in Table 1. The average inside diameter of circular pipe, when measured on the inside of the pipe, shall not be less than the nominal diameter and shall not exceed the nominal diameter by more than 3/16 in. [5 mm].

8.2 *Sheet Thickness*—Sheet thickness shall be as specified by the purchaser from the specified sheet thicknesses listed in Annex A1.

TABLE 3 Lock Seam Strength

Specified Sheet Thickness		Lock Seam Tensile Strength per Unit Width, min	
in.	mm	lbf/in.	kN/m
0.022	0.56	95	17
0.028	0.71	120	21

## 9. Coupling Bands

9.1 *Types of Coupling Bands*—Field joints for each type of closed rib pipe shall maintain pipe alignment during construction and prevent infiltration of fill material during the life of the installation. Coupling bands shall be of the following types: smooth, internal sleeve-type coupling with optional supplemental external coupling; and bands of special design. The type of coupling furnished shall be the option of the fabricator unless the type is specified in the order.

NOTE 2—Pipe joints are classified in accordance with their ability to resist shear, moment, and tensile forces as described in Practice A 798/A 798M and identified as "stab joints," "standard joints," and "special joints." Classification shall be determined by analysis or test.

9.2 *Requirements*—Coupling bands shall be fabricated to lap on an equal portion of each of the pipe sections to be connected. The coupling band sheet thickness shall be no less than the sheet thickness of the pipe to be connected.

9.2.1 Smooth internal sleeve-type couplings shall be close-fitting to hold the pipe firmly in alignment and shall contain a device so that it will lap equally on the two pipes being joined. Annular deformations 3/8 in. [9.5 mm] deep shall be permitted in the coupling band for seating gaskets as described in 9.2.2 and 9.2.5. The overall coupling width (dimension measured along the axis of the pipe) shall be a minimum of 6 in. [150 mm] for pipe diameters of 24 in. or greater, and shall be a minimum of 4 in. [100 mm] for smaller diameters.

9.2.2 Where infiltration or exfiltration is a concern, the use of supplemental external couplings with gaskets shall be considered. Supplemental external couplings shall be of steel having the same nominal thickness as the pipe being joined. The ends of the bands shall lap or be fabricated to form a tightly closed joint after installation. The overall width of the coupler shall be a minimum of 8 in. [200 mm] for pipe diameters of 24 in. or greater, and shall be a minimum of 7 in.

[175 mm] for smaller diameters. The bands shall be connected in a manner approved by the purchaser with suitable galvanized devices such as: angles, or integrally or separately formed and attached flanges, connected with bolts; bars and straps; wedge lock and straps; or lugs. Coupling bands shall be fastened with the following size of bolts:

9.2.3 Pipe diameters 18 in. [450 mm] and less,  $\frac{3}{8}$ -in. [Metric M 10] diameter.

9.2.4 Pipe diameters 21 in. [525 mm] and greater,  $\frac{1}{2}$ -in. [Metric M 12] diameter.

9.2.5 *Gaskets*—Gasket materials shall be as specified in 6.4. Closed-cell expanded rubber gaskets shall be a continuous band, with a width approximately equal to the width of the coupling band, and a thickness adequate to seal the joint. Rubber O-ring gaskets shall be of a diameter adequate to seal the joint. Other types of gaskets shall be permitted when approved by the purchaser.

9.3 Other types of coupling bands or fastening devices that are equally effective as those described, and which comply with the joint performance criteria of Practice A 798/A 798M, shall be permitted when approved by the purchaser.

## 10. Workmanship, Finish and Appearance

10.1 The completed pipe shall show carefully, finished workmanship in all particulars. Pipe that has been damaged, either during fabrication or in shipping, shall be subject to rejection unless repairs are made which are satisfactory to the purchaser. Among others, the following defects shall be considered as constituting poor workmanship, if of a magnitude likely to affect the integrity of the pipe:

10.1.1 Variation from a straight centerline.

10.1.2 Elliptical shape in pipe intended to be round.

10.1.3 Dents or bends in the metal.

10.1.4 Polymer coating or metallic coating that has been broken, disbanded, or otherwise damaged.

10.1.5 Lack of rigidity.

10.1.6 Illegible markings on the steel sheet.

10.1.7 Ragged or diagonal sheared edges.

10.1.8 Loosely formed lock seams.

## 11. Repair of Damaged Coatings

11.1 Pipe on which either the polymer coating or the underlying metallic coating has been damaged in fabricating or handling shall be repaired. Damage to the metallic coating shall be repaired as described in 11.2-11.4. Damage to the polymer coating shall be repaired as described in 11.5. The repair shall be done so that the completed pipe shall show carefully finished workmanship in all particulars. Pipe that, in the opinion of the purchaser, has not been cleaned or coated satisfactorily shall be subject to rejection. If the purchaser so elects, the repair shall be done in his or her presence.

11.2 Damage to the metallic coating shall be repaired as provided in Practice A 780, except as described herein. The damaged area shall be cleaned to bright metal by blast cleaning, power disk sanding, or wire brushing. The cleaned area shall extend at least  $\frac{1}{2}$  in. [13 mm] into the undamaged section of the coating. The cleaned area shall be coated within 24 h and before any rusting or soiling.

11.3 *Paints Containing Zinc Dust*—Paints containing zinc

dust as described in the Materials section of Practice A 780 shall be applied to a dry film thickness of at least 0.005 in. [0.13 mm] over the damaged section and surrounding cleared area.

11.4 *Metallizing Coating*—The damaged area shall be cleaned as described in 11.2, except it shall be cleaned to the near-white condition. The repair coating applied to the cleaned section shall have a thickness of not less than 0.005 in. [0.13 mm] over the damaged section and shall taper off to zero thickness at the edges of the cleaned undamaged section.

11.4.1 Where the zinc coating is to be metallized, it shall be done with zinc wire containing not less than 99.98 % zinc.

11.5 *Polymer Coating*—Areas of damaged polymer coating shall be repaired with a polymer coating similar and compatible with respect to durability, adhesion, and appearance of the original polymer coating. The coating material and method of application used for the repair must be approved by the manufacturer of the original polymer precoat material.

11.5.1 Polymer coating damaged during shipping or installation shall be repaired using materials as described in 11.5 or by the application of a protective coating material conforming to Specification A 849.

## 12. Inspection

12.1 The purchaser or representative shall have free access to the fabricating plant for inspection, and every facility shall be extended for this purpose. This inspection shall include an examination of the pipe for the items in 10.1 and the specific requirements of this specification applicable to the type of pipe.

12.2 On a random basis, samples shall be permitted to be taken for chemical analysis and metallic and polymer coating measurements for check purposes. These samples will be secured from fabricated pipe or from sheets or coils of the material used in fabrication of the pipe. The weight [mass] of metallic coating shall be determined in accordance with Test Method A 90/A 90M. The thickness of polymer coating shall be measured in accordance with Test Method D 1005.

## 13. Rejection

13.1 Pipe failing to conform to the specific requirements of this specification, or that shows poor workmanship, shall be subject to rejection. This requirement applies not only to the individual pipe, but to any shipment as a whole where a substantial number of pipe are defective. If the average deficiency in length of any shipment of pipe is greater than 1 %, the shipment shall be subject to rejection.

## 14. Certification

14.1 When specified in the purchase order or contract, a manufacturer's or fabricator's certification, or both, shall be furnished to the purchaser stating that samples representing each lot have been tested and inspected in accordance with this specification and have been found to meet the requirements for the material described in the order. When specified in the order, a report of the test results shall be furnished.

## 15. Keywords

15.1 closed-rib steel pipe; drainage pipe; metallic-coated steel pipe; polymer-precoated steel pipe; sewer pipe

**ANNEX**
**(Mandatory Information)**
**A1. MATERIAL REQUIREMENTS**
**A1.1 Scope**

A1.1.1 This annex covers requirements for the material for fabrication of closed rib steel pipe under this specification.

**A1.2 Polymer Precoated Sheet**

A1.2.1 The material shall be precoated polymer sheet that conforms to the requirements of Specification A 742/A 742M except as modified in A1.2.2 and A1.3.

A1.2.2 The polymer coating grade shall be as follows:

Grade	Coating Thickness	
	in.	µm
6/6 [150/150]	0.006/0.006	150/150

The thicknesses indicated are minimum values at any point not less than 3/8 in. [10 mm] from an edge.

A1.2.3 *Alternate Marking*—An alternate method and frequency of marking coils or finished pipe that provides the same information described in A 742/A 742M shall be permitted when approved by the purchaser.

**A1.3 Metallic-Coated Substrate**

A1.3.1 The metallic-coated substrate shall conform to all applicable requirements of Specification A 653/A 653M for a zinc coating.

A1.3.2 The specified thickness of the metallic coated substrate sheet, not including the thickness of the polymer coating, shall be selected from the following:

Specified Thickness, in. [mm]	Minimum Thickness, in. [mm]
0.022 [0.56]	0.020 [0.51]
0.028 [0.71]	0.026 [0.66]

A1.3.3 The metallic coating weight [mass] shall conform to the requirements for a G90 [Z275] coating listed in Table A1.1.

A1.3.4 Adhesion of the coating shall be such that no peeling or flaking occurs while forming during pipe fabrication.

**TABLE A1.1 Coating Weight [Mass] Requirements**

Type	Coating Weight [Mass], Total Both Sides <sup>A</sup>		Equivalent Coating Thickness, Total Both Sides <sup>B</sup>	
	Triple Spot Average, min oz/ft <sup>2</sup> [g/m <sup>2</sup> ]	Single Spot, min oz/ft <sup>2</sup> [g/m <sup>2</sup> ]	Triple Spot Average, min in. [µm]	Single Spot, min in. [µm]
Zn	0.90 [275]	0.80 [235]	0.0015 [38]	0.0014 [36]

<sup>A</sup> In case of dispute when sampling for coating weight [mass], the weigh-strip-weigh procedures of Test Method A 90 [A 90M] shall apply.

<sup>B</sup> Coating thicknesses are approximate, for information only. Conversions are based on the following relationship: 1 oz/ft<sup>2</sup>= 0.0017 in., 1 g/m<sup>2</sup>= 0.1401 µm.

**TABLE A1.2 Chemical Composition**

	Heat Analysis	Product Analysis
Sulfur, max, %	0.05	0.06
Sum of carbon, manganese, phosphorus, sulfur, and silicon, max, %	0.70	0.74

**TABLE A1.3 Mechanical Requirements (Properties of Flat Sheet Prior to Fabrication)<sup>A</sup>**

Tensile strength, min, <sup>B</sup> ksi [MPa]	45.0 [310]
Yield strength, min, <sup>B</sup> ksi [MPa]	33.0 [230]
Elongation in 2 in. [50 mm], min, %	20

<sup>A</sup> To determine conformance with this specification, round each value for tensile strength and yield strength to the nearest 0.1 ksi [1 MPa] and each value for elongation to the nearest 1 %, both in accordance with the rounding method of Practice E 29.

<sup>B</sup> Yield strength and tensile strength are based on the thickness of the base metal. If tests are made after coating, determine the base metal thickness after stripping the coating from the ends of the specimen contacting the grips of the tensile testing machine prior to tensile testing.

A1.3.5 *Base Metal Analysis*—The base metal heat or product analysis shall conform to the chemical requirements of Table A1.2.

A1.3.6 *Coating Bath Composition*:

A1.3.6.1 *Zinc Coating*—The coating bath metal shall contain not less than 99 % zinc.

A1.3.7 *Mechanical Properties*—The metallic coated sheet shall conform to the mechanical requirements listed in Table A1.3.

A1.3.7.1 Two tension tests shall be made on random samples of finished material (flat unformed sheet) from said heat. One test is sufficient when the finished material from said heat is less than 50 tons [45 Mg]. The samples shall be prepared and tested in accordance with the method specified in A 924 [A 924M].

A1.3.8 *Other Tests*—The manufacturer shall make such tests and measures as deemed necessary to ensure that the coated sheet produced complies with this specification.

A1.3.9 *Retention of Test Results*—The test results, including chemical composition, mechanical properties, coating type, and coating weight [mass] for each heat and coating lot, shall be maintained by the manufacturer for seven years. The test results shall be made available to the fabricator and purchaser upon request.

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# Standard Practice for Measuring Flatness Characteristics of Coated Sheet Products<sup>1</sup>

This standard is issued under the fixed designation A 1030/A 1030M; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon ( $\epsilon$ ) indicates an editorial change since the last revision or reapproval.

## 1. Scope

1.1 Flatness is a significant quality characteristic of coated sheet products. Sheet flatness is affected by mill process factors plus the grade, thickness and width of the material supplied. It is the purpose of this practice to define the different flatness characteristics and to describe the method(s) most commonly used to measure particular characteristics. The methods described are designed and intended to be used in mill situations and environments.

1.2 Quantitative limits are not addressed and are established in the general requirements, or individual product specifications, or both; or when applicable, as agreed to between supplier and user.

1.3 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

## 2. Referenced Documents

### 2.1 ASTM Standards:<sup>2</sup>

- A 308 Specification for Stainless Steel Sheet, Terne Lead-Tin Alloy Coated by the Hot-Dip Process
- A 463/A 463M Specification Steel Sheet, Aluminum-Coated, by the Hot-Dip Process
- A 591 Specification Steel Sheet, Electrolytic Zinc-Coated, for Light Coating Mass Applications
- A 653/A 653M Specification for Steel Sheet, Zinc-Coated (Galvanized) or Zinc-Iron Alloy-Coated (Galvannealed), by the Hot-Dip Process
- A 755/A 755M Specification for Steel Sheet, Metallic-Coated, by the Hot-Dip Process and Prepainted by the Coil-Coating Process for Exterior Exposed Building Products

- A 792/A 792M Specification for Steel Sheet, 55% Aluminum-Zinc Alloy-Coated, by the Hot-Dip Process
- A 875/A 875M Specification for Steel Sheet, Zinc-5% Aluminum Alloy-Coated, by the Hot-Dip Process
- A 879/A 879M Specification Steel Sheet, Zinc-Coated by the Electrolytic Process for Applications Requiring Designation of the Coating Mass on Each Surface
- A 917 Specification Steel Sheet, Coated by the Electrolytic Process for Applications Requiring Designation of the Coating Mass on Each Surface (General Requirements)
- A 918 Specification Steel Sheet, Zinc-Nickel Alloy-Coated by the Electrolytic Process for Applications Requiring Designation of the Coating Mass on Each Surface
- A 924/A 924M Specification for General Requirements for Steel Sheet, Metallic-Coated, by the Hot-Dip Process
- A 929/A 929M Specification for Steel Sheet, Metallic-Coated, by the Hot-Dip Process for Corrugated Steel Pipe

## 3. Classification

3.1 The substrate shall conform to all the requirements of the appropriate specifications as follows: Specifications A 308, A 463/A 463M, A 591, A 653/A 653M, A 755/A 755M, A 792/A 792M, A 875/A 875M, A 879, A 917, A 918, A 924/A 924M, and A 929/A 929M.

## 4. Significance and Use

4.1 The definitions and procedures for measuring flatness characteristics of coated sheet products are provided so that purchasers and suppliers have common definitions and measuring procedures for flatness characteristics. The intention of these definitions and measuring methods is not to provide a dimensional specification for flatness characteristics, but rather common procedure(s) for quantifying flatness anomalies. For determining compliance with flatness specifications, references are provided to appropriate ASTM standards.

## 5. Interferences

5.1 Measurement of flatness often has been subjective, at best. Successful measurement of various flatness anomalies on quantitative terms requires recognition of several factors that can interfere with accurate measurements.

<sup>1</sup> This practice is under the jurisdiction of ASTM Committee A05 on Metallic-Coated Iron and Steel Products and is the direct responsibility of Subcommittee A05.07 on Methods of Testing.

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<sup>2</sup> For referenced ASTM standards, visit the ASTM website, [www.astm.org](http://www.astm.org), or contact ASTM Customer Service at [service@astm.org](mailto:service@astm.org). For Annual Book of ASTM Standards volume information, refer to the standard's Document Summary page on the ASTM website.

5.1.1 Flat surfaces are required. Measurement of several anomalies requires laying of the sample, or a coil area, on a recognized flat surface. In most cases, laying the sample, or a coil area, on a floor will produce satisfactory results, as long as the floor is recognized as being flat. The flatness of coil areas is also measured on the flat tables of coil processing lines, with the strip tension released. If the measuring surface is not recognized as being flat, a machined flat surface is recommended.

5.1.2 Stepblock gages or tapered gages should be checked regularly with a calibrated hand micrometer. Wear or dirt build up will affect accuracy.

5.1.3 The flat tables of shape gages capable of measuring flatness characteristics must be clean and the sensors must be in good condition.

5.1.4 The sheet sample must be damage free.

**6. Apparatus**

6.1 Appropriate tools to measure flatness anomalies are described along with drawings as indicated.

6.1.1 *Flat Surfaces*—Accurate measurements of flatness anomalies require a flat surface, machined flat preferred.

6.1.2 *Machined Stepblock Gage*—See Fig. 1. Typically steps are in 1/16 in. [1 mm] increments.

6.1.3 *Tapered Gage*—See Fig. 2.

6.1.4 *Standard Ruler or Tape Measure*.

6.1.5 *Hand Micrometer*.

6.1.6 *Lightweight Straightedge*—Rigid, but light enough not to affect the test result.

6.1.7 Shape gages are computer-based systems designed for flatness measurements on samples of cold rolled sheet products. Typically these systems consist of a large steel table, computer-based operator’s console, and a motor-driven bridge containing LVDT position sensors to contact the strip, or laser sensors for noncontact measuring. See Appendix X2 for details of one such machine.

**7. Procedure**

7.1 *Wavy Edge* (see Fig. 3):

7.1.1 *Definition*—A series of rolling direction edge deviations or undulations of the sheet from a recognized flat surface, having a height (H) and a measurable cycle length (L).

7.1.2 *Measuring Methods*:

7.1.2.1 With a sheet sample, or coil area, of at least 4 ft [1.2 m] in length by coil width on a recognized flat surface, measure the height (H) at the peak point of each wave from the recognized flat surface with a ruler, tape measure, tapered gage, or stepblock gage. Also measure the cycle length (L) from peak to peak of each wave with a ruler or tape measure.

7.1.3 *Permissible Variations*

7.1.3.1 The height (H) of the highest peak measured in accordance with 7.1.2.1 shall comply with applicable limits, such as found in the tables on flatness tolerances of Specification A 924/A 924M. Note that the referenced tables apply to cut sheet that has received adequate flattening. While the wavy edge height result from a coil area still attached to a coil is a reasonable indication of flatness, it is not bound by the limits of the referenced tables.

7.1.3.2 As stated in the section on flatness tolerances of Specification A 924/A 924M, I-Unit and % Steepness rejection limits are subject to agreement between producer and purchaser. Using the procedures of Appendix X1, and the readings from 7.1.2.1, determine the I-Unit and % Steepness values, first using the distance between the two highest peaks, and second using the distance between two adjacent peaks. The highest I-Unit and % Steepness values obtained from these two situations shall be used to determine if the specification has been met.

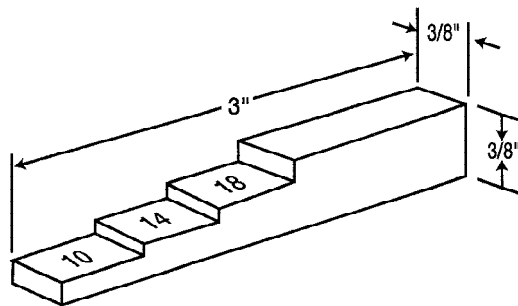
7.1.3.3 If the I-Unit and % Steepness values are supplied directly using a shape gage; determine if the results are within the maximum specified values.

7.2 *Ridge Buckle, Quarter Buckle, Center Buckle* (see Fig. 4):

7.2.1 *Definition*—Buckles are continuous deviations from a recognized flat surface, having a height (H) and a measurable cycle length (L), and usually occur in narrow width areas parallel to the rolling direction other than at the sheet edges.

7.2.2 *Measuring Methods*:

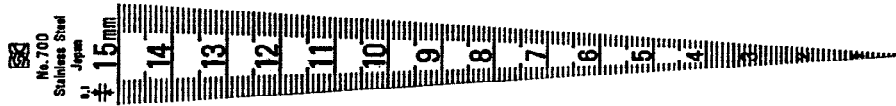
7.2.2.1 With a sheet sample, or coil area, of at least 4 ft [1.2 m] by coil width resting on a recognized flat surface, place a lightweight straightedge on the highest portion of a buckle and on the highest portion of the next repeating buckle. Measure the height (H) between the straightedge and a strip using a ruler, tape measure, tapered gage, or stepblock gage. Measure the cycle length (L) from peak to peak of each buckle with a ruler or tape measure.



NOTE 1—Stepblock gage for all thicknesses and sizes of cut sheets.

NOTE 2—Dimensions given are approximate overall dimensions.

**FIG. 1 Flatness Stepblock Gage**



NOTE 1—Tapered gage for all thicknesses and sizes of cut sheets.

FIG. 2 Flatness Tapered Gage

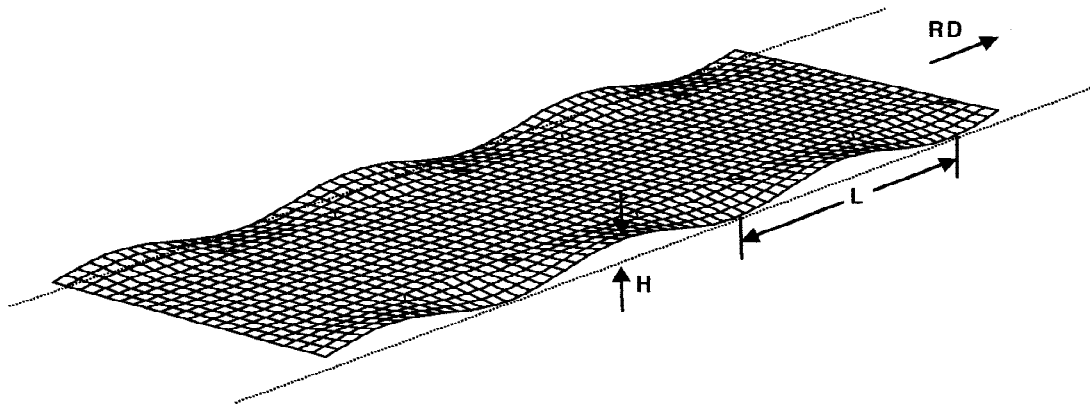


FIG. 3 Wavy Edge

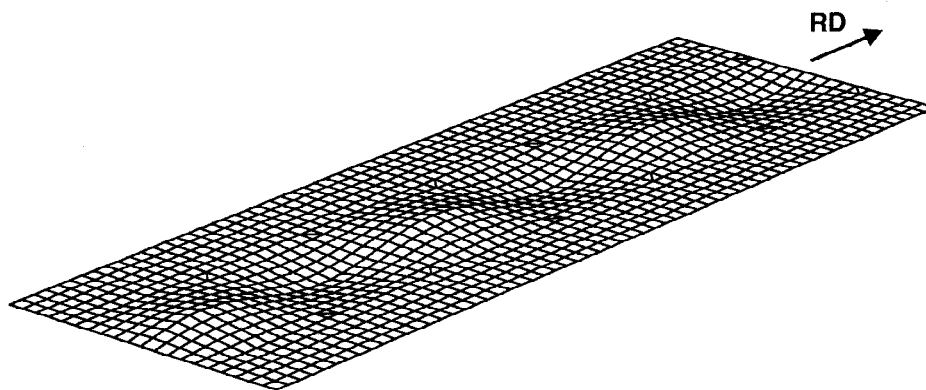


FIG. 4 Ridge Buckle, Quarter Buckle, Center Buckle

7.2.2.2 In the case of a sheet sample, it is permissible to shear through the centerline of the flatness anomaly and measure as an edge wave (see 7.1.2.1) using a ruler, tape measure, tapered gage, or stepblock gage.

7.2.3 Permissible Variations

7.2.3.1 The height (H) of the highest peak measured in accordance with 7.2.2.1 or 7.2.2.2 shall comply with applicable limits, such as found in the tables on flatness tolerances of Specification A 924/A 924M. Note that the referenced tables apply to cut sheet that has received adequate flattening. While the buckle height result from a coil area still attached to a coil is a reasonable indication of flatness, it is not bound by the limits of the referenced tables.

7.2.3.2 As stated in the section on flatness tolerances of Specification A 924/A 924M, I-Unit and % Steepness rejection limits are subject to agreement between producer and purchaser. Using the procedures of Appendix X1, and the readings

from 7.2.2.1 or 7.2.2.2, determine the I-Unit and % Steepness values, first using the distance between the two highest peaks, and second using the distance between two adjacent peaks. The highest I-Unit and % Steepness values obtained from these two situations shall be used to determine if the specification has been met.

7.2.3.3 If the I-Unit and % Steepness values are supplied directly using a shape gage; determine if the results are within the maximum specified values.

7.3 Full Center (see Fig. 5):

7.3.1 Definition—Any overall deviation of a sheet from a recognized flat surface, having a height (H) and a measurable cycle (L), and occurring over a major portion of the sheet width parallel to the rolling direction other than at the sheet edges.

7.3.2 Measuring Methods:

7.3.2.1 With a sheet sample, or a coil area, of at least 4 ft [1.2 m] by coil width resting on a recognized flat surface, place

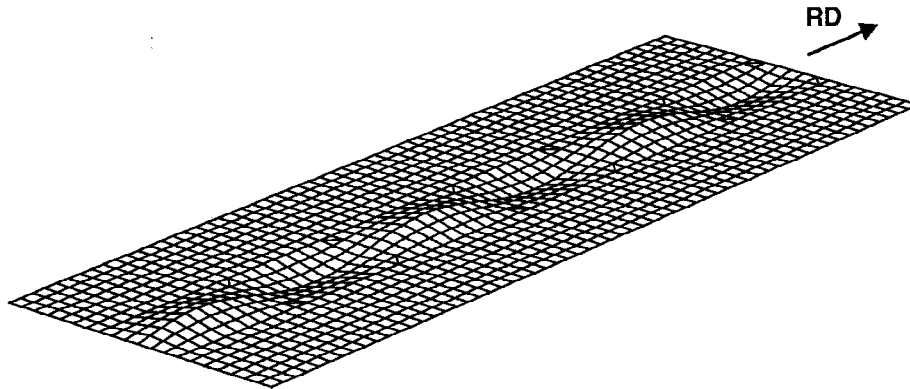


FIG. 5 Full Center

a lightweight straightedge on the highest portion of a full center region and on the highest portion of the next repeating region of full center. Measure the height (H) between the straightedge and the strip using a ruler, tape measure, tapered gage, or stepblock gage. Measure the cycle length (L) from peak to peak of a full center region with a ruler or tape measure.

7.3.2.2 In the case of a sheet sample, it is permissible to shear through the centerline of the flatness anomaly and measure as an edge wave (see 7.1.2.1) using a ruler, tape measure, tapered gage, or stepblock gage.

#### 7.3.3 Permissible Variations

7.3.3.1 The height (H) of the highest peak measured in accordance with 7.3.2.1 or 7.3.2.2 shall comply with applicable limits, such as found in the tables on flatness tolerances of Specification A 924/A 924M. Note that the referenced tables apply to cut sheet that has received adequate flattening. While the buckle height result from a coil area still attached to a coil is a reasonable indication of flatness, it is not bound by the limits of the referenced tables.

7.3.3.2 As stated in the section on flatness tolerances of Specification A 924/A 924M, I-Unit and % Steepness rejection limits are subject to agreement between producer and purchaser. Using the procedures of Appendix X1, and the readings from 7.3.2.1 or 7.3.2.2, determine the I-Unit and % Steepness values, first using the distance between the two highest peaks, and second using the distance between two adjacent peaks. The highest I-Unit and % Steepness values obtained from these two situations shall be used to determine if the specification has been met.

7.3.3.3 If the I-Unit and % Steepness values are supplied directly using a shape gage; determine if the results are within the maximum specified values.

#### 7.4 Coil Set and Reverse Coil Set (see Fig. 6):

7.4.1 *Definition*—A bow condition in the sheet, parallel with the rolling direction, as measured from a recognized flat surface. Coil set (also known as positive coil set) curves downward in the same direction as the upper outside lap of an overwound coil. Reverse coil set (also known as negative coil set) curves upward, opposite to the curvature of the upper outside lap of an overwound coil.

#### 7.4.2 Measuring Methods:

7.4.2.1 For coil set, place a sheet sample of approximately 4 ft [1.2 m] by coil width on a recognized flat surface. Measure

the highest rise (H) of the sheet edges from the flat surface. Use a ruler accurate to  $\frac{1}{16}$  in. [1 mm].

7.4.2.2 For reverse coil set, place an adequately leveled sheet sample of approximately 4 ft [1.2 m] by coil width on a recognized flat surface. Measure the highest rise (H) of the cut end(s) of the sheet from the flat surface. Use a ruler accurate to  $\frac{1}{16}$  in. [1 mm].

#### 7.4.3 Permissible Variations

7.4.3.1 The height (H) of the highest deviation measured in accordance with 7.4.2.1 or 7.4.2.2 shall comply with applicable limits, such as found in the tables on flatness tolerances of Specification A 924/A 924M, or a value agreed upon between the producer and purchaser.

#### 7.5 Crossbow and Reverse Crossbow (see Fig. 7):

7.5.1 *Definition*—A bow condition in the sheet, perpendicular to the rolling direction as measured from a recognized flat surface. Crossbow (also known as positive crossbow) curves downward, with the center portion of the sheet raised a measurable amount (H) above the sheet edges. Reverse crossbow (also known as negative crossbow) curves upward, with the edges of the sheet raised a measurable amount (H) above the center portion of the sheet. The degree of cross bow is determined in a horizontal position on a recognized flat surface.

#### 7.5.2 Measuring Methods:

7.5.2.1 For crossbow, place a sheet sample, or coil area, of approximately 4 ft [1.2 m] by coil width on a recognized flat surface. Measure the highest rise (H) of the center of the sheet from the flat surface. Use a ruler accurate to  $\frac{1}{16}$  in. [1 mm].

7.5.2.2 For reverse crossbow, place an adequately leveled sheet sample, or coil area, of approximately 4 ft [1.2 m] by coil width on a recognized flat surface. Measure the highest rise (H) of the edges of the sheet from the flat surface. Use a ruler accurate to  $\frac{1}{16}$  in. [1 mm] or a lightweight straightedge as required.

#### 7.5.3 Permissible Variations

7.5.3.1 The height (H) of the highest deviation measured in accordance with 7.5.2.1 or 7.5.2.2 shall comply with applicable limits, such as found in the tables on flatness tolerances of Specification A 924/A 924M, or a value agreed upon between the producer and purchaser.

#### 7.6 Camber (see Fig. 8):

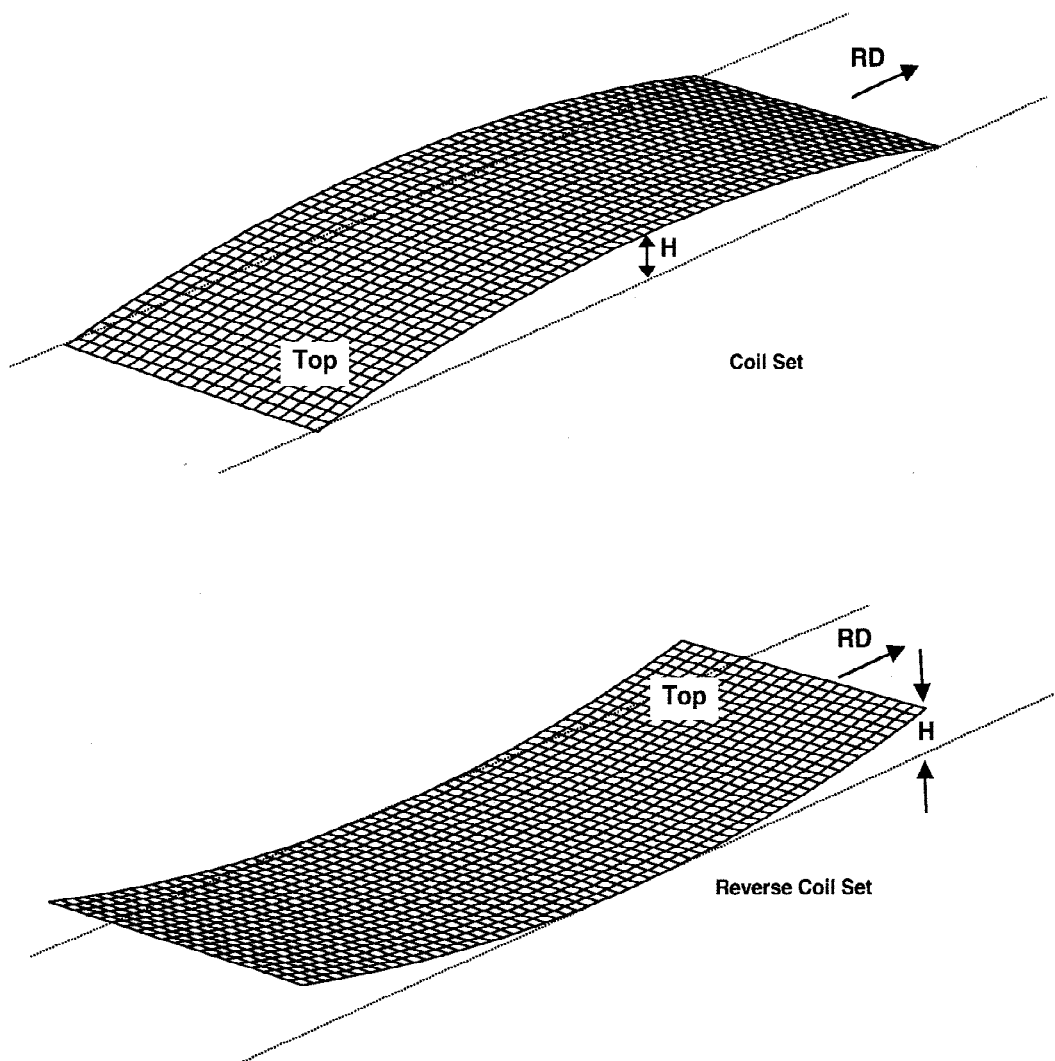


FIG. 6 Coil Set and Reverse Coil Set

7.6.1 *Definition*—The greatest deviation of a coil edge from a straight line. The measurement is taken on the concave side and is the perpendicular distance from a straight line to the point of maximum deviation (A).

7.6.2 *Measuring Methods:*

7.6.2.1 Lay a sample of at least 20 ft [6 m] next to recognized straightedge. The perpendicular distance (A) is measured using a ruler accurate to 1/16 in. [1 mm].

7.6.2.2 Cut two 20 ft [6 m] consecutive sections from the master coil. Butt together the sections lengthwise with the same edges together. At a 10 ft [3 m] distance from the end, measure the distance between the two edges. Divide this measurement in half to determine the actual camber (A).

7.6.3 *Permissible Variations*

7.6.3.1 The maximum deviation (A) measured in accordance with 7.6.2.1 or 7.6.2.2 shall comply with applicable limits of the table on camber tolerances of Specification A 924/A 924M, or a value agreed upon between the producer and purchaser.

8. **I-Unit Calculation**

8.1 This calculation assumes that flatness irregularities most closely conform to sinusoidal waveforms and uses the flatness wavelength and height for the calculation. An alternate approach is to use I-Unit or % Steepness as a measure of the severity of flatness anomalies. Refer to Appendix X1 for a complete discussion of I-Units.

8.2 Coated sheet processing units such as temper mills are sometimes equipped with sensor rolls and detection systems that directly measure flatness in terms of I-Units. These devices are an acceptable method of measuring flatness. While the operation of such devices is beyond the scope of this practice, the information they supply can be compared with the results obtained using this practice. I-Unit values obtained from such in-line measuring devices will not necessarily agree with those obtained using this practice.

9. **Keywords**

9.1 coated steel sheet; metallic coated steel sheet; steel sheet - metallic coated

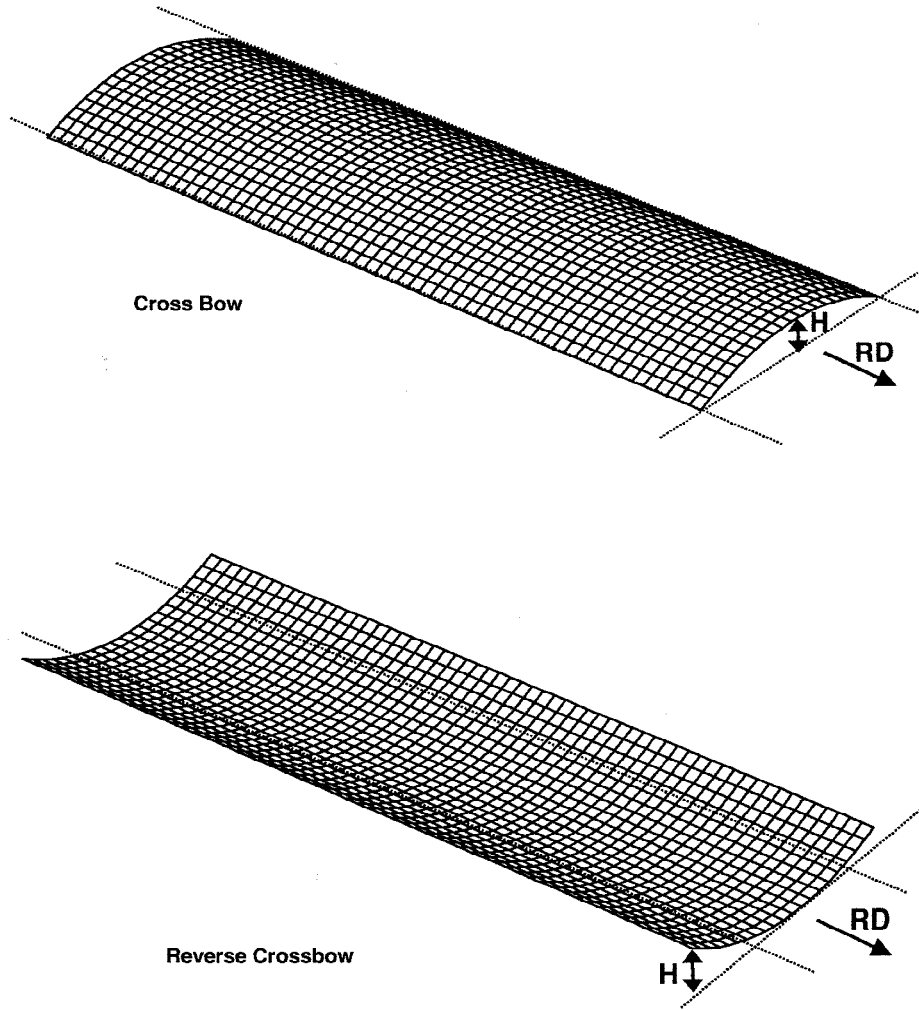


FIG. 7 Crossbow and Reverse Crossbow

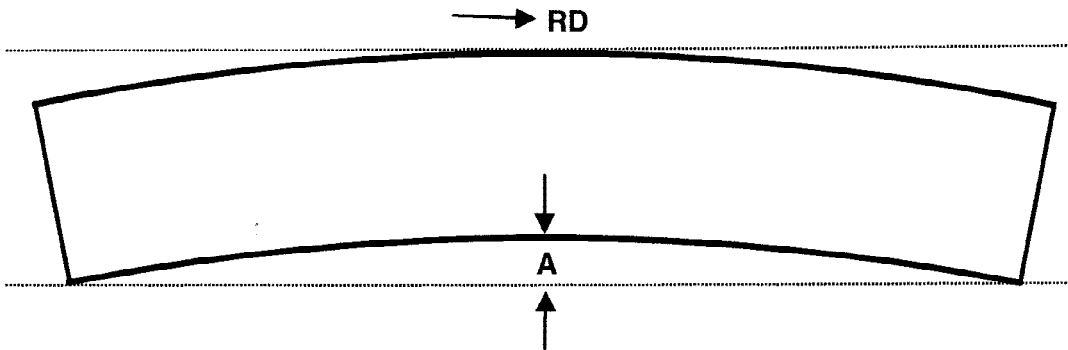


FIG. 8 Camber

**APPENDIXES**

(Nonmandatory Information)

**X1. ALTERNATIVE METHODS FOR EXPRESSING FLATNESS**

**X1.1 Introduction and Definitions:**

X1.1.1 In addition to the conventional expression of flatness, the “maximum deviation from a horizontal flat surface,” at least two other flatness parameters have been developed and are in use for characterizing sheet with longitudinal waves or buckles. These are Steepness Index and Flatness Index (or I-Unit), which are illustrated using the example in Fig. X1.1.

**X1.1.2 Steepness Index**

Fig. X1.1 (a) shows a representation of a sheet sample exhibiting edge waves of height *H* and interval *L*. The steepness index value for this sample is defined as follows:

$$\text{steepness index} = \frac{H}{L} \quad (\text{X1.1})$$

$$\% \text{ steepness} = S = \left(\frac{H}{L}\right) \times 100 \quad (\text{X1.2})$$

**X1.1.3 I-Units**

Making a series of lengthwise cuts to the sample in Fig. X1.1 (a) relaxes elastic stresses present in the sheet and results in narrow strips of differing lengths, as shown in Fig. X1.1 (b). Using the length of the shortest strip as a reference (*L<sub>ref</sub>*), the I-unit value (*I*) for an individual strip is defined as follows:

$$I = \left(\frac{\Delta L}{L_{ref}}\right) \times 10^5 \quad (\text{X1.3})$$

where

$\Delta L$  = difference between the length of a given strip and the reference strip.

X1.1.4 For the special case of waves/buckles that are perfectly sinusoidal in character, the following relationship applies:

$$I \left[ \left(\frac{\pi}{2}\right) \left(\frac{H}{L}\right) \right]^2 \times 10^5 \quad (\text{X1.4})$$

or

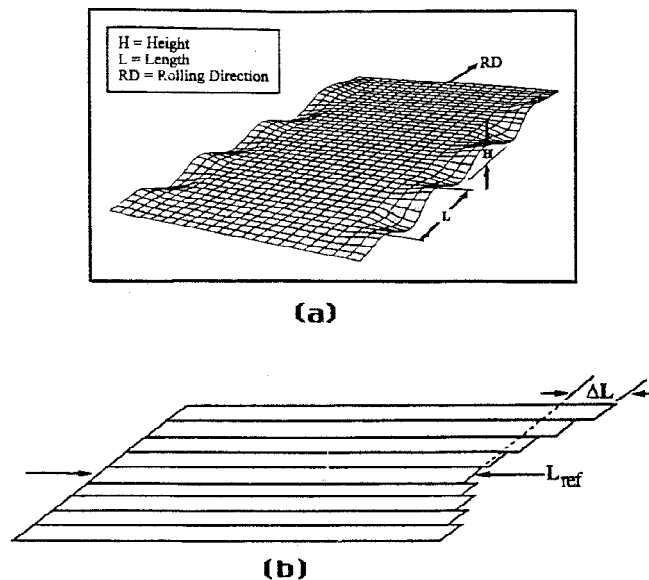
$$I = 24.7S^2 \quad (\text{X1.5})$$

X1.1.4.1 Fig. X1.2 provides I-unit values based on the sinusoidal approximation for wave heights up to 1/2 in. [10 mm] (increments of 1/32 in. [0.5 mm]) and intervals between 10 and 40 in. [250 and 1000 mm] (increments of 1 in. [25 mm]). Mathematical relationships between the three representations of flatness described here are given in Table X1.1; these relationships can be used to convert between I-unit, % steepness, and wave height values (see examples in Table X1.1).

**X1.2 Flatness Evaluation Example and Determination of I-Unit or % Steepness Value:**

X1.2.1 While the strip is on an inspection table, find the locations on the strip that are not lying flat on the table. If no flatness deviation can be found, that portion of the coil (head/middle/tail) can be described as flat (that is, zero I-unit or zero % steepness).

X1.2.2 If the coil is not totally flat, the height of the deviation must be determined and recorded. If the coil has edge waves, a step gage (incremented in intervals of 1/16 or 1/32 in. [1 or 0.5 mm]) can be inserted under a wave to determine the



**FIG. X1.1 Representation of Sheet Sample with Edge Waves (a) and Strips of Differing Length Which Result from Making Longitudinal Cuts Along the Sample (b)**

		Wavelength (in.)																																					
Wave Height (in.)		10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40							
1/32		2	2	2	1	1	1	1	1	1	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0				
1/16		10	8	7	6	5	4	4	3	3	3	2	2	2	2	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1				
3/32		22	18	15	13	11	10	8	8	7	6	5	5	4	4	4	3	3	3	3	3	2	2	2	2	2	2	2	2	2	1	1	1	1	1				
1/8		39	32	27	23	20	17	15	13	12	11	10	9	8	7	7	6	6	5	5	5	4	4	4	3	3	3	3	3	3	3	3	2	2	2				
5/32		60	50	42	36	31	27	24	21	19	17	15	14	12	11	10	10	9	8	8	7	7	6	6	6	5	5	5	4	4	4	4	4	4	4				
3/16		87	72	60	51	44	39	34	30	27	24	22	20	18	16	15	14	13	12	11	10	10	9	8	8	8	7	7	6	6	6	5	5	5					
7/32		118	98	82	70	60	53	46	41	36	33	30	27	24	22	21	19	17	16	15	14	13	12	12	11	10	10	9	9	8	8	7	7	7					
1/4		154	128	107	91	79	69	60	53	48	43	39	35	32	29	27	25	23	21	20	18	17	16	15	14	13	13	12	11	11	10	10	10	10					
9/32		195	161	136	116	100	87	76	68	60	54	49	44	40	37	34	31	29	27	25	23	22	20	19	18	17	16	15	14	14	13	12	12	12					
5/16		241	199	168	143	123	107	94	83	74	67	60	55	50	46	42	39	36	33	31	29	27	25	24	22	21	20	19	18	17	16	15	15	15					
11/32		292	241	203	173	149	130	114	101	90	81	73	66	60	55	51	47	43	40	37	35	32	30	29	27	25	24	23	21	20	19	18	17	16	15				
3/8		347	287	241	206	177	154	136	120	107	96	87	79	72	66	60	56	51	48	44	41	39	36	34	32	30	28	27	25	24	23	22	21	20	19				
13/32		408	337	283	241	208	181	159	141	126	113	102	92	84	77	71	65	60	56	52	48	45	42	40	37	35	33	31	30	28	27	25	24	23	22				
7/16		473	391	328	280	241	210	185	164	146	131	118	107	98	89	82	76	70	65	60	56	53	49	46	43	41	39	36	35	33	31	30	28	27	25				
15/32		543	449	377	321	277	241	212	188	168	150	136	123	112	103	94	87	80	74	69	65	60	56	53	50	47	44	42	40	38	36	34	33	31	30				
1/2		618	510	429	365	315	274	241	214	191	171	154	140	128	117	107	99	91	85	79	73	69	64	60	57	53	50	48	45	43	41	39	37	35	34				

		Wavelength (mm)																																		
Wave Height (mm)		250	275	300	325	350	375	400	425	450	475	500	525	550	575	600	625	650	675	700	725	750	775	800	825	850	875	900	925	950	975	1000				
0.5		1	1	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
1.0		4	3	3	2	2	2	1	1	1	1	1	1	1	1	1	1	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
1.5		9	7	6	5	5	4	3	3	3	2	2	2	2	2	2	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	
2.0		16	13	11	9	8	7	6	5	5	4	4	4	3	3	3	3	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	
2.5		25	20	17	15	13	11	10	9	8	7	6	6	5	5	4	4	4	3	3	3	3	3	3	3	2	2	2	2	2	2	2	2	2	2	
3.0		36	29	25	21	18	16	14	12	11	10	9	8	7	7	6	6	5	5	4	4	4	4	3	3	3	3	3	3	2	2	2	2	2	2	
3.5		48	40	34	29	25	22	19	17	15	13	12	11	10	9	8	8	7	7	6	6	5	5	5	4	4	4	4	4	3	3	3	3	3	3	
4.0		63	52	44	37	32	28	25	22	20	18	16	14	13	12	11	10	9	9	8	8	7	7	6	6	5	5	5	5	4	4	4	4	4	4	
4.5		80	66	56	47	41	36	31	28	25	22	20	18	17	15	14	13	12	11	10	10	9	8	8	7	7	6	6	6	5	5	5	5	4	4	
5.0		99	82	69	58	50	44	39	34	30	27	25	22	20	19	17	16	15	14	13	12	11	10	10	9	9	8	8	7	7	6	6	6	6	6	
5.5		120	99	83	71	61	53	47	41	37	33	30	27	25	23	21	19	18	16	15	14	13	12	12	11	10	10	9	9	8	8	7	7	7		
6.0		142	118	99	84	73	63	56	49	44	39	36	32	29	27	25	23	21	20	18	17	16	15	14	13	12	12	11	10	10	9	9	8	8		
6.5		167	138	116	99	85	74	65	58	52	46	42	38	34	32	29	27	25	23	21	20	19	17	16	15	14	14	13	12	12	11	10	10	9	9	
7.0		194	160	134	115	99	86	76	67	60	54	48	44	40	37	34	31	29	27	25	23	22	20	19	18	17	16	15	14	13	13	12	11	10	10	
7.5		222	184	154	132	113	99	87	77	69	62	56	50	46	42	39	36	33	30	28	26	25	23	22	20	19	18	17	16	15	15	14	13	12	11	
8.0		253	209	176	150	129	112	99	88	78	70	63	57	52	48	44	40	37	35	32	30	28	26	25	23	22	21	20	18	18	17	16	15	14	13	
8.5		286	236	198	169	146	127	112	99	88	79	71	65	59	54	50	46	42	39	36	34	32	30	28	26	25	23	22	21	20	19	18	17	16	15	14
9.0		320	265	222	189	163	142	125	111	99	89	80	73	66	61	56	51	47	44	41	38	36	33	31	29	28	26	25	23	22	21	20	19	18	17	16
9.5		357	295	248	211	182	159	139	123	110	99	89	81	74	67	62	57	53	49	45	42	40	37	35	33	31	29	28	26	25	23	22	21	20	19	18
10.0		395	327	274	234	202	176	154	137	122	109	99	90	82	75	69	63	58	54	50	47	44	41	39	36	34	32	30	29	27	26	25	23	22	21	20

**FIG. X1.2 Unit Conversion Chart**

**TABLE X1.1 Flatness Conversion Factors<sup>A,B</sup>**

	I-Unit	Height	% Steepness
I-Unit	1	$\frac{2L}{\pi} \sqrt{I 10^{-5}}$	$\frac{2}{\pi} \sqrt{I 10^{-1}}$
Height, H, peak to peak	$\left(\frac{H\pi}{2L}\right)^2 10^5$	1	$\frac{(100 H)}{L}$
% Steepness, S	$2.5 (\pi S)^2$	$\frac{(LS)}{100}$	1

<sup>A</sup>L = wave interval as defined in Fig. X1.1 (a).

<sup>B</sup>Examples:

(1) Assume % steepness is given as 1.5 and the corresponding I-unit value is desired. From Table X1.1,  $I = 2.5(\pi S)^2 = 2.5[(3.14)(1.5)]^2 = 55.5$ .

(2) Assume an I-unit value of 25 is given and the corresponding % steepness is desired. From Table X1.1,  $S = \frac{2}{\pi} \sqrt{\frac{I}{10^{-1}}} = \frac{2}{3.14} \sqrt{\frac{25}{10^{-1}}} = 1.0$ .

height. If the coil exhibits flatness deviation in the center of the strip, a lightweight straightedge can be placed on the highest portion of the buckle and on the highest portion of the next repeating buckle. The height can then be determined by inserting a step gage between the straightedge and the strip.

X1.2.3 Along with the height, the wave period or wave interval must also be determined. The wave interval can be obtained by using a standard tape measure or straightedge to

measure the distance between the highest point of one flatness deviation to the highest point of the next repeating flatness deviation.

X1.2.4 After determining the height and wave interval, either the I-unit or % steepness value can be obtained. To determine the I-unit flatness, locate the appropriate height and wave interval in Fig. X1.2 and read the I-unit value at the



intersection of the two measurements. To determine % steepness, divide the height by the wave interval and multiply the result by 100.

## **X2. AUTOMATED SHAPE GAGES**

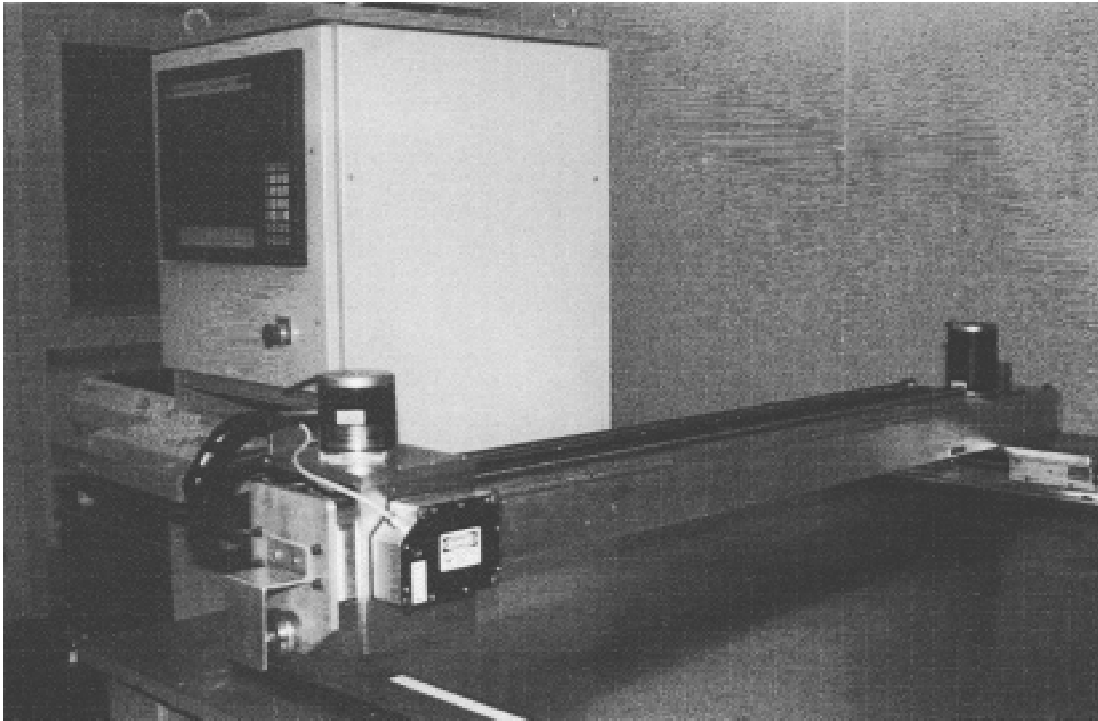
### **X2.1 Introduction:**

X2.1.1 Shape gages are computer-based systems designed for flatness measurements on samples of cold rolled sheet products. Typically these systems consist of a large steel table, computer-based operator's console, and a motor-driven bridge containing LVDT position sensors to contact the strip, or laser sensors for noncontact measuring.

### **X2.2 Available Shape Gages**

X2.2.1 One available shape gage is the Shapemaster<sup>™</sup>, a contact or noncontact flatness measuring instrument manufactured by SP & C Computer Systems, Inc., 7292 Park Drive, Bath, PA 18014. See Figs. X2.1 and X2.2 for the noncontact, laser sensor, Shapemaster TL 1000 flatness gage in use.

X2.2.2 Other instruments of appropriate design can also be used.



**FIG. X2.1 Shapemaster TL1000 Flatness Gage**



**FIG. X2.2 Shapemaster TL1000 Flatness Gage**

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# Standard Specification for Design, Fabrication, and Installation of Fences Constructed of Wood and Related Materials<sup>1</sup>

This standard is issued under the fixed designation F 537; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reappraisal. A superscript epsilon ( $\epsilon$ ) indicates an editorial change since the last revision or reappraisal.

*This standard has been approved for use by agencies of the Department of Defense.*

## 1. Scope

1.1 This specification covers all wood fences, including fences combined with wood and other materials.

1.2 This specification covers three classifications of wood fences. This specification is based on fundamental construction principles combined with long-standing traditional fence building skills, and covers the design, fabrication, and installation practices of wood fences.

1.3 This specification also provides a systematic method of purchase, inspection with basis for rejection, and certification of manufactured wood fences by the fence industry.

1.4 The values stated in inch-pound units are to be regarded as the standard. Acceptable industry-wide SI equivalents are being developed.

## 2. Referenced Documents

### 2.1 ASTM Standards:

- A 641 Specification for Zinc-Coated (Galvanized) Carbon Steel Wire<sup>2</sup>
- A 809 Specification for Aluminum-Coated (Aluminized) Carbon Steel Wire<sup>2</sup>
- B 221 Specification for Aluminum and Aluminum-Alloy Extruded Bars, Rods, Wire, Shapes, and Tubes<sup>3</sup>
- D 2605 Specification for Volatile Petroleum Solvent (LPG) for Preparing Pentachlorophenol Solutions<sup>4</sup>
- D 3225 Specification for Low-Boiling Hydrocarbon Solvent for Oil-Borne Preservatives<sup>5</sup>
- D 3506 Specification for Inhibited Grade Methylene Chloride for Preparing Pentachlorophenol Solutions<sup>6</sup>
- F 1043 Specification for Strength and Protective Coatings on Metal Industrial Chain Link Fence Framework<sup>2</sup>
- F 1667 Specification for Driven Fasteners: Nails, Spikes, and Staples<sup>7</sup>

### 2.2 Federal Standards:

TT-W-572B Fungicide: Pentachlorophenol<sup>8</sup>

### 2.3 Canadian Standards Association Document:

B 111-74 Specification for Wire Nails, Spikes, and Staples<sup>9</sup>

### 2.4 National Forest Products Association Standard:

National Design Specification for Stress Grade Lumber and Its Fastenings<sup>10</sup>

### 2.5 Voluntary Product Standards:

PS 20-70 Softwood Lumber<sup>11</sup>

PS 1-74 Softwood Plywood<sup>11</sup>

### 2.6 American Plywood Association Standard:

Specification for Plywood Design<sup>12</sup>

### 2.7 American Wood Preservers Association Standards:

C 1 All Timber Products, Preservative Treatment by Pressure Process<sup>13</sup>

C 2 Lumber, Timbers, Bridge Ties, Mine Ties, Preservative Treatment by Pressure Process<sup>13</sup>

C 5 Fence Post, Preservative Treatment by Pressure Process<sup>13</sup>

C 9 Plywood, Preservative Treatment by Pressure Process<sup>13</sup>

C 16 Wood Used on Farms, Preservative Treatment by Pressure Process<sup>13</sup>

C 23 Round Poles and Posts Used For Building Construction, Preservative Treatment by Pressure Process<sup>13</sup>

M 4 Care of Pressure Treated Wood Products<sup>13</sup>

## 3. Terminology

### 3.1 Definitions:

3.1.1 *back rails*—rails on which cover material is directly attached.

3.1.2 *boards*—lumber that is up to 1 in. in nominal thickness and 2 in. or wider in nominal width.

<sup>1</sup> This specification is under the jurisdiction of ASTM Committee F14 on Fences and is the direct responsibility of Subcommittee F14.20 on Wood Fence.

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<sup>2</sup> *Annual Book of ASTM Standards*, Vol 01.06.

<sup>3</sup> *Annual Book of ASTM Standards*, Vol 02.02.

<sup>4</sup> Discontinued; see *1992 Annual Book of ASTM Standards*, Vol 04.08.

<sup>5</sup> *Annual Book of ASTM Standards*, Vol 04.09.

<sup>6</sup> Discontinued; see *1992 Annual Book of ASTM Standards*, Vol 04.09.

<sup>7</sup> *Annual Book of ASTM Standards*, Vol 01.08.

<sup>8</sup> Available from Standardization Documents Order Desk, Bldg. 4 Section D, 700 Robbins Ave., Philadelphia, PA 19111-5094, Attn: NPODS.

<sup>9</sup> Available from Canadian Standards Association, 178 Rexdale Blvd., Rexdale, Ontario, Canada M 9W 1R3.

<sup>10</sup> Available from National Forest Products Association, 1619 Massachusetts Ave., N.W., Washington, DC 20036.

<sup>11</sup> Available from U.S. Department of Commerce, National Bureau of Standards, Washington, DC 20234.

<sup>12</sup> Available from American Plywood Association, 1119 A St., Tacoma, WA 98401.

<sup>13</sup> Available from American Wood Preservers Association, P.O. Box 849, Stevensville, MD 21666.

3.1.3 *cover material*—the face or fill material attached to a fence structural frame.

3.1.4 *custom fence design*—any fence design that is significantly different from those described in this specification. Custom fence designs are also required to meet all requirements regarding materials, fabrication, installation, workmanship, and structural equivalency as set forth within this specification.

3.1.5 *panel products*—all modular products available in standardized rectangular panels, many of which are suited to exterior applications such as privacy fencing. Examples are plywood, fiberglass, and corrugated metals.

3.1.6 *pickets*—narrow wood members that are sawn, split, sliced, milled, natural round or half-round, and are approximately 2 to 4 in. in face or coverage width.

3.1.7 *posts*—the vertical structural support members of the fence frame.

3.1.8 *rails*—the horizontal structural support members of the fence frame.

3.1.9 *slats or weave boards*—the horizontal or vertical members used in basketweave type fences normally  $\frac{3}{8}$  to  $\frac{3}{4}$  in. thick and 3 in. or wider in nominal width.

3.1.10 *standard fence design*—any fence structural frame or fence-type classification covered within this specification.

### 3.2 Definitions of Terms Specific to This Standard:

3.2.1 *boards or pickets*—fence boards or pickets are specified by the desired shape or manufacture of the upright end when installed vertically as described in 3.2.2 through 3.2.9.

3.2.2 *California clipped corners*—corners similar to 3.2.8, except the clip angle is steeper at approximately 65°.

3.2.3 *diamond point*—a board or picket similar to the standard point (3.2.9), except it consists of additional angular cuts, front and back, so that the top appears as a triangle from four angles of view, or pyramid shaped.

3.2.4 *flattop*—a simple flat or 90° square cut end.

3.2.5 *gothic*—a picket or board in which the shape is formed by two arc-shaped cuts that meet at center to form a graceful point at the top.

3.2.6 *handsplit*—pickets, posts, and rails which are split by machine or by hand using an axe or froe, etc.

3.2.7 *pencil point*—a picket or board that is conical in shape, and common to round and half-round pickets.

3.2.8 *standard clipped corners (or dog-eared corners)*—corners which are clipped diagonally (approximately 45°).

3.2.9 *standard point*—a picket or fence board cut to a point at approximately 45° angles.

3.2.10 *posts*—fence posts are specified by the desired shape or manufacture of their above ground tops as described in 3.2.11 through 3.2.15.

3.2.11 *chamfered posts*—in round or square posts, the shallow diagonal cut or easing of the otherwise square-cut end. Usually measures from  $\frac{3}{4}$  to 1½ in. along the chamfer.

3.2.12 *diamond-point posts*—the pyramid-shaped ends of post which are formed by angle cuts of approximately 45°.

3.2.13 *domed posts*—rounded ends of either round or square posts.

3.2.14 *flattop fence posts*—the square cut ends of post.

3.2.15 *pencil-point posts*—conically shaped round post tops.

## 4. Classification of Standard Fence Types

4.1 The generic classifications of wood fencing in 4.2 through 4.5 have gained common recognition throughout the fence industry and are adapted to this specification as a means of identifying a basic fence type. These classifications may be used in all cases as part of the purchase agreement between buyers and sellers of wood fencing; except a detailed description, drawing, or rendering of a custom fence design may be substituted where necessary.

### 4.2 Type I—Rail Fences:

4.2.1 *Split Rail*—The common country fence of alternating layers of handsplit rails laid up in zigzag tiers.

4.2.2 *Split or Sawn Post and Rail, or Both*—The rustic fence made up of split or sawn rails (two to four rails) installed into slotted split or sawn posts.

4.2.3 *Round Post and Rail*—A fence similar to that described in 4.2.2, except posts and rails are round or natural shaped; normally produced in two, three, and four rail fences. The rails are machined at ends to form a paddle-shaped scarf joint to be installed into post slots or formed into doweled ends for installing into posts with round connections.

4.2.3.1 *Herringbone Pattern Round Post and Rail*—A fence as described in 4.2.3, except it is normally a three-rail fence with small round wood inserts (doweled) which are installed between the upper two rails to form the familiar herringbone pattern.

4.2.3.2 *English Hurdle Fence*—A standard post and rail fence as described in 4.2.2 and 4.2.3, except that two smaller rails are installed diagonally from the fence posts (usually below the bottom rail connection) extending upwards to just above the fence top rail where they intersect and join a third decorative rail of the same approximate size, which extends downward to just below the bottom rail at a perpendicular angle.

4.2.4 *Post and Board*—The fence often referred to as corral fence is normally constructed using sawn wood posts, although round wood posts are sometimes used, with boards serving as rails. They are commonly constructed in two, three, or four board configurations.

4.2.4.1 *Crossbuck Post and Board*—A fence as described in 4.2.4, except that two boards diagonally cross each other between two standard top and bottom board rails.

4.2.4.2 *Crossbuck Post and Rail*—A fence as in 4.2.4.1, except rails are 2-in. or thicker nominal lumber.

4.2.4.3 *Hurdle Post and Board*—A fence having the same geometric arrangement as the English hurdle fence in 4.2.3.2, except all rails are sawn boards.

4.2.4.4 *Hurdle Post and Rail*—A fence as described in 4.2.4.3, except top and bottom rails are 2 in. or thicker nominal lumber.

4.3 *Type II—Board Fences*: Every design within this type may be supported by sawn wood posts, round wood posts, or metal posts.

4.3.1 *Solid Board Fence*—A fence that is constructed of ordinary wood fence boards which are usually installed vertically, but occasionally horizontally or diagonally, over a rather

conventional fence frame of from two to four rails between posts.

4.3.2 *Spaced Board Fence*—A fence as described in 4.3.1, except that open space is provided between the boards either for eye appeal or for ventilation.

4.3.3 *Shadow Box*—A fence that is constructed like a solid board fence (see 4.3.1), except that fence boards are installed alternately from one side of the fence rails to the other, providing interesting shadow lines as well as excellent ventilation. This fence is commonly offered in either vertical or horizontal panels.

4.3.4 *Louver*—A fence which is similar to common board fences (4.3.1) in frame configuration, except that fence boards are installed angularly between the fence rails with the effect of directing sunlight and air in a desirable way. These fences may be constructed with the board louvers installed vertically or horizontally.

4.3.5 *Weave*—A fence similar to the shadow box (4.3.3), except each individual fence board, normally 1 in. nominal in thickness, is alternately attached to one side of the top rail and the opposite side of the bottom rail. It may be constructed vertically as described, or horizontally (minus rails) by alternating installation of the boards directly to the fence posts.

4.3.6 *Basket Weave*—A fence similar to the weave (4.3.5), except basket boards (commonly  $\frac{3}{8}$  to  $\frac{3}{4}$  in. in thickness) are woven alternately between from one to five small wood members (sometimes 1 by 2, 1 by 3, or 1 by 4-in. nominal), which extend through the height of the weave perpendicularly. The fence may contain either a vertical or horizontal weave, but in either form, the top and bottom rails may be required for rigidity. The basket weave fence requires high quality wood because of its relative thinness.

4.4 *Type III—Picket Fences*: Every design within this type may be supported by sawn wood posts, round wood posts, or metal posts.

4.4.1 *Sawn Picket*—A fence in which the pickets are from 2 to 4-in. nominal width and are installed vertically. The pickets may be installed over two to four back rails of sawn lumber. The pickets may be installed solid or by specified spacing where desired for light and ventilation.

4.4.2 *Grape Stake Picket*—A fence that is sometimes referred to by the picket type, either handsplit or machine sliced. This is a popular fence in the durable species and is usually constructed with handsplit or machined back rails and posts. It is most often installed with solid picket cover, but can be utilized as a spaced picket fence.

4.4.3 *Stockade Picket*—A fence that is similar to other picket fences, except the pickets are natural, machine milled, round, or sliced to half-round; and are available with bark removed, or with bark on for an added rustic effect. This fence is popular in common wood species, and may be installed to round wood posts and round or half-round back rails, sawn posts, and back rails; or back rails attached to metal posts.

4.4.4 *Wire-Bound Picket*—This fencing is wire-bound, wooden picket fencing, in roll form. It is used for applications such as but not limited to, snow, shade, safety, sand, and screening. The fence is fabricated with a 2- or 4-in. maximum spacing between pickets as specified by the purchaser. Each

picket is held firmly by five pairs of zinc-coated wires. Each pair of wires is tightly twisted by rotating a twister head a minimum of  $2\frac{1}{2}$  complete revolutions ( $900^\circ$  of rotation) for 2-in. spacing and 5 complete revolutions ( $1800^\circ$  of rotation) for the 4-in. spacing.

4.4.4.1 The twist rotation shall be in opposite directions between each succeeding picket. The wire shall have a minimum coated diameter of 0.099 in. ( $12\frac{1}{2}$  gage) and a minimum zinc coating of 0.30 oz/ft<sup>2</sup> (Specification A 641, Class 1) or a minimum aluminum coating of 0.32 oz/ft<sup>2</sup> (Specification A 809) as selected by the purchaser. It shall have a minimum tensile strength of 70 000 psi in accordance with Specification A 641 or Specification A 809, Medium Temper. The wire spacing of top and bottom pairs of wires shall be not less than 3 in. and not more than 6 in. from the ends of the pickets, with the remaining pairs of wires spaced equidistant between the top and bottom wires.

4.4.4.2 The length of roll of fabricated fence shall be 50 ft  $\pm$  6 in. The pickets shall be made of spruce, hemlock, cedar, redwood, fir, or pine, air-dried and rough sawn. The pickets may be stained, painted with a red oxide coating, or pressure-treated in accordance with 9.4 as specified. Picket dimension shall be: length, either 48 or  $72 \pm \frac{3}{16}$  in.; width,  $1\frac{1}{2} \pm \frac{1}{16}$  in.; and thickness,  $\frac{3}{8} \pm \frac{1}{16}$  in.

#### 4.5 *Type IV—Solid Panel Fences*:

Every design within this type may be supported by sawn wood posts, round wood posts, or metal posts.

4.5.1 *Plywood Panel Fences*—A fence which includes any common post and back rail construction with an exterior grade of plywood that is installed on or within the frame.

4.5.2 *Other Panel Product Fences*—Other panel products suitable for exterior use and manufactured in standard panel sizes may be installed within any fence frame that provides adequate lateral support for the panel. Examples include corrugated fiberglass and corrugated metals.

## 5. Ordering Information

5.1 Complete information describing the desired fence product shall be provided with all purchase orders or inquiries. The information described in 5.1.1 through 5.1.10 shall be included as detailed within this specification:

5.1.1 *Fence-Type Classification or Description*—Provide the standard fence-type classification, as described in Section 4, or substitute a detailed description, drawing, or architectural rendering, depending on the complexity of a custom design, and the requirements of the fence supplier.

5.1.2 *Structural Frame Identification Number*—Provide the fence structural frame identification index number as provided in Tables 1-3 (see also Section 7). Also, specify the maximum post spacing in feet, center to center of posts and the height of the fence, which is the minimum measurement from ground level to the top of the cover material or top of the top rail, whichever is the greater when options are provided for a particular fence frame in the tables. For open post and rail fences, specify the desired number of rails where shown to be optional in Table 1. The fence frames listed in Tables 1-3 and Section 7 provide many common fence frame configurations and may be used for simplified specifying. Alternatively, fence frames of significantly different design may be used if they

**TABLE 1 Open Frame Post and Rail Fences**

Fence Type Classification	Structural Frame Identification Index	Nominal Post Size, in.	Nominal Top Rail Size, in.	Nominal Center Rail(s), in.	Nominal Bottom Rail Size, in.	Post Spacings, ft	Above Ground Height of Fence, ft	Total Number of Rails per Section
Split post and rail	No. 1	3 1/2 by 3 1/2	1 1/2 by 1 1/2	...	1 1/2 by 1 1/2	6	3	2
	No. 2	4 by 4	2 by 3	...	2 by 3	8	4	2
	No. 3	4 by 4	2 by 3	2 by 3	2 by 3	8	4	3
	No. 4	4 by 5	2 by 4	...	2 by 4	10	5	2
	No. 5	4 by 5	2 by 4	2 by 4	2 by 4	10	5	3
	No. 6	5 by 5	2 by 3	2 by 3	2 by 3	8	6	3
	No. 7	5 by 5	2 by 4	...	2 by 4	10	6	2
	No. 8	5 by 5	2 by 4	2 by 4	2 by 4	10	6	3
Round post and rail	No. 9	4 diameter	...	3 diameter	...	8	1, 2	1
	No. 10	5 diameter	...	4 diameter	...	8 to 10	1, 2	1
	No. 11	4 diameter	3 diameter	...	3 diameter	8	2, 3, 4	2
	No. 12	4 diameter	3 diameter	3 diameter	3 diameter	8	3, 4, 5	3
	No. 13	5 diameter	4 diameter	...	4 diameter	8 to 10	3, 4, 5	2
	No. 14	5 diameter	4 diameter	4 diameter	4 diameter	8 to 10	4, 5, 6	3
	No. 15	5 diameter	4 diameter	4 diameter	4 diameter	8 to 10	5, 6, 7	4
Sawn post and board	No. 16	3 by 4	1 by 4	...	1 by 4	8	2	2
	No. 17	4 by 4	1 by 4	1 by 4	1 by 4	8	3, 4, 5	3, 4, 5
	No. 18	4 by 4	1 by 6	1 by 6	1 by 6	8	4, 5, 6	3, 4, 5

**TABLE 2 Sawn Wood Fence Frames**

Fence Type Classification	Structural Frame Identification Index	Nominal Post Size, in.	Nominal Top Rail Size, in.	Nominal Center Rail(s), in.	Nominal Bottom Rail Size, in.	Post Spacings, ft.	Above Ground Height of Fence, ft	Total Number of Rails per Section
Fence frames for use with cover materials (up to and including solid, 100 %, cover or fill designs)	No. 19	3 by 4	2 by 3	...	2 by 3	6	3, 4	2
	No. 20	4 by 4	2 by 3	...	2 by 3	8	3, 4	2
	No. 21	4 by 4	2 by 3	2 by 3	2 by 3	8	4, 5, 6	3
	No. 22	4 by 4	2 by 4	...	2 by 4	8	4, 5, 6	2
	No. 23	4 by 4	2 by 4	2 by 4	2 by 4	8	6	3
	No. 24	4 by 4	2 by 6	...	2 by 6	8	6	2
	No. 25	4 by 4	4 by 4	...	4 by 4	8	6	2
	No. 26	4 by 6	2 by 4	2 by 4	2 by 4	6	7	3
	No. 27	4 by 6	2 by 6	...	2 by 6	6	7	2
	No. 28	4 by 6	4 by 4	...	4 by 4	6	7	2
	No. 29	6 by 6	2 by 6	2 by 6	2 by 6	6	8	3
	No. 30	6 by 6	4 by 4	4 by 4	4 by 4	6	8	3
	No. 31	6 by 6	2 by 4	2 by 4	2 by 4	6	8	4
	No. 19A	3 by 4	1 by 4	...	1 by 4	6	3	2
	No. 20A	3 by 4	1 by 4	1 by 4	1 by 4	6	4, 5	3
	No. 21A	4 by 4	1 by 4	1 by 4	1 by 4	8	4, 5, 6	3

provide structural integrity equal or superior to those described in Section 7, or if justified by structural engineering as provided in NFPA Specification for Stress Grade Lumber and Its Fastenings and APA Specification for Plywood Design.

**5.1.3 Architectural Class or Grade of Materials**—Include the architectural class of all sawn posts, rails, or boards as provided in Section 6 or their acceptable equivalent commercial lumber grade as provided in Tables 4-7. If handsplit, machine-sliced, or sawn pickets are to be used, specify the architectural class in accordance with Section 6. All other wood products are required to meet their minimum quality standards as established within Section 6.

**5.1.4 Species of Wood**—It is normally desirable for the

fence purchaser to specify the commercial species of wood to be used in the fence or its various component parts, as it relates vitally to the appearance, durability, and general performance of the fence structure (see Section 8).

**5.1.5 Preservative Pressure Treatment**—Specify the pressure treatment, where applicable, in accordance with AWPA Standards C 1, C 2, C 5, C 9, C 16, C 23, and M 4 (see Section 9).

**5.1.6 Sizes and Details for Cover Material(s)**—Sizes of boards, pickets, and other fence cover materials (such as basketweave stock) shall be included in all purchase orders and inquiries. Unless otherwise noted, all fence boards shall be taken to be 1 in. rough nominal in thickness. Details of cover

**TABLE 3 Metal Fence Posts and Frames**

Fence Type Classification	Structural Frame Identification Index	Nominal Outside Diameter or Dimensions of Metal Posts, in.	Nominal Top Rail Size-Wood, in.	Nominal Center Rail-Wood, in.	Nominal Bottom Rail-Wood, in.	Post Spacings, ft	Above Ground Height of Fence, ft	Total Number of Rails per Section
Metal/wood fence frames for use with cover materials (galvanized steel pipe)	No. 1M	1.90	2 by 3	...	2 by 3	8	3 to 4	2
	No. 2M	1.90	2 by 3	2 by 3	2 by 3	8	4 to 5	3
	No. 3M	1.90	2 by 4	...	2 by 4	8	4 to 5	2
	No. 4M	2.375	2 by 3	2 by 3	2 by 3	8	4, 5, 6	3
	No. 5M	2.375	2 by 4	...	2 by 4	8	4, 5, 6	2
	No. 6M	2.375	2 by 4	2 by 4	2 by 4	8	5 to 6	3
Same usage as above but post and rails are metal channels	No. 7M	1.875 by 1.625	2 by 3	2 by 3	2 by 3	8	3 to 4	2
	No. 8M	1.875 by 1.625	2 by 3	...	2 by 3	8	4 to 5	3
	No. 9M	1.875 by 1.625	2 by 4	2 by 4	2 by 4	8	4 to 5	2
	No. 10M	2.25 by 1.70	2 by 3	2 by 3	2 by 3	8	4, 5, 6	3
	No. 11M	2.25 by 1.70	2 by 4	...	2 by 4	8	4, 5, 6	2
	No. 12M	2.25 by 1.70	2 by 4	2 by 4	2 by 4	8	5 to 6	3
	No. 13M	2.375 × 2 aluminum	2.375 × 2 aluminum	...	2.375 × 2 aluminum	6 to 10	3 to 6	2
	No. 14M	2.375 × 2 galvanized steel	2.375 × 2 galvanized steel	...	2.375 × 2 galvanized steel	6 to 10	3 to 6	2

**TABLE 4 Lumber for Fence Boards (2 in. and Wider)**

Species	Architectural Class I	Architectural Class II	Architectural Class III	Grade Rule Writing Agencies <sup>A</sup>
Western Red Cedar	select	quality	utility	ICA NLGA
Western Cedars (Incense and Red)	select merchantable	standard/construction	utility	WCLIB, WWPA, NLGA
Cypress	2 and btr common	3 common	4 common	WWPA, NLGA
Douglas Fir-Larch	1 common	2 common	3 common or peck	SCMA, NHLA
Douglas Fir-Larch	select merchantable	standard/construction	utility	WCLIB, WWPA, NLGA
Hem-Fir (Hemlock-White Fir)	2 and btr common	3 common	4 common	WWPA, NLGA
Western or Idaho White Pine	select merchantable	standard/construction	utility	WCLIB, WWPA, NLGA
Western Pines	2 and btr common	3 common	4 common	WWPA, NLGA
Norway Pine	sterling	standard	utility	WWPA, NLGA
Eastern White Pine	2 and btr common	3 common	4 common	WWPA, NLGA
Eastern White Pine	premium	premium	standard	NELMA
Northern Pine and Norway Pine (NHPMA)	2 and btr common	3 common	4 common	NELMA
Southern Pine	2 and btr common	3 common	4 common	NLGA
Eastern Hemlock and Tamarack	No. 1 boards	No. 2 boards	No. 3 boards	NHPMA, NELMA, NLGA
Aspen-Alder	2 and btr common	3 common	4 common	NHPMA, NELMA, NLGA, WWPA
Balsam Fir and Eastern Spruce	2 and btr common	3 common	4 common	NHPMA, NELMA, NLGA
Englemann Spruce	2 and btr common	3 common	4 common	WWPA
Sitka Spruce	select merchantable	standard/construction	utility	WCLIB, NLGA
Spruce-Pine-Fir	2 and btr common	3 common	4 common	NLGA
Redwood	select heart or select	construction heart or construction common	merchantable	RIS
Redwood				RIS
Northern White Cedar	2 and btr common	3 common	4 common	NELMA, NLGA
Alpine Fir	2 and btr common	3 common	4 common	WWPA, NLGA
All hardwoods	No. 1 construction	No. 2 construction	No. 3 construction	NLHA, SHLMA

<sup>A</sup> For identification of agencies, refer to Appendix X2.

material selection should be included where necessary (for example, nominal face widths of fence boards or pickets should be specified, including the style in which they are laid-up). Sizes are provided in Section 10.

**5.1.7 Manufacture**—Special shapes or dressed ends of vertical fence boards, pickets, or posts shall be specified by the terminology provided in Section 3. Round post and rail fences may be specified with paddle-shaped scarf joints in cases where rail scarfs are fitted into slotted posts; or rails may be manufactured with doweled ends for installation into posts

with special round-hold connections. Other special manufacturing details may be specified by including a detailed description, drawing, or rendering of the fence.

**5.1.8 Post Embedment**—The required fence post installation shall be specified as compact soil embedment, gravel or sand-gravel embedment, or set in concrete collar footings in accordance with Section 11. However, if the fence is installed by the purchaser, only the required post length need be specified, based on the depth of embedment as determined in accordance with Section 11.

**TABLE 5 Lumber for Posts and Rails (2 to 4 in. Thick and 2 to 4 in. Wide)**

Species	Architectural Class I	Architectural Class II	Architectural Class III	Grade Rule Writing Agencies <sup>A</sup>
Western Red Cedar	select	quality	utility	ICA
Western Cedars (Incense and Red)	construction/No. 2	standard, No. 3, or stud	utility	WWPA, WCLIB, NLGA
Cypress	1 common	2 common	3 common	SCMA, NHLA
Douglas Fir-Larch	construction/No. 2	standard, No. 3, or stud	utility	WWPA, WCLIB, NLGA
Hemlock-Fir	construction/No. 2	standard, No. 3, or stud	utility	WWPA, WCLIB, NLGA
Western Pine	construction/No. 2	standard, No. 3, or stud	utility	WWPA, NLGA
Eastern White Pine	construction/No. 2	standard, No. 3, or stud	utility	NELMA, NHPMA, NLGA
Western or Idaho White Pine	construction/No. 2	standard, No. 3, or stud	utility	WWPA, NLGA
Northern Pines	construction/No. 2	standard, No. 3, or stud	utility	NELMA, NHPMA, NLGA
Southern Pine	construction/No. 2	standard, No. 3, or stud	utility	SPIB
Eastern Hemlock, Tamarack	construction/No. 2	standard, No. 3, or stud	utility	NELMA, NHPMA
Aspen-Alder	construction/No. 2	standard, No. 3, or stud	utility	NELMA, NHPMA, NLGA
Balsam Fir, Eastern Spruce	construction/No. 2	standard, No. 3, or stud	utility	NELMA, NHPMA, NLGA
Engelmann Spruce	construction/No. 2	standard, No. 3, or stud	utility	WWPA
Sitka Spruce	construction/No. 2	standard, No. 3, or stud	utility	WCLIB, NLGA
Spruce, Pine, Fir	construction/No. 2	standard, No. 3, or stud	utility	NLGA
Redwood	select, select heart, or No. 2 open grain	construction common, construction heart, or No. 3 open grain, standard stud	merchantable utility	RIS
Alpine Fir	construction/No. 2	standard, No. 3, or stud	utility	WWPA, NLGA
All hardwoods	No. 1 dimension	No. 1 dimension	No. 2 dimension	NHLA, SHLMA
Northern White Cedar	construction/No. 2	standard, No. 3, or stud	utility	NELMA, NLGA

<sup>A</sup> For identification of agencies, refer to Appendix X2.

**TABLE 6 Lumber for Posts and Rails (2 to 4 in. Thick and 6 in. and Wider)**

Species	Architectural Class I	Architectural Class II	Architectural Class III	Grade Rule Writing Agencies <sup>A</sup>
Western Red Cedar	select	quality	utility	ICA
Western Cedars (Incense and Red)	No. 1	No. 2	No. 3	WWPA, WCLIB, NLGA
Cypress	1 common	2 common	3 common	SCMA, NHLA
Douglas Fir-Larch	No. 1	No. 2	No. 3	WWPA, WCLIB, NLGA
Hemlock-Fir	No. 1	No. 2	No. 3	WWPA, WCLIB, NLGA
Western Pine	No. 1	No. 2	No. 3	WWPA, NLGA
Eastern White Pine	No. 1	No. 2	No. 3	NELMA, NHPMA, NLGA
Western or Idaho White Pine	No. 1	No. 2	No. 3	WWPA, NLGA
Northern Pines	No. 1	No. 2	No. 3	NELMA, NHPMA, NLGA
Southern Pine	No. 1	No. 2	No. 3	SPIB
Eastern Hemlock, Tamarack	No. 1	No. 2	No. 3	NELMA, NHPMA
Aspen-Alder	No. 1	No. 2	No. 3	NELMA, NHPMA, WWPA, NLGA
Balsam Fir, Eastern Spruce	No. 1	No. 2	No. 3	NELMA, NHPMA, NLGA
Engelmann Spruce	No. 1	No. 2	No. 3	WWPA
Sitka Spruce	No. 1	No. 2	No. 3	WCLIB, NLGA
Spruce, Pine, Fir	No. 1	No. 2	No. 3	NLGA
Redwood	No. 1 open grain, select/select heart	No. 2 open grain, construction common/construction heart	No. 3 open grain, merchantable	RIS
Northern White Cedar	No. 1	No. 2	No. 3	NELMA, NLGA
Alpine Fir	No. 1	No. 2	No. 3	WWPA, NLGA
All hardwoods	No. 1 dimension	No. 1 dimension	No. 2 dimension	NHLA, SHLMA

<sup>A</sup> For identification of agencies, refer to Appendix X2.

5.1.9 *Fastenings and Connections*—This aspect of fence construction may be specified with considerable detail or may be omitted, in which case all fastenings and connections shall comply with Section 11.

5.1.10 *Finish*—When and if a special finish is desired, the color, method of application, and number of coats shall be specified (see Section 12).

**6. Quality of Materials of Manufacture**

6.1 *Quality Classification of Sawn Posts and Rails*—The following quality classifications of sawn lumber posts and rails may be achieved by ripping or cross cutting commercial grades of lumber to meet the requirements as listed. Compliance can

also be achieved by using the minimum commercial grades of lumber which are acceptable alternatives and in reasonable accordance with these architectural quality classifications. Tables 4-7 relate commercial lumber grades by size and use categories to the following fence industry component-part quality classifications:

6.1.1 *Architectural Class I, Sawn Posts and Rails*—This classification is recommended where the highest combination of both strength and appearance is required. Allowable growth characteristics and limiting provisions are described in 6.1.1.1 through 6.1.1.7.

6.1.1.1 Stained sapwood allowed, stained heartwood in 25 % of the piece.



TABLE 7 Lumber for Large Posts (5 in. and Thicker and 5 in. and Wider)

Species	Architectural Class I	Architectural Class II	Architectural Class III	Grade Rule Writing Agencies <sup>A</sup>
Western Red Cedar	select	quality	utility	ICA
Western Cedars (Incense & Red)	select structural	No. 1	No. 2	WWPA
Cypress	select structural	No. 1 structural	standard	WCLIB, NLGA
Douglas Fir-Larch	1 common	2 common	3 common	SCMA, NHLA
Douglas Fir-Larch	select structural	No. 1 structural	standard	WCLIB, NLGA
Hemlock-Fir	select structural	No. 1	No. 2	WWPA
Hemlock-Fir	select structural	No. 1 structural	standard	WCLIB, NLGA
Hemlock-Fir	select structural	No. 1	No. 2	WWPA
Western Pines	select structural	No. 1	No. 2	WWPA
Western Pines	select structural	No. 1	standard	NLGA
Eastern White Pine	select structural	No. 1	No. 2	NELMA, NHPMA
Eastern White Pine	select structural	No. 1	standard	NLGA
Northern Pines	select structural	No. 1	standard	NLGA
Northern Pines	select structural	No. 1	No. 2	NHPMA
Northern Pines	select structural	No. 1	No. 2	NELMA
Southern Pine	No. 1 dense stress or dense structural "65"	No. 1 stress rated or No. 1 timber	No. 2 stress-rated or No. 2 timber	SPIB
Eastern Hemlock, Tamarack	select structural	No. 1	No. 2	NELMA
Aspen-Alder	select structural	No. 1	No. 2	NHPMA
Aspen-Alder	select structural	No. 1	No. 2	NELMA, NHPMA, WWPA
Aspen-Alder	select structural	No. 1	standard	NLGA
Balsam Fir, Eastern Spruce	select structural	No. 1	No. 2	NHPMA, NELMA
Engelmann Spruce	select structural	No. 1	standard	NLGA
Sitka Spruce	select structural	No. 1	No. 2	WWPA
Spruce, Pine, Fir	select structural	No. 1	standard	WCLIB, NLGA
Redwood	select, select heart or select structural open grain	construction common, construction heart, or No. 1 open grain	merchantable, No. 2 open grain	NLGA
Redwood	select, select heart or select structural open grain	construction common, construction heart, or No. 1 open grain	merchantable, No. 2 open grain	RIS
All hardwoods	No. 1 dimension	No. 1 dimension	No. 2 dimension	NHLA, SHLMA

<sup>A</sup> For identification of agencies, refer to Appendix X2.

6.1.1.2 Seasoning checks not limited except through checks at end limited as splits; allowable splits equivalent in length to the width of the piece.

6.1.1.3 Knots, sound and tight, approximately one third the face width; small unsound or not firmly fixed knots allowed.

6.1.1.4 Skips, hit and miss.

6.1.1.5 Slope of grain, not to exceed a 1-in. deviation in 8 in. of length.

6.1.1.6 No spike knot or other growth characteristic shall displace more than one third of a cross-sectional area.

6.1.1.7 Wane, one sixth of any face; or one fourth of any face up to half the length; except an occasional piece may have wane up to one half the thickness and one third the width for one fourth of the length.

6.1.2 *Architectural Class II, Sawn Posts and Rails*—This classification provides high strength in a fence, while providing a rustic appearance. Allowable growth characteristics and limiting provisions are described in 6.1.2.1 through 6.1.2.10.

6.1.2.1 Stain and other rustic colorations due to normal weathering or seasoning not limited.

6.1.2.2 Seasoning checks not limited except through checks at end limited as splits; allowable splits equivalent in length to 1½ times the width of the piece.

6.1.2.3 Knots, unsound or not firmly fixed approximately one third the face width.

6.1.2.4 Holes, knot holes, or holes from any cause, approximately 1 in. or equivalent smaller for each 2 ft of length.

6.1.2.5 Skips, hit and miss.

6.1.2.6 Small spots or streaks of unsound wood, or peck, equal to one sixth the width permitted.

6.1.2.7 Light shake permitted; through shakes, in 2 through

4-in. material, up to 2 ft long permitted away from ends. If through at edges or ends, limited as splits.

6.1.2.8 Slope of grain, not to exceed 1-in. deviation in 8 in. of length.

6.1.2.9 No spike knot or other growth characteristic shall displace more than one third of a cross-sectional area.

6.1.2.10 Wane, one third of any face; except, that an occasional piece may have wane up to two thirds the thickness and one half the width for one fourth the length.

6.1.3 *Architectural Class III, Sawn Posts and Rails*—The most rustic of all classifications but suitable and even desirable for many wood fence designs. Allowable growth characteristics and limiting provisions are described in 6.1.3.1 through 6.1.3.10.

6.1.3.1 Stained wood permitted.

6.1.3.2 Seasoning checks not limited, except through checks at end limited as splits; allowable splits equivalent in length to twice the width of the piece, but in no case may exceed one sixth of the length.

6.1.3.3 Knots, unsound or not firmly fixed not larger than one half the face width.

6.1.3.4 Holes, knot holes, or holes from any cause, not larger than one third of the face width.

6.1.3.5 Skips, hit or miss up to ⅛-in. scant.

6.1.3.6 Unsound wood, honeycomb, or peck permitted in spots or streaks but shall not displace more than one third of a cross-sectional area.

6.1.3.7 Medium shake permitted; occasional through shakes permitted when tight and nearly parallel to edges, and limited in length as splits, measured on the through side.

6.1.3.8 Slope of grain, not to exceed a 1-in. deviation in 4 in. of length.

6.1.3.9 No spike knot or other growth characteristic, singularly or in combination, shall displace more than one half of a cross-sectional area.

6.1.3.10 Wane, one half of any face; except that an occasional piece may have wane up to two thirds the thickness for one fourth the length.

6.1.4 *Definitions of Growth Characteristics*—For definitions relating to allowable growth characteristics and limiting provisions as allowed in 6.1.1 through 6.1.3, refer to Appendix X1 of this specification.

6.2 *Quality Standards for Split Posts and Rails*—Split posts and rails shall be graded on the basis of strength and appearance. Tolerances for dimensional variation are also provided since it is impossible for each post or rail to be exactly alike due to its hand-crafted method of manufacture; therefore the dimensions are average and approximate within tolerances shown.

6.2.1 A  $-\frac{1}{2}$ -in. tolerance in girth shall be allowed for variation in the finished product.

6.2.2 All longitudinal shaping shall be developed by splitting with axe, froe, wedge, or machine. Cut, torn, or rough grain shall not be classified as defects.

6.2.3 Knots shall not exceed one half of the narrowest dimension in size.

6.2.4 Spiral grain shall not exceed a one-quarter twist within the length of the piece.

6.2.5 Kinks, bends, crooks, or sweep shall not be greater than the equivalent of the narrowest dimension, measured as a deviation from a straight line drawn along the center from end to end.

6.2.6 No outer bark, sap rot, char, or unsightly discolorations shall be permitted. Limited heart rot or peck in streaks or pockets shall be permitted. Rustic colorations due to normal weathering and seasoning shall be permitted.

6.2.7 Scars, wounds, or splits shall not exceed one fourth the depth of the member at the area affected.

6.3 *Quality Standards for Round and Half-Round Posts and Rails*—These posts and rails shall be graded on the basis of strength and appearance. Tolerances for diameter variation are also provided since it is impossible for each natural round post or round and half-round rails to be exactly alike; therefore, diameters are average and approximate within the tolerances shown.

6.3.1 A  $-\frac{1}{4}$ -in. or a  $+\frac{1}{2}$ -in. variation in the nominal small-end diameter shall be allowed.

6.3.2 Natural taper shall be permitted.

6.3.3 Knots or limbs shall be trimmed flush and shall be limited to a maximum of a 50 % displacement within any 6 in. of length.

6.3.4 Kinks, bends, or crook shall be limited to an amount equivalent in inches to half the average diameter, measured as a deviation from a straight line drawn along the center from end to end.

6.3.5 No end rot, saw cut, or major defect shall be permitted. No outer bark shall be permitted, except for small spots or streaks limited to a maximum of 10 % of the total surface area.

Rustic colorations due to normal weathering and seasoning shall be permitted.

6.3.6 Seasoning checks or cracks are normal characteristics and shall be limited to one half the diameter.

6.3.7 Length of round posts may be  $\pm 2$  in. Length of rails may be  $\pm 1$  in.

6.4 *Quality Classification of Sawn Fence Boards*—The following quality classifications of sawn lumber fence boards may be achieved by ripping or cross-cutting ordinary commercial grades of lumber to meet the requirements as listed. Compliance can also be achieved by using the minimum commercial grades of lumber which are acceptable alternatives and in reasonable accordance with these architectural quality classifications. Tables 4-7 relate commercial lumber grades by size and use categories to the following fence industry component-part quality classifications:

6.4.1 *Architectural Class I, Sawn Fence Boards*—This classification provides first-rate fence boards of high strength and appearance quality. In addition to disallowing such through-defects as knot holes, other allowable growth characteristics and limiting provisions are described in 6.4.1.1 through 6.4.1.9.

6.4.1.1 Light stain allowed; medium stain allowed on occasional pieces if otherwise superior quality.

6.4.1.2 Small seasoning checks permitted, with an occasional medium check not through.

6.4.1.3 Short splits, limited to one on each end.

6.4.1.4 Knots, sound and tight, approximately one third the face width.

6.4.1.5 Skips, hit and miss.

6.4.1.6 Scattered pin holes.

6.4.1.7 Shake, fine.

6.4.1.8 Spike knots, approximately one half the face width or equivalent; but no spike knot or other growth characteristic shall displace more than one third of a cross-sectional area.

6.4.1.9 Wane, not permitted.

6.4.2 *Architectural Class II, Sawn Fence Boards*—This classification provides good strength and appearance qualities, while allowing occasional through-defects and offering a decidedly more rustic look. Allowable growth characteristics and limiting provisions are described in 6.4.2.1 through 6.4.2.11.

6.4.2.1 Medium stain allowed; heavy stain allowed on occasional pieces if otherwise superior quality.

6.4.2.2 Medium seasoning checks permitted.

6.4.2.3 Short splits permitted, or one tight medium split.

6.4.2.4 Knots, sound and tight up to one half the face width but not over  $4\frac{1}{2}$  in. in diameter or equivalent; knots unsound or not firmly fixed limited to approximately one third the face width but not over  $2\frac{1}{2}$  in. in diameter or equivalent.

6.4.2.5 Skips, hit or miss.

6.4.2.6 Pin holes not limited.

6.4.2.7 Shake, light. Through shakes limited to one fourth the length.

6.4.2.8 Spike knots, approximately three fourths of face width; but, no spike knot or other growth characteristic shall displace more than one half of a cross-sectional area.

6.4.2.9 Wane, one half of the thickness, one third of the width.

6.4.2.10 Small spots or streaks of unsound wood, or peck, equal to one sixth the width and not more than one eighth of the area.

6.4.2.11 Holes, knot holes, or holes from any cause, approximately 1 in. or equivalent for each 3 ft of length.

6.4.3 *Architectural Class III, Sawn Fence Boards*—The most rustic of all fence board classifications but highly suitable and even desirable for many wood fence designs. Allowable growth characteristics and limiting provisions are described in 6.4.3.1 through 6.4.3.11.

6.4.3.1 Heavy stain permitted.

6.4.3.2 Large seasoning checks permitted.

6.4.3.3 Splits, approximately one fourth the length.

6.4.3.4 Knots, unsound or not firmly fixed up to approximately one half the face width.

6.4.3.5 Skips, hit or miss up to  $\frac{1}{8}$ -in. scant.

6.4.3.6 Pin holes or small holes not limited.

6.4.3.7 Medium through shake permitted.

6.4.3.8 Spike knots, or other growth characteristics, shall not displace more than approximately one half of a cross-sectional area.

6.4.3.9 Wane, approximately one half the thickness and one third the width except heavy wane permitted on back. When through face, limited as holes.

6.4.3.10 Unsound wood, honeycomb, or peck permitted in spots or streaks over one third the surface area, but not displacing more than approximately one half of a cross-sectional area.

6.4.3.11 Holes, knot holes, or holes from any cause, not larger than approximately one third the face width. Knot holes, or loose knots, or both of maximum size are limited to one for each 4 ft of length, or equivalent smaller.

6.4.4 *Definitions of Growth Characteristics*—For definitions related to allowable growth characteristics and limitations described within 6.4.1 through 6.4.3, refer to Appendix X1.

6.5 *Quality Standards for Machined or Hand-Split Pickets*—These pickets are available in two quality levels, Architectural Class I and II; both will provide more than adequate performance while offering distinctly different appearance characteristics. Faces shall have 100 % longitudinal shaping by splitting with axe, froe, wedge, or machine.

6.5.1 *Class I*—Allowable growth characteristics and limiting provisions are described in 6.5.1.1 through 6.5.1.6.

6.5.1.1 Pickets shall be free of rot and bark with one clear split face. They may have saw marks on back.

6.5.1.2 Pickets shall have straight and parallel edges full width within a  $\pm\frac{1}{16}$ -in. tolerance.

6.5.1.3 Pickets shall be split  $\frac{1}{16}$  in. thick; split end or top shall have a minimum thickness of  $\frac{7}{16}$  in.; minimum thickness at butt shall be not less than  $\frac{3}{16}$  in. at one point or one edge, average minimum  $\frac{5}{16}$  in.; maximum thickness at any point not to exceed  $1\frac{1}{8}$  in., including dimension at spike knot.

6.5.1.4 Pickets shall be square and trimmed to a length tolerance of  $\frac{1}{2}$  in. plus or minus.

6.5.1.5 Twist and knot curls shall not exceed  $\frac{1}{2}$  in.; further, two pickets standing side by side shall not show a hole or

noticeable gap through, when viewed from a distance of approximately 10 ft.

6.5.1.6 A 6-in. bow or sweep in the flat surface that will pull out by bundling or nailing is allowed.

6.5.2 *Class II*—Allowable growth characteristics and limiting provisions are described in 6.5.2.1 through 6.5.2.6.

6.5.2.1 Rot spots or streaks of bark not to exceed one third of the edge thickness.

6.5.2.2 Small knots or holes not to exceed  $\frac{1}{2}$  in. in face.

6.5.2.3 Curved edges or edge sweep not to exceed  $\frac{1}{4}$  in.; width tolerance may be  $\pm\frac{1}{8}$  in.

6.5.2.4 Thickness on split end allowed to be  $\frac{3}{32}$  in., minimum; allowable butt thickness,  $\frac{1}{8}$  in., minimum; maximum thickness not to exceed  $1\frac{1}{2}$  in.

6.5.2.5 Length tolerance permitted is  $\pm\frac{3}{4}$  in.

6.5.2.6 Twist and knot curls allowed.

6.6 *Quality Standards for Machine-Sliced Pickets*—These pickets are available and acceptable in two qualities, Class I and II; both will provide more than adequate performance while offering distinctly different appearance characteristics.

6.6.1 *Class I*—Allowable growth characteristics and limiting provisions are described in 6.6.1.1 through 6.6.1.4.

6.6.1.1 Pickets shall be free of rot and bark with one clear sliced face. They may have saw marks on back.

6.6.1.2 Pickets shall have straight and parallel edges full width with a tolerance of  $\pm\frac{1}{16}$  in.

6.6.1.3 Pickets shall be sliced  $\frac{1}{16}$  in. thick. They shall have a minimum thickness of  $\frac{7}{16}$  in.

6.6.1.4 All pickets shall be square end trimmed to a length tolerance of  $\pm\frac{1}{8}$  in.

6.6.2 *Class II*—Allowable growth characteristics and limiting provisions are described in 6.6.2.1 through 6.6.2.4.

6.6.2.1 Sound knots not to exceed two thirds of the width.

6.6.2.2 Small loose knots or holes not to exceed  $\frac{1}{2}$  in. in face.

6.6.2.3 Curved edges not to exceed a  $\pm\frac{1}{4}$  in. tolerance; the allowable width tolerance shall be  $\pm\frac{1}{16}$  in.

6.6.2.4 Length tolerance permitted is  $\pm\frac{1}{4}$  in.

6.7 *Quality Standards for Round and Half-Round Pickets*—All round and half-round pickets shall be manufactured within the minimum standards as provided herein. Allowable growth characteristics and limiting provisions are described in 6.7.1 through 6.7.8.

6.7.1 It is impossible for all round and half-round pickets to be exactly alike; therefore, diameters or widths are approximate and average along the length of the picket.

6.7.2 A  $\pm\frac{1}{2}$ -in. variation in the average nominal diameter or width is permitted.

6.7.3 Natural taper shall be permitted, but shall be reasonably uniform with extreme irregularities or natural deformations not permitted.

6.7.4 All knots or limbs shall be trimmed flush. Sound and tight knots may not exceed  $\frac{3}{4}$  in. in diameter or equivalent, except that no single knot or combination of knots shall exceed a 50 % displacement along any 3 in. of length.

6.7.5 No loose knots, rot, or holes-through shall be permitted.

6.7.6 No outer bark shall be permitted, except for occasional

very small spots or streaks, the combined area of which shall not exceed 10 % of the total surface.

6.7.7 The length tolerance permitted shall be  $\pm 1/4$  in.

6.7.8 *Bark-on Pickets*—Round and half-round pickets are optionally available and acceptable under all requirements of 6.7.1 through 6.7.7, with the exception that the natural outer bark is left on the picket, and the limbs are not trimmed as closely.

6.8 *Quality Standards for Sawn Pickets*—Sawn wood pickets are available and acceptable under two commercial grades of quality as provided by the regional lumber grading rules authorities. Table 8 lists the acceptable grades of sawn pickets which have been collated in accordance with the near equivalence to Classes I and II, as described in 6.5 and 6.6 (see also Appendix X2).

6.9 *Quality Standards for Machine-Moulded (Milled) Fence Pickets*:

6.9.1 *Class I*—This classification provides first-rate fence pickets of high strength and appearance quality. In addition to disallowing such through defects as knot holes, other allowable growth characteristics and limiting provisions are described in 6.9.1.1 through 6.9.1.10.

6.9.1.1 Medium stain allowed.

6.9.1.2 Small seasoning checks allowed.

6.9.1.3 No splits allowed.

6.9.1.4 Knots, sound and tight approximately one third the face width.

6.9.1.5 Light skip ( $1/32$  in. in depth and 2 in. in width).

6.9.1.6 No pin holes.

6.9.1.7 Shake, light.

6.9.1.8 No spike knot allowed.

6.9.1.9 Wane, not permitted.

6.9.1.10 Dimensional tolerances: width and thickness,  $\pm 1/16$  in.; length,  $\pm 1/8$  in.

6.9.2 *Class II*—This classification provides good strength and appearance qualities. Allowable growth characteristics and limiting provisions are described in 6.9.2.1 through 6.9.2.12.

6.9.2.1 Medium stain allowed.

6.9.2.2 Medium seasoning checks allowed.

6.9.2.3 Very short split allowed.

6.9.2.4 Knots, sound and tight up to one half the face width.

6.9.2.5 Medium skip, hit and miss.

6.9.2.6 No pin holes permitted.

6.9.2.7 Shake, medium.

6.9.2.8 No spike knot allowed.

6.9.2.9 Wane, limited to back face and back edge not to exceed one third the width of face or one third the length of

piece. No inner or outer bark allowed. Saw marks allowed on back face.

6.9.2.10 Peck, not to exceed 1 % of surface area.

6.9.2.11 Holes, none permitted.

6.9.2.12 Dimensional tolerance: width and thickness  $1/16$  in.; length  $3/16$  in.

6.9.3 *Class III*—This classification provides fair strength and appearance qualities, while allowing some through defects and offering a decidedly more rustic look. Allowable growth characteristics and limiting provisions are described in 6.9.3.1 through 6.9.3.12.

6.9.3.1 Heavy stain permitted.

6.9.3.2 Large seasoning checks permitted.

6.9.3.3 Splits, approximately one fourth of the length.

6.9.3.4 Knots, unsound or not firmly fixed up to approximately one half the face width.

6.9.3.5 Skips, hit and miss.

6.9.3.6 Pin holes or small holes not limited.

6.9.3.7 Medium through shake permitted.

6.9.3.8 Spike knots or other growth characteristics shall not displace more than approximately one half of the cross-sectional area.

6.9.3.9 Wane, approximately one third of any face, except one half of back surface. All bark shall be removed.

6.9.3.10 Unsound wood, honeycomb, or peck are permitted in spots or streaks over one third the surface area, but not displacing more than approximately one half of the cross-sectional area.

6.9.3.11 Holes, knot holes, or holes from any cause, not larger than approximately one fourth the face width. Knot holes or loose knots, or both, of medium size are limited to one for each 4 ft of length or equivalently smaller.

6.9.3.12 Dimensional tolerance: thickness  $1/16$  in., width  $1/8$  in., length  $1/4$  in.

6.10 *Quality Requirements for Plywood*—All exterior grades of plywood, all species, manufactured under the requirements of U.S. Department of Commerce Voluntary Product Standard PS 1-74 are acceptable for use under this specification.

6.11 *Requirements for Round Galvanized Steel Posts*—Round galvanized steel posts meeting the criteria outlined in 6.11.1, 6.11.2, and 6.11.3 may be selected from Table 3.

NOTE 1—Alternative design, strength calculations, and weight tolerances are derived from Specification F 1034.

6.11.1 Bending strength is defined as the product ( $Z \times Y$ ) of the section modulus ( $Z$ ) and the yield strength ( $Y$ ). Stiffness

TABLE 8 Acceptable Grades of Sawn Pickets

Commercial Species (Softwoods)	Architectural Class I	Architectural Class II	Grading Rule Writing Agency <sup>A</sup>
Western Red Cedar	No. 1	No. 2	WCLIB, WWPA, NLGA
Douglas Fir	No. 1	No. 2	WCLIB, WWPA, NLGA
Hemlock Fir	No. 1	No. 2	WCLIB, WWPA, NLGA
Sitka Spruce	No. 1	No. 2	WCLIB, NLGA
All other Western American species	No. 1	No. 2	WWPA
All other Canadian species	No. 1	No. 2	NLGA
Cypress	No. 1	No. 2	SCMA
Southern Yellow Pine	D and Btr.	No. 1	SPIB
Redwood	select	construction common	RIS

<sup>A</sup> For identification of agencies, refer to Appendix X2.

is defined as the product ( $E \times I$ ) of the modulus of elasticity ( $E$ ) and the moment of inertia ( $I$ ).

6.11.2 Galvanized round steel posts of 1.900 in. outside diameter shall have a nominal weight of 2.27 lb/linear ft minimum. The bending strength shall not be less than 8150 lbf-in. and the stiffness shall not be less than  $7.68 \times 10^6$  lbf-in.

6.11.3 Galvanized round steel posts of 2.375 in. outside diameter shall have a nominal weight of 3.12 lb/linear ft minimum. The bending strength shall not be less than 19 600 lbf-in. and the stiffness shall not be less than  $16.0 \times 10^6$  lbf-in.

6.11.4 *Coatings*—Protective coating requirements on steel posts shall be as selected from Specification F 1043.

6.12 *Requirements for Aluminum Channel Posts and Rails for Engineered Fence Framing*—The rectangular aluminum channel line posts and rails specified in Section 7 (Table 3) shall be extruded aluminum alloys 6061-T6 or 6063-T6 conforming to the requirements of Specification B 221. The posts and rails shall be manufactured of sufficient weight or gage to resist all induced design loads as determined and justified by engineering analysis.

6.13 *Requirements for Steel Channel Posts and Rails for Engineered Fence Framing*—Roll formed C-Section steel line posts may be selected from Table 3 provided they meet the following criteria and will withstand all associated load requirements and shall meet the protective coating requirements as selected from Specification F 1043.

6.13.1 Galvanized steel channel posts of 1.875 by 1.625 in. outside dimensions shall have a nominal weight of 2.28 lb/linear ft minimum. The bending strength shall not be less than 8150 lbf-in. and the stiffness shall not be less than  $7.68 \times 10^6$  lbf-in.

6.13.2 Galvanized steel channel posts of 2.25 by 1.70 in. outside diameter shall have a nominal weight of 2.64 lb/linear ft minimum. The bending strength shall not be less than 19 600 lbf in. and the stiffness shall not be less than  $16.0 \times 10^6$  lbf-in.

6.14 *Required Specifications for Factory-Built Fence Panels of Vertically Applied Wood Cover Material*—This specification provides a basis for specifying factory assembled fence panels. Due to the nature of the manufacturing process and economic factors prevalent in the industry, it has been the practice for a substantial portion of the stockade fence panels sold and manufactured in the northeast section of the country to be sold as factory assembled panels. A basis for specifying these panels is therefore felt to be necessary and desirable.

6.14.1 *General Specifications*:

6.14.1.1 All panels shall be manufactured in a rectangular form, with sides and top and bottom square and parallel to each other unless otherwise specified. Fence panels shall have a maximum length of 8 ft.

6.14.1.2 Terminal pickets shall be triple-nailed in all classes of panels in order to provide for safe handling. Double nailing, where specified, means that the pickets shall be fastened to the top and bottom backers with two nails per picket, and to the interior backers with at least one nail or fastener per picket. Single nailing, where permitted, means that all pickets with the exception of terminal pickets shall be fastened to the backers with one nail or fastener per picket. Boards or other cover material shall be similarly fastened.

6.14.1.3 The class of cover material shall be the same as the class of the panel, unless otherwise specified.

6.14.2 *Architectural Class I*: —

6.14.2.1 *Frame*—In order to allow for local custom and technical constraints applicable to various mills, three alternative frame types are necessary. Unless otherwise specified, the use of any frame type will be deemed in accordance with this specification.

(a) A 2 by 3-in. minimum smooth sawn or dressed frame (see Section 7 and Table 2). Allowable defects are described in 6.1.1.

(b) A half-round frame shall be manufactured from material that has a minimum diameter of 4 in. before splitting. Allowable defects are described in 6.7.

(c) Full round and flattened frames shall be manufactured from material that has a minimum diameter of 3½ in. before flattening. Allowable defects are described in 6.7.

6.14.2.2 *Fasteners*—Corrosion-resistant fasteners are required. Staples are not permitted. Double nailing is required. The minimum length of fastener shall be 2 in.

6.14.2.3 *Length Tolerance*—The length tolerance shall be ⅛ in.

6.14.2.4 *Height Tolerance*—The height tolerance shall be in accordance with the requirements for cover material (see 5.1.2).

6.14.2.5 *Reinspection*—To allow for differences of opinion between graders, up to 5 % of panels may be below standard grade in any single shipment without causing the entire shipment to be downgraded or rejected.

6.14.3 *Architectural Class II*:

6.14.3.1 *Frame*—In order to allow for local custom and technical constraints applicable to various mills, three alternative frame types are necessary. Unless otherwise specified, the use of any frame type will be deemed in compliance with the specification.

(a) A 2 by 3-in. smooth sawn or dressed frame (see Section 7 and Table 2). Allowable defects are described in 6.1.2.

(b) A half-round frame shall be manufactured from material that has a minimum diameter of 3½ in. before splitting. Allowable defects are described in 6.7.

(c) Full round and flattened frames shall be manufactured from material that has a minimum of 3 in. before flattening. Allowable defects are described in 6.7.

6.14.3.2 *Fasteners*—Rust-resistant fasteners are required. Staples are not allowed. Double nailing is required. Minimum length of fastener shall be 2 in.

6.14.3.3 *Length Tolerance*— $\pm 3/16$  in.

6.14.3.4 *Height Tolerance*—The height tolerance shall be in accordance with the requirements for cover material (see 5.1.2).

6.14.3.5 *Reinspection*—Up to 5 % of any single shipment may be below standard grade.

6.14.4 *Architectural Class III*:

6.14.4.1 *Frame*—In order to allow for local custom and technical constraints applicable to various mills, three alternative frame types are necessary. Unless otherwise specified, the use of any frame type will be deemed in accordance with this specification.

(a) A 2 by 3-in. minimum smooth sawn or dressed frame (see Section 7 and Table 2). Allowable defects are as specified in 6.1.3.

(b) A half-round frame shall be manufactured from material that has a minimum diameter of 2½ in. before splitting. Allowable defects are specified in 6.7.

(c) Full-round and flattened frames shall be manufactured from material that has a minimum diameter of 2½ in. before flattening. Allowable defects are specified in 6.7.

6.14.4.2 *Fasteners*—Rustproof or rust-resistant fasteners are recommended, but not required. Staples are permissible. Single nailing is allowed. The minimum length of fastener shall be 2¼ in. if single nailed, otherwise the length shall be 2-in. minimum.

6.14.4.3 *Length Tolerance*—The length tolerance shall be ±¼ in.

6.14.4.4 *Height Tolerance*—The height tolerance shall be in accordance with the requirements for cover material (see 5.1.2).

6.14.4.5 *Reinspection*—Up to 7 % of any single shipment may be below the standard grade.

6.15 *Top Design of Posts and Cover Material*—The tops of posts and cover material shall maintain a flat area on top of ½ by ½ in. to create a blunt area for safety purposes.

**7. Standard Fence Structural Frames**

7.1 Tables 1-3 contain commonly used fence frame constructions. The tables provide a means of determining acceptable constructions with the materials, fastenings, and workmanship described in this specification. Tables 1-3 also provide a structural frame identification index that may be used to identify a specific construction within a buyer’s purchase order or inquiry. However, any wood or combination of wood with other interacting material(s), otherwise not shown within these tables, may be considered acceptable if it provides at least equal or superior structural integrity to those shown, or if it can otherwise be justified by structural analysis using methods provided in NFPA Specification for Stress Grade Lumber and Its Fastenings and APA Specification for Plywood Design.

7.1.1 *Handsplit or Machined Picket Fences*—Structural frame No. 2 may be used for the support frame of grape stake pickets (that is, handsplit or machined), which are 4 ft in total above ground height. Structural frames No. 3 and No. 4 are acceptable for use in fences which are 5 ft in total above ground height. Structural frames No. 6 and No. 7 are acceptable for use in fences which are 6 ft in total above ground height. Nominal rough sawn rails may be substituted. Allowable post spacing shall be as shown in Table 1.

7.1.2 *Stockade Picket Fences*—Structural frames No. 12 and No. 13 may be used for the support frame of the stockade picket fence (that is, round or half-round pickets), which are 4 ft in total above ground height. Structural frame No. 13 is acceptable for use in fences which are 5 ft in total above ground height. Structural frame No. 14 is acceptable for use in fences which are 6 ft in total above ground height. Structural frame No. 15 is acceptable for use in stockade fences which are 7 ft in total height. The back rails may be the half-round product of the round rail diameters shown in Table 1, or 2 by

3-in. nominal rails may be substituted. All post spacings shall be 8 ft maximum.

7.1.3 *Metal Channel Frames*—Frames, No. 13M and No. 14M may be used at heights and post spacings provided by manufacturer based on various cover materials or fill as related to wind loading and derived by structural analysis.

**8. Species of Wood**

8.1 Many species of both hardwoods and softwoods are suitable for wood fence construction. However, some may offer superior performance with respect to a particular physical or mechanical property. As an aid to selecting the best suited available commercial species for a specific fence installation, and in order to compare their general properties, refer to Table 9 and Table 10.

8.2 The properties or factors compared within these tables include: hardness, bending strength, stiffness, strength as a post, fastener withdrawal resistance or nail-holding power, ease of keeping well painted, conspicuousness of checking, resistance to cupping, dimensional stability, and decay resistance or durability of heartwood.

**9. Durability of Wood**

9.1 *Decay*—Like other materials used in construction, wood is susceptible to deterioration under adverse conditions. Accordingly, special consideration is required to ensure long-lasting service life of wood used in fence construction. Wood may be subject to decay under the following conditions: a moisture content of more than 19 %, sufficient oxygen, and moderate temperatures. Therefore, under such conditions, the wood should be preservatively pressure treated or the heartwood of a durable species as described in 9.2 should be used.

9.1.1 *Termites*—Protection against termites or similar destroyers shall be clearly stated as a requirement, otherwise, it will not be the responsibility of the vendor.

9.2 *Durable Species*—The expression “durable species” refers to the heartwood of the following species with the exception that an occasional piece with corner sapwood may be included if 90 % or more of the width of each side on which it occurs is heartwood:

9.2.1 *Decay Resistant:*  
Redwood, Cedars, Black Locust, Bald Cypress (Tidewater Red), and Black Walnut.

9.2.2 *Termite Resistant:*  
Redwood, Bald Cypress (Tidewater Red), and Eastern Red Cedar.

9.3 The following species are rated by the Wood Handbook,<sup>14</sup> as moderately durable. Although they are not acceptable for in-ground use without preservative pressure treatment, the species are recommended for above-ground use wherever preservative pressure treatment is not contemplated as follows:

Bald cypress (young growth)	Pine, Eastern White
Douglas Fir	Southern Pine:
Honeylocust	Longleaf
Larch, Western	Slash
Oak, Swamp Chestnut	Tamarack

<sup>14</sup> *Wood Handbook No. 72*, U.S. Dept. of Agriculture, Forest Products Laboratory, August, 1974.

TABLE 9 General Comparison of a Few Properties of Common Commercial Species (Softwoods)

	Hardness <sup>A</sup>	Bending Strength <sup>A</sup>	Stiffness <sup>A</sup>	Strength as a Post <sup>A</sup>	Fastener Withdrawal Resistance <sup>A</sup>	Dimensional Stability <sup>A</sup>	Decay Resistance of Heartwood <sup>A</sup>	Ease of Keeping Well Painted <sup>B</sup>	Resistance to Cupping <sup>C</sup>	Conspicuousness of Checking <sup>C</sup>
<i>Western Softwoods:</i>										
Alpine Fir	C	B	C	C	C	B	C	III	2	2
Douglas Fir	B	A	A	A	A	B	B	IV	2	2
Ponderosa Pine	C	B	C	B	C	A	C	III	2	2
Western Hemlock	B	A	B	A	B	B	C	III	2	2
Western Red Cedar	C	C	C	B	C	A	A	I	1	1
White Firs	B	B	B	B	C	B	C	III	2	2
Redwood	B	B	C	B	B	A	A	I	1	1
Engelmann Spruce	C	C	C	C	C	B	C	III	2	2
Western Larch	B	A	A	A	A	B	B	IV	2	2
Sitka Spruce	B	B	B	B	B	B	C	III	2	2
Idaho White Pine	C	B	C	B	C	B	C	II	2	2
Sugar Pine	C	C	C	C	C	A	C	II	2	2
Lodgepole Pine	B	B	C	B	B	B	C	III	2	2
Port Orford Cedar	B	B	B	B	B	B	A	I	1	1
Incense Cedar	C	C	C	B	C	A	A	I	1	1
Alaskan Cedar	B	B	C	B	B	A	A	I	1	1
<i>Northern and Southern Softwoods:</i>										
Eastern White Pine	B	B	C	C	C	A	B	II	2	2
Red Pine	B	B	B	B	B	B	C	III	2	2
Jack Pine	B	B	B	B	B	B	C	III	2	2
Eastern Hemlock	B	B	C	B	C	B	C	III	2	2
Balsam Fir	C	B	C	C	C	B	C	III	2	2
Tamarack	B	B	B	B	A	B	B	IV	2	2
Eastern Spruces	B	B	C	B	B	B	C	III	2	2
Eastern Red Cedar	B	B	C	B	B	A	A	I	1	1
Northern White Cedar	C	C	C	C	C	A	A	I	1	1
Atlantic White Cedar	C	C	C	C	C	A	A	I	1	1
Baldcypress	B	B	C	B	B	A	A	I	1	1
Southern Pines	B	A	A	A	A	B	C	IV	2	2
Longleaf and Slash Pines	A	A	A	A	A	B	B	IV	2	2

<sup>A</sup> A = among the woods relatively high in that respect; B = among the woods intermediate in that respect; C = woods moderately low in that respect.

<sup>B</sup> I = easiest; V = most exacting.

<sup>C</sup> 1 = best; 4 = worst.

9.4 *Preservative Pressure Treatments*—When species classified as durable are not selected or available, and are within the heartwood requirements specified in 9.2.1, in-ground structural members (posts) shall be preservative-treated under the requirements of this specification. Where maximum durability for above-ground wood is desired, and the species classified as durable in 9.2 are not selected or available, it may also be desirable for them to be preservative treated.

9.4.1 When painting, staining or other finishing is necessary after treatment, water-borne pressure treatments or pentachlorophenol in light solvent, LPG, or methylene chloride pressure treatment should be used (Specification D 3225, Specification D 2605, Specification D 3506).

9.4.2 Where oil-borne treatments are used for wood fences, special preparation in accordance with manufacturers' recommendations must be used before paint, stain, or other finish is applied. Water-borne treatments may be painted, stained, or otherwise finished as soon as the material has sufficiently dried for the purpose.

9.4.3 Where preservative pressure treated wood products are cut after treatment, the affected area shall be brush coated with preservative in accordance with AWWA Standard M 4.

9.5 *Treatable Species:*

9.5.1 It is recognized that heartwood of all species is

difficult to pressure treat with a chemical preservative, but in some species it is less difficult. APA Specification for Plywood Design and Wood Handbook No. 72<sup>14</sup> recognize this and accordingly list only those species which are readily treatable.

9.5.2 The commercial species of wood that are referenced as acceptable for treatment under the AWWA and ASTM standards are:

- |                      |                    |
|----------------------|--------------------|
| Southern Yellow Pine | Redwood            |
| Ponderosa Pine       | Jack Pine          |
| Douglas Fir:         | Lodgepole Pine     |
| Coastal or           | Red Pine           |
| Intermountain        | Eastern White Pine |
| Douglas Fir South    | Western White Pine |
| Western Larch        | Sugar Pine         |
| Western Hemlock      | Oaks, White or Red |
| Gum, Black or Red    |                    |

10. **Manufactured Sizes of Materials**

10.1 *Lumber Sizes (Posts, Rails, and Boards):*

10.1.1 *Surfaced Sizes*—Lumber is normally identified by nominal sizes that are based on unseasoned sawn dimensions; however, when the lumber is dried and surfaced, the finished net sizes are somewhat less than nominal sizes of product nomenclature. For example, a nominal 2 by 4 would have a surfaced net size of 1½ by 3½ in. at a maximum moisture content of 19 % (dry). Table 11 shows net sizes for common

TABLE 10 General Comparison of a Few Properties of Common Commercial Species (Hardwoods)

	Hardness <sup>A</sup>	Bending Strength <sup>A</sup>	Stiffness <sup>A</sup>	Strength as a Post <sup>A</sup>	Fastener Withdrawal Resistance <sup>A</sup>	Dimensional Stability <sup>A</sup>	Decay Resistance of Heartwood <sup>A</sup>	Ease of Keeping Well Painted <sup>B</sup>	Resistance to Cupping <sup>C</sup>	Conspicuousness of Checking <sup>C</sup>
<i>Northern, Appalachian and Southern Hardwoods:</i>										
Ash	A	A	B	B	A	B	C	V	4	2
Aspen	C	B	C	C	C	A	C	III	2	1
Basswood	C	B	C	C	C	C	C	III	2	2
Beech	A	A	B	A	A	C	C	IV	4	2
Birch	A	A	A	A	A	C	C	IV	4	2
Black Cherry	A	A	B	B	A	B	A	V	...	...
Chestnut	B	B	C	B	B	A	A	V	3	2
Cottonwood	C	B	C	C	C	B	C	III	4	2
Elm	A	A	B	B	A	B	C	V	4	2
Hackberry	A	B	C	B	B	B	C	...	...	...
Hickory	A	A	A	A	A	B	C	V	4	2
Black Locust	A	A	A	A	A	B	A	...	...	...
Magnolia	A	B	B	B	B	B	C	III	2	...
Maple	A	A	B	B	A	B	C	IV	4	2
Red Oak	A	A	A	A	A	B	C	V	4	2
White Oak	A	A	A	A	A	B	A	V	4	2
Sweet Gum	B	A	B	B	A	C	C	IV	4	2
Sycamore	B	B	C	B	A	B	C	IV	...	...
Tupelo	B	B	C	B	A	B	C	...	...	...
Black Walnut	A	A	B	A	A	B	A	V	3	2
Black Willow	C	B	C	C	C	B	C	...	...	...
Yellow Poplar	B	B	B	B	B	B	C	III	2	1
<i>Western Hardwoods:</i>										
Red Alder	B	B	C	B	C	B	C	III	...	...
Oregon Ash	A	B	C	B	A	B	C	V	4	2
Aspen	C	B	C	C	C	A	C	III	2	1
Black Cottonwood	C	B	C	C	C	B	C	III	4	2
Bigleaf Maple	B	B	B	B	A	B	C	IV	4	2
Paper Birch	A	A	B	B	A	C	C	IV	4	2
Tanoak	B	A	B	B	A	C	C	V	4	2

<sup>A</sup> A = among the woods relatively high in that respect; B = among the wood intermediate in that respect; C = woods moderately low in that respect.

<sup>B</sup> I = easiest; V = most exacting.

<sup>C</sup> 1 = best; 4 = worst.

TABLE 11 Simplified Table of Standard S 4S Sizes<sup>A</sup>

Nominal, in.	Inch-pound Units		SI Units	
	Net Dry, in.	Net Green, in.	Net Dry, mm	Net Green, mm
1 <sup>B</sup>	3/4	25/32	19.0	19.8
2	1 1/2	1 9/16	38.1	39.7
3	2 1/2	2 9/16	63.5	65.1
4	3 1/2	3 9/16	88.9	90.5
6	5 1/2	5 5/8	139.7	142.9
8	7 1/4	7 1/2	184.2	190.5
10	9 1/4	9 1/2	235.0	241.3
12	11 1/4	11 1/2	285.8	292.1

<sup>A</sup> Established by American Lumber Standards Committee in conjunction with the U.S. Dept. of Commerce Standard PS 20-70.

<sup>B</sup> See PS 20-70 for standard sizes of lumber less than 1 in. nominal.

board and dimensional lumber.

10.1.2 *Surfaced Posts and Timbers*—Nominal timber sizes 5 by 5 in. and larger are exceptions to Table 9 in that they are surfaced unseasoned to a net size 1/2 in. less than their nominal dimensions.

10.1.3 *Minimum Rough Sizes*—Thicknesses and widths, dry or unseasoned, for all lumber requires that 80 % of the pieces in a shipment shall be at least 1/8 in. thicker than the standard surfaced size, with the remaining 20 % at least 3/32 in. thicker than the surfaced size. Widths shall be at least 1/8 in. wider than standard surfaced widths.

10.1.4 All fence lumber sizes less than 1 in. nominal shall be identified by their actual net thicknesses. Manufacturing tolerances for this material of less than 1 in. nominal (or 3/4 in. net) thickness shall be ± 1/16 in.

10.2 *Split Posts and Rails Sizes*—Standard sizes are shown in Table 12.

10.3 *Round and Half-Round Post and Rail Sizes*—Round and half-round posts and rails are measured by their nominal top diameter, or width if half-round. Sizes are approximate within the tolerances allowed under their quality standards provisions in 6.3. They are available in the following sizes: 6 1/2-ft lengths are manufactured in top-sizes ranging from 2 1/2 to 7 in. in diameter, on 1/2-in. intervals; 8-ft lengths are available in the same top-sizes, except that an 8-in. top is also provided; 10, 12, and 14-ft lengths are available with 4, 5, or 6-in. top-sizes.

10.4 *Machine or Hand-Split Picket Sizes*—These pickets are available in 2 1/2, 3, and 4-in. nominal widths, and 4, 5, and 6-ft lengths, within the manufacturing tolerances allowed under the quality standards provisions in 6.5.

10.5 *Machine-Sliced Picket Sizes*—Machine-sliced pickets are available in 2 and 2 1/2-in. nominal widths, and 4, 5, and 6-ft lengths, within the manufacturing tolerances allowed under the quality standards provisions in 6.6.

10.6 *Round and Half-Round Picket Sizes*—These pickets



TABLE 12 Standard Sizes for Split Posts and Rails

Item	Inch-pound Units			SI Units		
	Length, in.	Minimum Girth, in.	Approximate Proportions, in.	Length, m	Minimum Girth, mm	Approximate Proportions, mm
Post	96	20	5 by 5	2.44	508.0	127.0 by 127.0
Post	78	18	4 by 5	1.98	457.2	101.6 by 127.0
Post	64	18	4 by 5	1.63	457.2	101.6 by 127.0
Post	78	16	4 by 4	1.98	406.4	101.6 by 101.6
Post	64	16	4 by 4	1.63	406.4	101.6 by 101.6
Post	48	13	3.5 by 3.5	1.22	330.2	88.9 by 88.9
Rail	120	12	2 by 4	3.05	304.8	50.8 by 101.6
Rail	96	12	2 by 4	2.44	304.8	50.8 by 101.6
Rail	120	10	2 by 3	3.05	254.0	50.8 by 76.2
Rail	96	10	2 by 3	2.44	254.0	50.8 by 76.2
Rail	72	8	1.5 by 1.5	1.83	203.2	38.1 by 38.1

are produced in 2, 2½, and 3-in. nominal diameters (or width if half-round), and in 4, 5, 6, and 7-ft lengths, within the manufacturing tolerances allowed under the quality standards provisions in 6.7.

10.7 *Standard Sawn Picket Sizes*—Since the standard net sizes of sawn pickets vary between the commercial lumber grading rules published by the regional grading rules writing agencies, it is necessary to compare the sizes in Table 13 with the species and grades in Table 8 in order to determine the standard dressed size.

10.7.1 *Sawn Picket Lengths*—Sawn wood pickets are produced in 3, 4, 5, and 6-ft lengths, and shall be square end-trimmed to a tolerance of ±1/8 in.

10.8 *Moulded (Milled) Picket Sizes*—The minimum thickness shall be not less than 5/8 in. thick for pickets 2 to 3 in. wide, ¾ in. minimum for 3¼ in. and wider.

10.9 *Plywood Sizes*—Sizes of plywood used in construction are actual net sizes within tolerances prescribed in Voluntary Product Standard PS 1-74.

**11. Installation**

11.1 *Wood Cover Materials*—All wood cover materials which are acceptable under appropriate sections of this specification, may be installed to any fence frame shown in Section 7 (see also Tables 1-3), as applicable.

11.2 *Non-Wood Cover Materials*—All non-wood fence cover materials, such as corrugated metal, fiberglass, chain link, wire, and other fill materials, may be specified for

installation on or within any of the fence frames shown in Section 7 (see also Table 1, Table 2, and Table 3), as applicable.

11.3 *Expansion Allowance Fence Boards and Pickets*—When wood pickets or fence boards are attached to a fence frame as a solid fill or cover material, a small space between the fence boards shall be allowed to account for expansion due to change in moisture content as a result of wetting and drying cycles. For widths from 2 to 4 in., a 1/16-in. space shall be provided; for 6 and 8-in. widths, a minimum space of 1/8 in. shall be provided; for 10-in. wide material, a 3/16-in. space shall be provided; and for 12-in. material, a 1/4-in. space shall be provided.

11.4 *Expansion Allowance for Plywood*—When solid panel fences are constructed of plywood, care should be taken to allow space for expansion due to moisture. A minimum of 1/8 in. shall be allowed along the long edge of the panel, and 1/4 in. at the end of the panel.

11.5 *Installation of Wood Posts:*

11.5.1 All wood posts shall be set in holes at least 4 in. larger in diameter than the largest dimension or diameter of the post.

11.5.1.1 Footings must extend to a depth of one half the finished height of fence minus 6 in. (maximum depth 48 in.).

11.5.2 Posts tamped into place with good tamping material can be considered as set in the next firmer soil. For example, instead of using loose or medium soil, use medium- or hard-packed soil, respectively.

11.5.2.1 When concrete is used as a footing depth extension,

TABLE 13 Standard Sawn Picket Sizes

Inch-pound Units		SI Units		Grading Rules Agency <sup>A</sup>
Nominal Size, in.	Net Size, in.	Nominal Size, mm	Net Size, mm	
1 by 1	13 / 16 by 13 / 16	25.4 by 25.4	20.6 by 20.6	SCMA
1 1 / 4 by 1 1 / 4	1 by 1	31.8 by 31.8	25.4 by 25.4	SPIB
1 1 / 4 by 1 1 / 4	1 1 / 32 by 1 1 / 32	31.8 by 31.8	26.2 by 26.2	NLGA
1 1 / 4 by 1 1 / 4	1 1 / 16 by 1 1 / 16	31.8 by 31.8	27.0 by 27.0	WWPA, WCLIB, SCMA
1 1 / 2 by 1 1 / 2	1 1 / 4 by 1 1 / 4	38.1 by 38.1	31.8 by 31.8	SPIB
1 1 / 2 by 1 1 / 2	1 9 / 32 by 1 9 / 32	38.1 by 38.1	32.5 by 32.5	NLGA
1 1 / 2 by 1 1 / 2	1 5 / 16 by 1 5 / 16	38.1 by 38.1	33.3 by 33.3	WWPA, WCLIB, SCMA
3 / 4 by 3	11 / 16 by 2 1 / 2	19.1 by 76.2	17.5 by 63.5	RIS
1 by 3	3 / 4 by 2 1 / 4	25.4 by 76.2	19.1 by 57.2	SPIB
1 by 3	11 / 16 by 2 1 / 2	25.4 by 76.2	17.5 by 63.5	NLGA
1 by 3	3 / 4 by 2 1 / 2	25.4 by 76.2	19.1 by 63.5	WWPA, RIS, WCLIB, SCMA

<sup>A</sup> For identification of agencies, refer to Appendix X2.

the post should extend to within 6 in. of the bottom of the footing, unless the footing is three times the cross section of the diameter of the post.

11.5.3 All wood posts shall be set and embedded in holes with minimum depths as specified in Table 14, based on soil-type classification and method of embedment.

11.5.4 Concrete footings may be one of two basic types as follows:

11.5.4.1 A concrete collar footing is employed by simply filling standard post holes with 2000 psi (13.8 MPa) minimum concrete.

11.5.4.2 Where high risk of frost or expansive soil upheaval is present, the concrete collar footing should be worked to approximately 4 in. in diameter larger at the base than at the top of the standard post hole. This may be accomplished by tapering the hole larger to the base or by otherwise enlarging the diameter at the base to provide equivalence. In loose soils it is necessary to employ a fine wire mesh or other suitable material to hold back the soil until the concrete can be poured.

11.5.4.3 In areas where frost is common, footings shall extend a minimum of 6 in. below maximum frost level or above rule, whichever is deeper.

NOTE 2—Grave diggers frost conditions usually more closely resemble fence conditions than water pipes in the street.

11.5.5 If water fills the post hole, a sturdy plastic bag may be used as a liner, into which the concrete may be slowly poured, causing it to sink and displace water without dilution of the concrete mix.

11.5.6 Post installations based on the allowable soil loading and engineering analysis are not prohibited as an alternative to these simplified criteria.

11.6 *Installation of Metal Posts:*

11.6.1 All metal posts should be set in holes having a diameter at least 3 times the size of the largest dimension or diameter of the post.

11.6.2 All metal posts shall be set in concrete, 2000 psi (13.8 MPa) minimum.

11.6.3 The metal post shall be submerged in the concrete to a depth sufficient to adequately support the post.

11.6.4 All other requirements for metal post installation are identical to those for wood, as specified in 11.5.

11.7 *Fastenings:*

11.7.1 The strength and utility of any wood component is in great measure dependent upon the fastenings used to hold the

assembly together. The most common wood fasteners are nails and spikes, followed by screws, bolts, metal connectors, and straps of various shapes.

11.7.2 The NFPA Specification for Stress Grade Lumber and Its Fastenings shall be used for all engineered fastener design when specific information is not included in this specification.

11.7.3 *Nails:*

11.7.3.1 In order to ensure satisfactory durability, all nails or spikes shall be corrosion-resistant such as hot-dipped galvanized, aluminum, or stainless steel, unless otherwise specified. Protection of metal parts against rust or corrosion shall be clearly stated in a requirement or it shall not be the responsibility of the vendor.

11.7.3.2 Smooth shank nails are acceptable for all uses under this specification, except where wood members are subjected to direct withdrawal loads induced primarily by wind forces.

11.7.3.3 Deformed-shank nails are recommended for wood members, such as fence boards or pickets, which are exposed to direct withdrawal forces. Such nails are available as annularly threaded (ring shanked), helically threaded (spiral shanked), or barbed shank.

11.7.3.4 Always fasten a thinner member to a thicker member, unless clinched nails are used.

11.7.3.5 Use blunt nails, or any nail with a point not sharper than the standard medium-diamond point.

11.7.3.6 With very hard, dense woods or those otherwise tending to split when nailed, predrilling may be employed; however, predrill only three fourths of the nail diameter.

11.7.3.7 Place nails no closer to the edge than one half of the board thickness, and no closer to the end than the board thickness.

11.7.3.8 Toenailing may be used with the following stipulations: allow an end distance (distance from the end of the attached member to the point of initial nail entry) of approximately one third the length of the nail; drive the nail at a slope of 30° with the attached member; and bury the full shank of the nail while avoiding excessive mutilation of the wood from hammer blows.

11.7.3.9 Use only two nails per crossing for fence boards 4 in. and wider (nominal), and only one nail per crossing for pickets up to, but not including, 4-in. nominal widths.

11.7.3.10 Avoid end-grain nailing. When unavoidable, use screws or a side grain wood cleat adjacent to end-grain member (as in posts); or use deformed shank nails or spikes. However, end-grain nailing shall not be allowed under any circumstances when subjected to withdrawal forces.

11.7.3.11 A nail shall be long enough to penetrate the receiving member a distance twice the thickness of the thinner member but not less than 1½ in. (for example, in ¾-in. board, the nail should penetrate the receiving member 1½ in.; thus, at least a 7-penny nail is required). Slant-driven, clinched, or deformed shank nails shall be used when the combined thickness is less than the recommended nail length. Refer to Table 15 for aid in proper nail selection.

11.7.4 *Wood Screws:*

11.7.4.1 A screw should be long enough to penetrate the

**TABLE 14 Footing Table for Solid Covered Fences**

NOTE 1—For fence with posts on 8-ft centers. For 10-ft spacing add 25 % to diameter or depth.

Fence Height, ft	Diameter and Depth of Footing, in.		
	Loose Soil	Medium Soil	Hard-Packed Soil
4	9 by 24	8 by 24	7 by 24
5	9 by 24	8 by 24	7 by 24
6	10 by 30	8 by 30	7 by 30
7	11 by 36	9 by 36	7 by 36
8	12 by 42	10 by 42	8 by 42
9	13 by 48	11 by 48	9 by 48
10	14 by 48	12 by 48	10 by 48
11	15 by 48	13 by 48	11 by 48
12	16 by 48	14 by 48	12 by 48

**TABLE 15 Selection of Nails**

Penny Size	Gage	Length, in. (mm)	Diameter, in. (mm)
<i>Bright, Common Wire Nails:</i>			
6d	11	2 (50.8)	0.113 (2.87)
	1/2		
8d	10	2 (63.5)	0.131 (3.33)
	1/4		
10d	9	3 (76.2)	0.148 (3.76)
12d	9	3 (82.6)	0.148 (3.76)
	1/4		
16d	8	3 (88.9)	0.162 (4.11)
	1/2		
20d	6	4 (101.6)	0.192 (4.88)
30d	5	4 (114.3)	0.207 (5.26)
	1/2		
40d	4	5 (127.0)	0.225 (5.72)
50d	3	5 (139.7)	0.244 (6.20)
	1/2		
60d	2	6 (152.4)	0.262 (6.66)
<i>Smooth Box Nails:</i>			
3d	14	1 (31.8)	0.076 (1.93)
	1/2	1/4	
4d	14	1 (38.1)	0.080 (2.03)
		1/2	
5d	14	1 (44.5)	0.080 (2.03)
		3/4	
6d	12	2 (50.8)	0.098 (2.49)
	1/2		
7d	12	2 (57.2)	0.098 (2.49)
	1/2	1/4	
8d	11	2 (63.5)	0.113 (2.87)
	1/2	1/2	
10d	10	3 (76.2)	0.128 (3.25)
	1/2		
16d	10	3 (88.9)	0.135 (3.43)
		1/2	
20d	9	4 (101.6)	0.148 (3.76)
<i>Helically and Annularly Threaded Nails:</i>			
6d	...	2 (50.8)	0.120 (3.05)
8d	...	2 (63.5)	0.120 (3.05)
		1/2	
10d	...	3 (76.2)	0.135 (3.43)
12d	...	3 (82.6)	0.135 (3.43)
		1/4	
16d	...	3 (88.9)	0.148 (3.76)
		1/2	
20d	...	4 (101.6)	0.177 (4.50)
30d	...	4 (114.3)	0.177 (4.50)
		1/2	
40d	...	5 (127.0)	0.177 (4.50)
50d	...	5 (139.7)	0.177 (4.50)
		1/2	
60d	...	6 (152.4)	0.177 (4.50)

receiving member at least the thickness of the thinner (outside) member, but with not less than 1 in. of penetration (for example, fastening a 3/4-in. member to a 2-by-4 wooden plank would require a 1 3/4-in. long screw).

11.7.4.2 Screws shall also be rustproof or made of rust-resistant metals (see 11.7.3.1).

11.7.5 *Other Timber Fasteners*—All other connectors such as lag screws, common bolts, or drift bolts shall be used in accordance with the recommendations of the NFPA Specification for Stress Grade Lumber and Its Fastenings.

11.7.6 *Other Light Fasteners (Mechanically Installed)*:

11.7.6.1 Different types of staples have been developed with various modifications in points, shank treatment and coatings,

gage, crown width, and length. These fasteners are available in clips or magazines to permit their use in pneumatically operated portable staplers. The withdrawal resistances vary almost directly with the circumference and depth of point when the type of point and shank are similar.

11.7.6.2 Staples shall be manufactured in accordance with Specification F 1667 or Canadian Standards Association Specification B 111.

11.7.6.3 Staples shall be of the corrosion-resistant type.

11.7.6.4 Use and installation of staples and other mechanically driven light fasteners shall be in accordance with I-SANTA Manual 19-73.<sup>15</sup>

## 12. Finish

12.1 Exterior finishes for wood include natural finishes, penetrating stains, and paint. In general, the natural finishes and stains containing a water repellent and a preservative are preferred over paint for exposed wood, primarily because they penetrate the surface, are usually more durable, and are easily renewed. For finish application recommendations, refer to Table 16.

12.2 Because of the many possible finish applications and options available, this section is intended only as a guide to selection of finish-type and application method. Manufacturers recommendations for application and use of the various finish products shall be considered mandatory.

12.3 *Natural Finish, or Water-Repellent Preservatives*—These finishes are often used for exposed wood, not only because they afford some degree of protection to the wood during the weathering process, but because they enhance the natural colors and grain of wood, and are easily reapplied. Further, the use of a good water-repellent preservative, conforming to U.S. Fed. Specification TT-W-572B, Composition A can greatly improve the lasting quality of surface coatings of wood (paint). The most commonly used of these water-repellent preservatives consists of a 5 % solution of pentachlorophenol.

12.4 *Semitransparent Stains*—These stains, sometimes called penetrating stains, are lightly pigmented but still allow the wood grain and texture to show through. They penetrate deeply into the wood and are formulated for exterior use.

12.5 *Opaque Stains*—This type of stain forms a nongloss, opaque finish that will not crack, blister, or peel. The heavily pigmented stain generally hides the wood color and grain, but not the texture.

12.6 *Paint*—Paint is still one of the most widely used finishes for wood. However, due to the relative difficulty in maintaining a paint finish under extreme exterior conditions, opaque stains are finding much wider use where opaque finishes are desired out of doors. Still, a properly applied paint job can provide many years of satisfactory service. Proper application methods and materials have been published.<sup>14, 16</sup>

<sup>15</sup> I-SANTA Manual 19-73, Pneumatic and Mechanically Driven Building Construction Fasteners, Industrial Stapling and Nailing Technical Assn., 1973.

<sup>16</sup> Research Note FPL-0123, *Wood Finishing: Painting Outside Wood Surfaces*, U.S. Dept. of Agriculture, Forest Products Laboratory.

TABLE 16 Finish Application Recommendations

Desired Effect	Type of Finish	General Product Type	How Applied	Instructions
Durable opaque finish	paint	alkyd-base	brush, roller, spray	apply alkyd primer and two finish coats use a zinc-free primer plus two finish coats
	paint	oil-base	brush, roller, spray	
Durable semi-opaque finish	heavy-body stain	latex	brush, roller, spray	use a zinc-free primer plus two finish coats
		oil-base	brush, dip, roller, spray	one coat for dark colors; two coats for light colors
Durable semi-transparent finish, subtle colorations		semi-transparent oil-base stains	brush, dip, roller	apply two coats (may be sprayed if smoothed with brush)
		semi-transparent resin stains	brush, dip, roller	apply two coats
Natural finish	water repellent preservative	...	brush, dip, roller, spray	apply two coats (preferably dip first coat)
Weathered-gray (driftwood)	commercial bleaching	...	brush	apply one coat initially, apply second coat in approximately 6 months
	agents			

**13. Inspection**

13.1 Commercial lumber, plywood, and other wood products quality standards and grades shall be inspected in accordance with provisions provided by their respective industry grading rules and standards.

13.2 In all other cases, including prefabricated fence sections, inspection of the material shall be as agreed upon between the purchaser and seller as part of the purchase contract.

13.3 The complainant buyer shall unload the shipment and request inspection within 10 days after unloading. The seller shall acknowledge the inspection request within 10 days after

receipt of such request. The disputed material must be held intact for a period not exceeding 30 days after filing of the request.

**14. Certification**

14.1 Upon request of the purchaser in the contract or order, the manufacturer or installer, or both, shall furnish a certification that all materials and workmanship meet all requirements stipulated or implied by this specification at the time of shipment or installation.

**APPENDIXES**

**(Nonmandatory Information)**

**X1. DESCRIPTIONS OF TERMS RELATING TO ALLOWABLE GROWTH CHARACTERISTICS AND LIMITING PROVISIONS OF SAWN LUMBER FENCE POSTS, RAILS, AND BOARDS**

X1.1 *stain*—stained sapwood has no effect on the strength or intended use of the pieces in which it is permitted, but affects appearance in varying degrees. It is usually brown, red, or blue.

X1.1.1 *light stain*

sapwood is so slightly discolored that it does not materially affect the natural appearance.

X1.1.2 *medium stain*

has a pronounced difference in coloration in obvious contrast to the unstained wood.

X1.1.3 *heavy stain*

has so pronounced a difference in color that the grain may be partially or totally obscured.

X1.2 *checks*—a separation of the wood normally occurring across or through the rings of annual growth and usually as a result of seasoning.

X1.2.1 *surface check*

occurs only on one surface.

X1.2.2 *through check*

extends from one surface to the opposite or adjoining surface.

X1.2.3 *small check*

not over 1/32 in. wide and not over 4 in. long.

X1.2.4 *medium check*

not over 1/32 in. wide and not over 10 in. long.

X1.2.5 *large check*

larger than medium.

X1.3 *splits*—a separation of the wood due to the tearing apart of the wood cells.

X1.3.1 *short split*

equal in length to the width of the piece and in no case exceeding one sixth the length.

X1.3.2 *medium split*

equal in length to twice the width and in no case exceeds one sixth the length.

X1.4 *knots*—a portion of a limb or branch that has become incorporated in a piece of lumber.

X1.4.1 *round knot*

one cut at right angles to the length of the knot (limb).

X1.4.2 *spike knot*

a knot cut either lengthwise of a limb, or diagonally across it.

X1.4.3 *small knot*

not over  $\frac{3}{4}$  in. in diameter.

X1.4.4 *sound knot*

contains no decay. It may be red or black.

X1.4.5 *unsound knot*

contains decay.

X1.4.6 *tight knot*

so fixed by growth, shape, or position that it retains its place in the piece. It may be red or black.

X1.4.7 *not firmly fixed knot*

a loose knot or one not held in place by growth, shape, or position.

X1.5 *skips*—areas on a piece that failed to surface clean.

X1.5.1 *hit and miss*

series of skips not over  $\frac{1}{16}$  in. deep with surface areas between.

X1.5.2 *hit or miss*

completely surfaced, partly surfaced, or entirely rough. Scantness may be  $\frac{1}{16}$  in.

X1.6 *wane*—bark or lack of wood from any cause, except eased edges, on the edge or corner of a piece of lumber.

X1.7 *shake*—a lengthwise separation of the wood which usually occurs between or through the rings of annual growth.

X1.7.1 *light shake*

not over  $\frac{1}{32}$  in. wide.

X1.7.2 *medium shake*

not over  $\frac{1}{8}$  in. wide.

X1.7.3 *surface shake*

occurs only on one surface of a piece.

X1.7.4 *through shake*

extends from one surface to the opposite or adjoining surface.

X1.8 *unsound wood*—contains decay, or a general disintegration of the wood substance due to action of wood-destroying fungi.

X1.9 *holes*—extends partially or entirely through a piece and may be from any cause.

X1.9.1 *pin holes*

not over  $\frac{1}{16}$  in. in diameter.

X1.9.2 *small holes*

not over  $\frac{1}{4}$  in. in diameter.

X1.10 *honeycomb*—large white specks or pockets caused by the fungus “Fomes pini.” It develops in living trees and does not develop further in wood in service. It is no more subject to decay than pieces which do not contain it.

X1.11 *peck*—channeled or pitted areas or pockets as often found in cedar and cypress. Wood tissue between pecky areas remains unaffected in appearance and strength. All further growth of the fungus causing peckiness ceases after the trees are felled.

X1.12 *occasional piece*—not over 10 % of the pieces.

## X2. LUMBER GRADING RULES AND AGENCIES

X2.1 *ICA*—Inland Cedar Assn., 105 N. Fourth St., Couer d’Alene, ID 83814.

X2.2 *NELMA*—Northeastern Lumber Manufacturers Assn., Four Fundy Rd., Falmouth, ME 04105.

X2.3 *NHLA*—National Hardwood Lumber Assn., P.O. Box 34518, Memphis, TN 38104.

X2.4 *NHPMA*—Northern Hardwood and Pine Manufacturers Assn., Suite 50—Northern Building, Green Bay, WI 54301.

X2.5 *NLGA*—National Lumber Grades Authority, 1460-1055 W. Hastings St., Vancouver, B.C., V 6E 2G1 Canada.

X2.6 *RIS*—Redwood Inspection Service, 591 Redwood Highway, Suite 3100, Mill Valley, CA 94941.

X2.7 *SCMA*—Southern Cypress Manufacturers Assn., 805 Sterick Building, Memphis, TN 38103.

X2.8 *SHLMA*—Southern Hardwood Lumber Manufacturers Assn., 805 Sterick Building, Memphis, TN 38103.

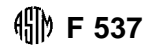
X2.9 *SPIB*—Southern Pine Inspection Bureau, 4709 Scenic Highway, Pensacola, FL 32504.

X2.10 *WCLIB*—West Coast Lumber Inspection Bureau, P.O. Box 23145, Portland, OR 97225.

X2.11 *WWPA*—Western Wood Products Assn., 1500 Yeon Building, Portland, OR 97204.

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## Standard Terminology Relating to Chain Link Fencing<sup>1</sup>

This standard is issued under the fixed designation F 552; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon ( $\epsilon$ ) indicates an editorial change since the last revision or reapproval.

*This standard has been approved for use by agencies of the Department of Defense.*

**aluminized**—*in chain link fabric*, describes fabric woven from steel wire that is coated with aluminum before weaving (see Specification A 491<sup>2</sup>).

**barb**—as related to barbed wire— a short length of wire, with exposed ends cut on a bias to produce sharp points. See Specifications F 1665 and A 121.

**barbed tape**—strip of metal, machined to produce clusters of sharp points (see Terminology F 1379<sup>2</sup> for further information).

**barbed wire**—a fabricated wire product consisting of two line wires twisted to form a two-wire strand, into which 2–point or 4–point barbs are tightly wrapped and locked into place at specific intervals. (*Syn.* barbwire). See Specifications F 1665 and A 121.

**barbed wire arm**—a post fitting used to hold barbed wire in place. May be vertical or angled to hold three or more strands of barbed wire, or “V” shaped to hold six or more strands of barbed wire.

**barbed wire arm base**—a casting of aluminum, malleable iron, or steel, used in combination with one or two barbed wire extension arms held in place by a bolt and nut.

**barbed wire extension arm**—pressed aluminum or pressed galvanized steel used in combination with barbed wire arm base to hold three strands of barbed wire either vertically or angled in or out from the fence line. Also used in pairs in a “V” configuration to hold 6 strands of barbed wire.

**bottom protective plate**—a safety device installed on a Type II, Class 1, cantilever slide gate with external rollers to isolate the lower roller mechanism to reduce the possibility of contact with the roller mechanism by a person. See Specification F 1184<sup>2</sup>.

**bottom rail**—horizontal member of the framework running continuously along the bottom edge of the fence.

**boulevard clamp**—a two piece clamp with carriage bolts and nuts designed for 180° horizontal rail connections to a line post (also called *line rail clamp*).

**brace band**—a symmetrically formed strip of metal shaped to

fit around a post and used with a carriage bolt and nut to attach the rail end or brace rail end truss rod tightener to the post (see Fig. 1). Also used for attaching barbed wire, tension wire, and other items to a terminal post.

**brace rail**—a compression member at terminal posts or corner posts.

**brace rail end**—a cup-shaped fitting similar to a rail end with provision for attaching a truss rod.

**cantilever slide gate**—any horizontal slide gate spanning an opening lacking a top or bottom support within that opening (see Specification F 1184<sup>2</sup>).

**center stop**—a device to receive and hold the drop bar on a double gate.

**corner barbed wire arm**—a combination post cap and fitting used to hold barbed wire in place on a corner post. May be angled in or out from the fence line to hold three or more strands of barbed wire, or “V” shaped to hold six or more strands of barbed wire.

**corner post**—a terminal post, at which the direction of the line of fence changes in two or more directions (see Fig. 2).

**corner rail clamp**—a two-piece clamp with carriage bolts and nuts designed for horizontal rail connections to a 90° corner post.

**diamond**—the opening formed by the woven wires in chain link fence fabric.

**diamond count**—the number of diamond openings from one edge of fabric to the other. The count of a given fabric shall begin at the first completed diamond at one edge and continue to the unfinished (half) or full opening at the other edge (see Fig. 3).

**double drive gate**—a gate comprised of two gate leaves which is used to close a gate opening through which vehicles are intended to pass. While often referring to a swing gate (that is, double swing gate), the gate may be any double leaf gate intended for vehicular (that is, slide gate or others). See specifications F 654, F 900, and F 1184<sup>2</sup>.

**drop bar**—component of a double gate latch assembly (sometimes called *drop rod*) (see Specification F 900<sup>2</sup>).

**end post**—the terminal post at the end of a line of fence (see Fig. 4).

**end rail clamp**—a two-piece clamp with carriage bolt and nut designed for horizontal rail connections to an end post.

**fabric (chain link fence)**—a fencing material made from wire

<sup>1</sup> This terminology is under the jurisdiction of ASTM Committee F14 on Fences and is the direct responsibility of Subcommittee F14.40 on Chain Link Fence and Wire Accessories.

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<sup>2</sup> See *Annual Book of ASTM Standards*, Vol 01.06 for full title.

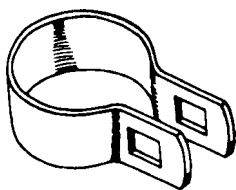


FIG. 1 Brace Band

Corner Post.  
Two or more  
Fence Lines  
Meet

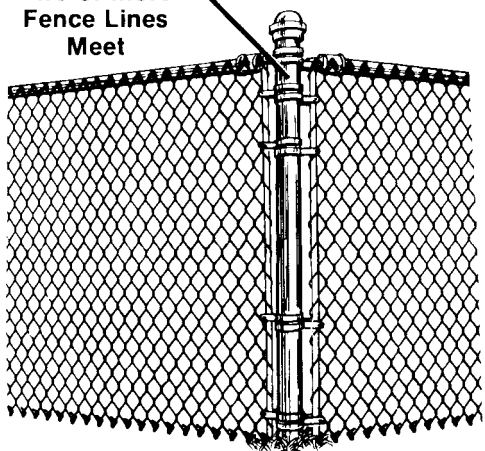
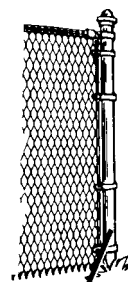


FIG. 2 Corner Post



FIG. 3 Diamond Count



End Post.  
Fence Line Ends  
FIG. 4 End Post

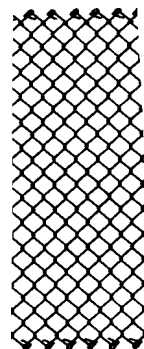


FIG. 5 Chain Link Fence Fabric

helically wound and interwoven in such a manner as to provide a continuous mesh without knots or ties except in the form of knuckling or of twisting the ends of the wires to form the selvages of the fabric (see Fig. 5).

**flange**—in chain link fencing, a plate or casting for securing a post to a floor or a horizontal rail to a wall.

**frame hinge**—a fitting that attaches to the gate frame and functions with the post hinge.

**framework**—the basic structure supporting installed fabric, namely the posts, rails, and tension wire.

**galvanized**—pertaining to zinc-coated articles.

**galvanized after weaving**— *in chain link fabric*, describes steel fabric that is hot-dip coated with zinc after weaving (see Specification A 392<sup>2</sup>).

**galvanized before weaving**— *in chain link fabric*, describes fabric that is woven from steel wire galvanized before weaving.

**gate**—a moveable barrier placed in a fence opening (gate

opening) which allows the opening to be closed. See Specifications F 654, F 900, and F 1184.

**gate clip**—a galvanized pressed steel or pressed aluminum fitting designed to secure chain link fabric to the vertical sides of a gate frame.

**gate frame**—the structural member(s) of the gate.

**gate holdback or keeper**—a device to receive and hold the gate leaf in an open position.

**gate latch**—a fitting to hold the gate in place when closed.

**gate leaf**—a component of a swing gate which consists of a gate frame covered with chain link fabric and/or other material. See Specifications F 654 and F 900.

**gate opening**—the clear distance between the gate posts.

**gate post**—the post to which a gate is attached via hinges. It may also be used as a terminal post.

**gate transom**—a panel of chain link fabric over the top of a gate opening, framed with top and bottom rail. Typically used in tennis court fence (see Practice F 969<sup>2</sup>).

**height**—the distance before stretching from one outer edge of a knuckle or twist to the outer edge of the knuckle or twist on the opposite edge of fabric.

**hinge pin**—an upright pivot used to connect the gate frame hinge to the post hinge, allowing a swing gate to open or close. See frame hinge and post hinge.

**hog ring**—a preformed open wire clip designed to close up into a ring to secure chain link fabric to horizontal tension wire (see Specification F 626<sup>2</sup>).

**intermediate rail**—horizontal member of the framework running continuously at any point between the top and bottom of the fence (sometimes called *middle rail*).

**knuckle**—the selvage obtained by interlocking adjacent pairs



of wire ends and bending the wire back into a loop (see Fig. 6).

**line post**—the intermediate post in a fence line supporting the top rail or tension wire and barb arm where applicable (see Fig. 7).

**line post cap**—a cap or top with a loop used to position the top rail or tension wire on top of the line posts (see Fig. 8).

**line rail clamp**—See **boulevard clamp**.

**loop cap**—See **line post cap**.

**marcelling**—a process whereby either a uniform helix or a series of waves put in a wire to facilitate tensioning the wire when installed to support the top or bottom or both, of the chain link fence fabric (that is, marcelled tension wire). See **tension wire** and Specification A 824.

**mesh**—in *chain link fabric*, the clear distance between parallel wires forming a diamond.

**middle rail**—See **intermediate rail**.

**offset hinge**—a swing gate hinge that permits the gate to swing 180° from the closed to the open position (see Specification F 900<sup>2</sup>).

**overhead slide gate**—any horizontal slide gate supported only from above (see Specification F 1184<sup>2</sup>).

**pedestrian gate**—a gate, usually comprised of a single leaf, which is used to close a gate opening through which pedestrians are intended to pass. While often referring to a swing gate, the gate may be of any single leaf gate intended for pedestrian use (that is, slide gate or others). See Specifications F 654, F 900, and F 1184<sup>2</sup>.

**panel clamp**—a two-piece clamp with carriage bolt and nut, designed to secure prefabricated panels on free standing enclosures.

**picket**—a helically formed steel wire interwoven in the manufacture of chain link fabric or used for field splicing rolls of fabric into continuous chain link mesh from terminal post to terminal post.

**polymer coating**—a term used to describe color coatings such as PVC (poly(vinyl chloride)), polyester, and clear coatings such as polyurethane and acrylic urethane (see Specifications F 668, F 934, and F 1234<sup>2</sup>).

**post cap**—a fitting atop a post usually to exclude water from tubular posts.

**post hinge**—a fitting that attaches to the gate post, the pintle of which fits the frame hinge permitting the gate to swing (see Fig. 9).

**pull post**—a terminal post used in a line of fence to brace a long stretch or to effect a change in elevation along the fence line.

**PVC**—poly(vinyl chloride) coating on fence materials.

**rail end**—a cup-shaped fitting used with a brace band to connect the top rail or brace to a post (see Fig. 10).

**raid end band**—See **brace band**.

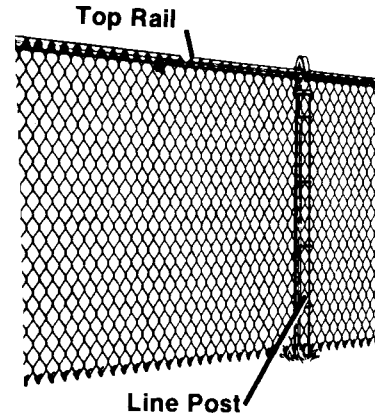


FIG. 7 Line Post and Top Rail



FIG. 8 Line Post Cap

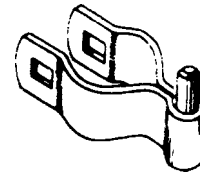


FIG. 9 Post Hinge

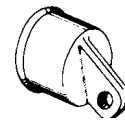


FIG. 10 Rail End

**scroll**—a decorative ornament on top of a gate.

**selvage**—the edge finish on woven chain link fabric joining pairs of pickets. The selvage may be knuckled or twisted (see Fig. 6 and Fig. 11).

**sleeve, post**—a specified length of tube or pipe set into a concrete wall, grade beam, or slab, into which fence posts are later placed.

**sleeve, toprail**—a fitting used to join two pieces of toprail when a swedged toprail is not used (see Fig. 12).

**stretching**—the process of putting tension on the fabric to make it hang uniformly along the line of fence between terminal posts.



FIG. 6 Knuckle



FIG. 11 Twist

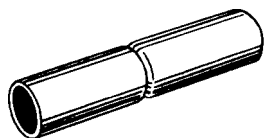


FIG. 12 Toprail Sleeve

**swedge**—the formed end of a piece of top rail so that it will fit into and join another piece of top rail (see Fig. 13).

**swing gate**—a gate leaf attached to one gate post using hinges (frame and post hinges) which allow the gate leaf to open or close by pivoting on the hinges and to the opposite gate post or another gate leaf with a latch or other device. Swing gates may be single swing (one leaf) or double swing (two leaves). See Specifications F 654 and F 900.

**tension band**—an offset strip of metal shaped to fit around the terminal post and used with a carriage bolt and nut to attach the tension bar to the post (see Fig. 14).

**tension bar**—the bar used with tension bands or other post connectors to secure the fabric to a terminal post (see Fig. 15).

**tension wire**—a wire, with or without a marcelled pattern (see **marcelling**), typically used along the top of a chain link fence in place of a top rail and along the bottom of a chain link fence for additional security. See Specification A 824<sup>2</sup> for *marcelled tension wire*. (*Syn. coil spring wire.*)

**terminal post**—the basic load-bearing component for a line of fence, to or from which the fabric is stretched; it may be an end, gate, corner or pull post.

**tie**—wire, clip, or band used to attach the fabric to the top rail and line posts (see Fig. 16 and Specification F 626<sup>2</sup>).

**top rail**—horizontal member of the framework running from terminal post to terminal post on top of the line posts (see Fig. 7).

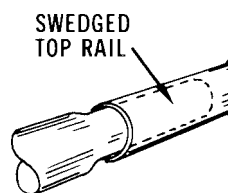


FIG. 13 Swedge

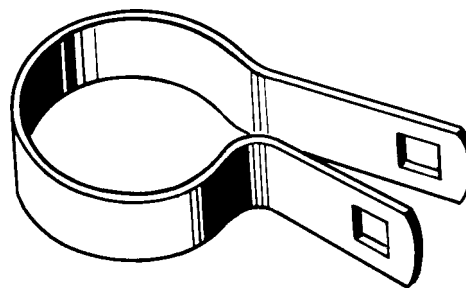


FIG. 14 Tension Band



FIG. 15 Tension Bar



FIG. 16 Tie Wire

**top roller guard**—a safety device installed on a Type II, Class 1, cantilever slide gate with external rollers to isolate the upper roller mechanism to reduce the possibility of contact with the roller mechanism by a person. See Specification F 1184<sup>2</sup>.

**truss rod**—a tensioning rod, used for bracing in gates and at terminal posts. May be threaded at one or both ends or contain a tightener or turnbuckle for adjusting tension.

**truss rod tightener**—a tightening device used with an adjusting nut and a truss rod (sometimes incorrectly called *turnbuckle*).

**turnbuckle**—a tightening device with left hand and right hand threads at opposite ends, used with a truss rod.

**twist**—the type of selvage obtained by twisting adjacent pairs of wire ends together in a close helix of 1½ machine turns, which is equivalent to three full twists (see Fig. 11).

**vehicular gate**—a structure used to close a gate opening through which vehicles are intended to pass. See Specifications F 654, F 900, and F 1184.

**Zn-5Al-MM**—an abbreviation describing an alloy of zinc, 5 % aluminum, and mischmetal, employed as a metallic coating over steel wire or steel sheet used in the manufacture of chain link fabric, fence framework materials, and other products (see Specifications F 1234 and F 1345<sup>2</sup>).

*This standard is subject to revision at any time by the responsible technical committee and must be reviewed every five years and if not revised, either reapproved or withdrawn. Your comments are invited either for revision of this standard or for additional standards and should be addressed to ASTM International Headquarters. Your comments will receive careful consideration at a meeting of the responsible technical committee, which you may attend. If you feel that your comments have not received a fair hearing you should make your views known to the ASTM Committee on Standards, at the address shown below.*

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## Standard Practice for Installation of Chain-Link Fence<sup>1</sup>

This standard is issued under the fixed designation F 567; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon ( $\epsilon$ ) indicates an editorial change since the last revision or reapproval.

### 1. Scope

1.1 This practice covers the installation procedure for chain-link fence.

1.2 This practice is intended primarily to guide those responsible for or concerned with the installation of chain-link fence.

1.3 This practice does not intend to preclude any practice that has proven equal to or given better performance under varying conditions, that is, location, weather, intended use, materials, etc.

1.4 *This standard does not purport to address all of the safety problems, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.* For specific precautionary statements, see Section 12.

### 2. Referenced Documents

#### 2.1 ASTM Standards:

F 654 Specification for Residential Chain-Link Fence Gates<sup>2</sup>

F 900 Specification for Industrial and Commercial Swing Gates<sup>2</sup>

F 1184 Specification for Industrial and Commercial Horizontal Slide Gates<sup>2</sup>

### 3. Site Preparation

3.1 The purchaser shall indicate the location of fence lines, gates, and terminal posts with suitable stakes. Stake intervals shall not exceed 500 ft (152.5 m) or line of sight.

3.2 All underground utility locations, USC&G benchmarks, property monuments, and other underground structures shall be indicated by the purchaser.

3.3 Before installing chain-link fence, all necessary site clearing and grading shall be performed by the purchaser. An adequate clearance on both sides of the fence line is required.

### 4. Post Location

4.1 Space line posts equidistant at intervals not exceeding 10 ft (3.05 m). Measure the interval parallel to the grade of the proposed fence and in the line of fence from center to center of the post.

4.2 Set terminal posts (end, corner, and gate) at the beginning and end of each continuous length of fence and at abrupt changes in vertical and horizontal alignments.

### 5. Post Setting

5.1 Set posts in concrete in holes of diameter and depth as follows. Intended use and local conditions shall determine post footing dimensions; that is, under normal conditions the diameter shall be four times the largest cross section of the post. The depth shall be a minimum of 24 in. (609.6 mm) plus an additional 3 in. (76.2 mm) for each 1-ft (305-mm) increase in the fence height over 4 ft (1.22 m).

5.2 Dig or drill holes in the line of the fence in accordance with 5.1. Forms are not necessary.

5.3 Set posts in a vertical position, plumb and in line. Backfill concrete (2500 psi) (17.2 MPa) into the excavation and extend 2 in. (50 mm) above grade. An alternative method is to stop footing 2 in. (50.8 mm) below grade to allow for cover with sod, black top, or other materials. Crown the concrete at the top to shed water and extend a minimum of 2 in. (50.8 mm) below the bottom of the post.

5.4 The use of mechanical devices for the setting of fence posts is acceptable under this practice, provided the mechanical device develops a strength in the ground equal or superior to the strength developed by the concrete footing as recommended.

5.5 When solid rock or concrete is encountered, without an overburden of soil, set posts in the solid rock or concrete. The depth of the hole shall be three times the largest cross section of the posts. The diameter of the hole shall be  $\frac{1}{2}$  in. (13 mm) greater than the largest cross section of the post.

5.6 The use of sleeves in order to leave voids in new concrete construction is recommended.

<sup>1</sup> This practice is under the jurisdiction of ASTM Committee F14 on Fences and is the direct responsibility of Subcommittee F14.80 on Installation Practices.

Current edition approved June 10, 2000. Published August 2000. Originally published as F 567 – 78. Last previous edition F 567 – 93 (1998).

<sup>2</sup> *Annual Book of ASTM Standards*, Vol 01.06.

5.7 Half-fill the void with nonshrinkable hydraulic cement and force post to the bottom of the hole and plumb. Thoroughly work additional grout into the hole so as to leave no voids. Crown the grout to shed water.

5.8 Drive posts are to be driven by mechanical means to a minimum depth of 36 in. (914.4 mm) or 6 in. (152.4 mm) greater than that called for in 5.1, for the height of fence.

5.9 Where soil conditions are unstable or rock is encountered, the drive post imbedment must be altered to maintain stability. The depth should be in keeping with standard fence construction practices for the local area or refer to 5.5.

5.10 The post tops must be protected to prevent distortion of the exposed end. The use of a drive cap is recommended.

5.11 *Residential Swing Gate Posts:*

5.11.1 See Table 1.

5.12 *Industrial and Commercial Swing Gate Posts:*

5.12.1 See Table 2.

5.13 *Cantilever Slide Gate Posts* (Specification F 1184, Type II)—Refer to Specification F 1184, Type II Cantilever Slide Gates, for post setting requirements.

5.14 *Overhead Slide Gate Posts* (Specification F 1184, Type I)—Refer to Specification F 1184, Type I Overhead Slide Gates, for post setting requirements.

## 6. Terminal Post Bracing

6.1 No braces are required on fabric 6 ft (1.83 m) high or less where the top rail is specified. On all fabric over 6 ft, braces are required. On fabric over 12 ft (3.66 m) in height, a center rail is required; regardless of height, all fences installed without a top rail shall have braces on all terminals.

6.2 Securely fasten diagonal braces to the terminal post and the adjacent line post or its footing or a footing of equal size. There shall be no more than a 50° angle between the brace and the ground. Securely fasten horizontal braces with truss rods to the adjacent line post and terminal posts.

6.3 When the top rail is used, attach the brace at the halfway point of the terminal post above grade and, when the top rail is omitted, at the two-thirds point above grade.

## 7. Top Rail and Tension Wire

7.1 Support the top rail at each post so that a continuous brace from end to end of each stretch of fence is formed. Securely fasten the top rail to the terminal posts and join with sleeves or coupling to allow for expansion and contraction.

7.2 When the top rail is omitted, stretch a tension wire from end to end of each stretch of fence at a height that will enable

it to be fastened to the fabric within the top 1 ft (305 mm) of the chain-link fabric. If specified, fasten the bottom tension wire within the bottom 6 in. (150 mm) of fabric. Securely fasten the tension wire to the terminal posts. The tension wire shall be taut and free of sag.

## 8. Chain-Link Fabric

8.1 Place chain-link fabric on the outside of the area enclosed or as directed by the purchaser.

8.2 Place the fabric by securing one end, applying sufficient tension to remove all slack before making attachment elsewhere. Tighten the fabric to provide a smooth uniform appearance free from sag.

8.3 Cut the fabric by untwisting a picket and attach each span independently at all terminal posts. Use stretcher bars with tension bands at maximum 15-in. (380-mm) intervals or any other approved method of attachment.

8.4 Install fence fabric 2 in. (50 mm) above ground level. Measure clearance at the post with a tolerance of  $\pm 3$  in. ( $\pm 76$  mm). Fasten the fabric to the line posts at intervals not exceeding 15 in. (380 mm). Fasten the fabric to the rail or tension wire at intervals not exceeding 24 in. (609 mm).

8.5 Join rolls of wire fabric by weaving a single picket into the ends of the rolls to form a continuous mesh.

## 9. Barbed Wire

9.1 If barbed wire is required, pull it taut to remove all sag, firmly install it in the slots of the extension arms, and secure it to a post or terminal arm.

## 10. Gates

10.1 The purchaser shall indicate the operational direction of the gates. Grade clearance and possible gate obstruction shall be considered in the design to provide adequate operational clearance so that the gate can operate freely.

10.2 Install gates true to opening and plumb in a closed position.

## 11. Appearance

11.1 The area of installation shall be left neat and free of any debris caused by the erection of the fence.

## 12. Safety

12.1 Perform all work in a safe and orderly fashion in accordance with the Williams-Steiger Occupational Safety and Health Act of 1970.

**TABLE 1 Minimum Requirements for Setting Residential Gate Posts**

Gate Leaf Width	Height	Post Size Specification	Size of Hole			
			Diameter		Depth	
			Dirt	Solid Rock or Concrete	Dirt	Solid Rock or Concrete
4 ft (1.2 m) or less	6 ft (1.8 m) or less	Table 2	8 in. (203 mm)	Post O.D. + ½ in.	30 in. (762 mm)	Post O.D. × 3
Over 4 ft (1.2 m) Up to 6 ft (1.8 m)	6 ft (1.8 m) or less	Table 3	10 in. (254 mm)	Post O.D. + ½ in.	30 in. (762 mm)	Post O.D. × 3

**TABLE 2 Minimum Requirements for Setting Industrial and Commercial Swing Gate Posts**

Gate Leaf Width	Height	Post Size Specification F 900	Size of Hole			
			Diameter		Depth	
			Dirt	Solid Rock or Concrete	Dirt	Solid Rock or Concrete
4 ft (1.2 m) or less	6 ft (1.8 m) or less	Steel 2.375 (60.3) Alum. 2.375 (60.3)	10 in. (254 mm)	Post O.D. + ½ in. (+13 mm)	30 in. (762 mm)	Post O.D. × 3
Over 4 to 10 ft (1.2 to 3.7 m)	6 ft (1.8 m) or less	Steel 2.875 (73.0) Alum. 2.875 (73.0)	12 in. (304 mm)	Post O.D. + ½ in. (+13 mm)	36 in. (914.5 mm)	Post O.D. × 3
Over 10 to 18 ft (3.7 to 5.5 m)	6 ft (1.8 m) or less	Steel 4.0 (101.6) Alum. 4.0 (101.6)	14 in. (356.4 mm)	Post O.D. + ½ in. (+13 mm)	36 in. (914.5 mm)	Post O.D. × 3
6 ft (1.8 m) or less	Over 6 ft (1.8 m)	Steel 2.875 (73.0) Alum. 2.875 (73.0)	10 in. (254 mm)	Post O.D. + ½ in. (+13 mm)	36 in. (914.5 mm)	Post O.D. × 3
Over 6 to 12 ft (1.8 to 3.7 m)	Over 6 ft (1.8 m)	Steel 4.0 (101.6) Alum. 4.0 (101.6)	12 in. (304 mm)	Post O.D. + ½ in. (+13 mm)	36 in. (914.5 mm)	Post O.D. × 3
Over 12 to 18 ft (3.7 to 5.5 m)	Over 6 ft (1.8 m)	Steel 6.625 (168.3)	16 in. (406.4 mm)	Post O.D. + ½ in. (+13 mm)	42 in. (1066 mm)	Post O.D. × 3
Over 18 to 24 ft (5.5 to 7.3 m)	Over 6 ft (1.8 m)	Steel 8.625 (219.1)	18 in. (457.2 mm)	Post O.D. + ½ in. (+13 mm)	48 in. (1.2 m)	Post O.D. × 3

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## Standard Specification for Fence Fittings<sup>1</sup>

This standard is issued under the fixed designation F 626; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon ( $\epsilon$ ) indicates an editorial change since the last revision or reapproval.

### 1. Scope

1.1 This specification covers the materials, coating requirements, and inspection of fence accessories for chain-link fence for the following:

- 1.1.1 Post and line caps,
- 1.1.2 Rail and brace ends,
- 1.1.3 Top rail sleeves,
- 1.1.4 Tie wires, clips, and fasteners,
- 1.1.5 Tension and brace bands,
- 1.1.6 Tension bars,
- 1.1.7 Truss rod assembly,
- 1.1.8 Barbed wire arms,
- 1.1.9 Color coating of fittings, and
- 1.1.10 Fitting size terminology.

1.2 The values stated in inch-pound units are to be regarded as the standard. The SI values given in parentheses are for information only.

### 2. Referenced Documents

#### 2.1 *ASTM Standards:*

- A 641 Specification for Zinc-Coated (Galvanized) Carbon Steel Wire<sup>2</sup>
- A 641M Specification for Zinc-Coated (Galvanized) Carbon Steel Wire (Metric)<sup>2</sup>
- A 809 Specification for Aluminum-Coated (Aluminized) Carbon Steel Wire<sup>2</sup>
- A 817 Specification for Metallic-Coated Steel Wire for Chain Link Fence Fabric<sup>2</sup>
- B 26/B 26M Specification for Aluminum-Alloy Sand Castings<sup>3</sup>
- B 85 Specification for Aluminum-Alloy Die Castings<sup>3</sup>
- B 108 Specification for Aluminum-Alloy Permanent Mold Castings<sup>3</sup>
- B 117 Practice for Operating Salt Spray (Fog) Testing Apparatus<sup>4</sup>

- B 209 Specification for Aluminum and Aluminum-Alloy Sheet and Plate<sup>3</sup>
- B 209M Specification for Aluminum and Aluminum-Alloy Sheet and Plate (Metric)<sup>3</sup>
- B 211 Specification for Aluminum and Aluminum-Alloy Bar, Rod, and Wire<sup>3</sup>
- B 211M Specification for Aluminum and Aluminum-Alloy Bar, Rod, and Wire (Metric)<sup>3</sup>
- B 221 Specification for Aluminum-Alloy Extruded Bars, Rods, Wire, Shapes, and Tubes<sup>3</sup>
- B 221M Specification for Aluminum-Alloy Extruded Bars, Rods, Wire, Shapes, and Tubes (Metric)<sup>3</sup>
- B 429 Specification for Aluminum-Alloy Extruded Structural Pipe and Tube<sup>3</sup>
- B 800 Specification for 8000 Series Aluminum Alloy Wire for Electrical Purposes: Annealed and Intermediate Temper
- F 552 Terminology Relating to Chain Link Fencing<sup>2</sup>
- F 668 Specification for Poly(Vinyl Chloride) (PVC)-Coated Steel Chain-Link Fence Fabric<sup>2</sup>
- F 934 Specification for Standard Colors for Polymer Coated Chain Link Fence Materials<sup>2</sup>
- 2.2 *U.S. Government Standard:*
  - MIL-R-60346-C Roving, Glass, Fibrous (For Prepreg Tape and Roving, Filament Winding, and Pultrusion Applications)<sup>5</sup>

### 3. Post and Line Caps

3.1 Post and line caps shall be fabricated from pressed steel or cast iron and hot-dip galvanized with a minimum of 1.2 oz/ft<sup>2</sup> [366 g/m<sup>2</sup>] of zinc coating of surface area, or from aluminum alloy 360.0 conforming to die cast Specification B 85, or sand cast or permanent mold alloy 356.0 or 713.0 conforming to Specification B 26/B 26M or B 108.

3.2 Post and line caps shall be designed to fit snugly over posts and exclude moisture from inside when tubular posts are used.

<sup>1</sup> This specification is under the jurisdiction of ASTM Committee F14 on Fences and is the direct responsibility of Subcommittee F14.40 on Chain Link Fence and Wire Accessories.

Current edition approved January 10, 2003. Published March 2003. Originally approved in 1979. Last previous edition approved in 1996 as F 626 - 96a.

<sup>2</sup> *Annual Book of ASTM Standards*, Vol 01.06.

<sup>3</sup> *Annual Book of ASTM Standards*, Vol 02.02.

<sup>4</sup> *Annual Book of ASTM Standards*, Vol 03.02.

<sup>5</sup> Available from Standardization Documents Order Desk, Bldg. 4 Section D, 700 Robbins Ave., Philadelphia, PA 19111-5094, Attn: NPODS.

#### 4. Rail and Brace Ends

4.1 Rail and brace ends, when required, shall be fabricated from pressed steel or cast iron, and hot-dip galvanized with a minimum of 1.2 oz/ft<sup>2</sup> [366 g/m<sup>2</sup>] of zinc coating of surface area, or from aluminum alloy 360.0 (see Specification B 85), or alloy 356.0 or 713.0 (see Specification B 26/B 26M or Specification B 108).

4.2 Rail and brace ends, or other approved means of connection, shall be provided when top rail or brace are required.

#### 5. Top Rail Sleeves

5.1 Top rail sleeves shall be fabricated from pressed steel or round steel tubing and hot-dip galvanized with a minimum of 1.2 oz/ft<sup>2</sup> [366 g/m<sup>2</sup>] of zinc coating of surface area, or from aluminum alloy 6063-T6 (see Specification B 221, B 221M or Specification B 429).

5.2 Rail sleeve material shall be a minimum of 0.051 in. [1.3 mm] in thickness if steel, or a minimum of 0.062 in. [1.8 mm] in thickness if aluminum alloy, and a minimum of 6 in. [152.4 mm] in length.

5.3 The rail sleeve must be fabricated to prevent movement along the rail.

#### 6. Tie Wires and Clips

6.1 Tie wires or clips, or both, for attaching chain-link fabric to round tubular or rectangular roll-formed horizontal rails and intermediate posts shall be one of the following systems, as selected by the purchaser:

6.1.1 *Standard Round Wire Ties* with either a preformed hook or pigtail at one end, designed to engage one picket of the chain-link fabric at the preformed end, wrap around the rail or post a minimum of 180°, and wrap around one picket of the chain link fabric at least one full turn at the other end in a manner that will draw up tightly around the rail or post. Standard round wire ties shall be of one of the following materials, as selected by the purchaser:

6.1.1.1 Twelve-gage (0.106 ± 0.004-in. [2.69 ± 0.10-mm]) steel with a tensile strength range from 55 to 65 ksi and with one of the following coatings, as selected by the purchaser:

(1) A minimum of 0.80 oz/ft<sup>2</sup> [230 g/m<sup>2</sup>] of zinc in accordance with Specification A 641 (A 641M), Class 3 or A coating.

(2) A minimum of 0.35 oz/ft<sup>2</sup> [107 g/m<sup>2</sup>] of aluminum in accordance with Specification A 809.

6.1.1.2 Nine-gage (0.148 ± 0.005-in. [3.76 ± 0.10-mm]) steel with a tensile strength range from 55 to 65 ksi and with one of the following coatings, as selected by the purchaser:

(1) A minimum of 0.90 oz/ft<sup>2</sup> [270 g/m<sup>2</sup>] of zinc in accordance with Specification A 641 (A 641M), Class 3 or A coating.

(2) A minimum of 0.40 oz/ft<sup>2</sup> [122 g/m<sup>2</sup>] of aluminum in accordance with Specification A 809.

NOTE 1—Heavier zinc coatings than those listed in 6.1.1.1 (1) and 6.1.1.2 (1) may be specified if desired, to match the minimum zinc coating specified for the fence fabric.

6.1.1.3 Nine-gage (0.148 ± 0.005-in. [3.76 ± 0.125-mm]) or (6-gage 0.192 ± 0.005-in. [4.88 ± 0.125-mm]) aluminum Alloy 1350-H19 or approved equal.

6.1.2 *High-Security Round Wire Ties* shall be one of the following, as selected by the purchaser:

6.1.2.1 *Power-Fastened Round Wire Ties*, preformed to the radius of the rail or post and configured to wrap a full 360° around the rail or post and minimum of one complete diamond of the chain-link fabric. The two ends of the tie shall be preformed in such a manner that they can be twisted together in a close helix of 1½ machine turns, which is equivalent to 3 full twists, thereby drawing up tightly around the rail or post and the chain-link fabric. Power-fastened round wire ties shall be of either 6-gage (0.192 ± 0.005-in. [4.88 ± 0.125-mm]) or 9-gage (0.148 ± 0.005-in. [3.76 ± 0.125-mm]) steel as selected by the purchaser, with a tensile strength range from 65 to 75 ksi, and with one of the following coatings, as selected by the purchaser:

(1) A minimum of 2.00 oz/ft<sup>2</sup> [600 g/m<sup>2</sup>] of zinc for 6-gage or 1.80 oz/ft<sup>2</sup> [540 g/m<sup>2</sup>] of zinc for 9-gage in accordance with Specification A 641 (A 641M), Class B coating.

(2) A minimum of 0.40 oz/ft<sup>2</sup> [122 g/m<sup>2</sup>] of aluminum for 6-gage or 9-gage in accordance with Specification A 809.

6.1.2.2 *Manually Fastened Round Wire Ties*, of sufficient length to weave through the fence fabric, wrap around the post or rail a full 360° and be twisted securely with three full twists. At the contractor's option, these ties may be power twisted. After twisting, the protruding wire ends shall be cut off to prevent untwisting by hand. Manually fastened round wire ties shall be of either 6-gage (0.192 ± 0.005-in. [4.88 ± 0.125 mm]) or 9-gage (0.148 ± 0.005-in. [3.76 ± 0.125-mm]) steel as selected by the purchaser, with a tensile strength range from 55 to 65 ksi, and with one of the following coatings, as selected by the purchaser:

(1) A minimum of 1.2 oz/ft<sup>2</sup> [366 g/m<sup>2</sup>] of zinc in accordance with Specification A 817, Type 2, Class 1.

(2) A minimum of 0.40 oz/ft<sup>2</sup> [122 g/m<sup>2</sup>] of aluminum in accordance with Specification A 809.

6.1.3 *Interlocking Flat Wire Ties*, preformed to the radius of the rail or post and configured to wrap a full 360° around the rail or post and one picket of the chain-link fabric. The ends of the tie shall be preformed in such a manner that they will interlock and flatten down into a double closed loop against the rail or post. Interlocking flat wire ties shall be fabricated from 0.0625 by 0.375-in. [1.59 by 9.53-mm] flat aluminum Alloy 5052-H32 wire with a tolerance of ±0.005 in. [±1.25 mm].

6.1.4 *Power-Driven Fasteners*, consisting of a knurled pin of carbon steel, heat treated to a hardness of RC 52–56 and a minimum tensile strength of 240 000 psi [1655 MPa]. Finish shall be zinc electroplating of 0.0003-in. [0.0076-mm] minimum thickness, evaluated for corrosion resistance for 72 consecutive hours with no signs of rust or corrosion when tested in accordance with Practice B 117. Cap shall be Type 304 stainless steel ⅜ in. [2.38 mm] thick. For 9-gage or 11-gage fabric other than ⅜-in. [9.53-mm] mesh, the pin shall be 1 in. [25.4 mm] long. For ⅜-in. mesh and 6-gage fabric, the pin shall be 1¼ in. [31.75 mm] long.

6.2 Round wire clips for attaching chain-link fabric to H-beam posts shall be a minimum of 7-gage ( $0.177 \pm 0.005$ -in. [ $4.50 \pm 0.125$ -mm]) wire, preformed and configured to engage both edges of the fabric side of the flange of the H-beam and one picket of the chain-link fabric. Round wire clips for H-beam posts shall be fabricated from either steel wire with a minimum of  $0.90 \text{ oz/ft}^2$  [ $275 \text{ g/m}^2$ ] of zinc coating in accordance with Specification A 641 (A 641M), Class 3 or A coating, or aluminum Alloy 1350-H19 wire.

6.3 Round wire hog rings for attaching chain-link fabric to horizontal tension wire shall be either 12-gage ( $0.106 \pm 0.005$ -in. [ $2.69 \pm 0.125$ -mm]) steel wire with a minimum of  $0.80 \text{ oz/ft}^2$  [ $230 \text{ g/m}^2$ ] of zinc coating in accordance with Specification A 641 (A 641M), Class 3 or A coating, or 9-gage ( $0.148 \pm 0.005$ -in. [ $3.76 \pm 0.125$ -mm]) aluminum Alloy 1350-H19 wire.

6.4 Round metallic-coated steel tie wires, clips, and hog rings shall withstand all forming or twisting operations, or both, without cracking or flaking of the coating to such an extent that any zinc or aluminum can be removed by rubbing with the bare fingers.

NOTE 2—Loosening or detachment during forming or twisting operations, or both, of superficial, small particles of coating metal formed by mechanical polishing of the surface of the coating wire shall not be considered cause for rejection.

6.5 Where specified, round metallic-coated tie wires, clips, and hog rings shall be polymer coated to match the color of the chain-link fabric, as selected from Specification F 934. The coating process and metallic-coated core wire materials shall be in accordance with Specification F 668. The diameter of the metallic-coated core wire shall be identical to that specified for the chain-link fabric, but shall not be smaller than 11 gage ( $0.120 \pm 0.005$  in. [ $3.05 \pm 0.125$  mm]) and not larger than 9 gage ( $0.148 \pm 0.005$  in. [ $3.76 \pm 0.125$  mm]). The tensile strength of the core wire constituting the tie wires, clips, and hog rings shall be suitable to accommodate a manual or power fastening process without causing damage to the metallic or polymer coatings.

NOTE 3—Although rust formation on the cut ends or other unprotected surface areas of steel tie wires is primarily an inherent characteristic of aluminum coated steel wire, rejections of material exhibiting this condition will not be warranted irrespective of the core wire material employed unless it causes significant and noticeable staining of the tie, the chain-link fabric, the post surface, or the rail surface.

## 7. Tension and Brace Bands

7.1 Tension and brace bands shall be fabricated from pressed steel and hot-dip galvanized with a minimum of  $1.2 \text{ oz/ft}^2$  [ $366 \text{ g/m}^2$ ] of zinc coating of surface area, or from aluminum alloy 6063-T5, 6063-T6, or 8176-H19 (see Specification B 211, B 211M, B 221, B 221M, or B 800).

7.2 Tension bands shall be a minimum of 14 gage (0.074 in. [1.88 mm]) in thickness and a minimum of  $\frac{3}{4}$  in. [19.05 mm] in width.

7.3 Brace bands shall be a minimum of 12 gage (0.105 in. [2.66 mm]) in thickness and a minimum of  $\frac{3}{4}$  in. [19.05 mm] in width.

## 8. Tension Bars

8.1 Steel tension bars shall be fabricated from merchant quality steel and hot-dip galvanized with a minimum of  $1.2 \text{ oz/ft}^2$  [ $366 \text{ g/m}^2$ ] of zinc coating of surface area.

8.2 Fiberglass tension bars shall be manufactured from unidirectional E-glass fibers in accordance with MIL-R-60346-C and processed to produce the desired shape and mechanical properties. The outer surface shall consist of a minimum average 1.5 mil (0.0015 in. [0.038 mm]) thick weather resistant plastic coating.

8.3 Aluminum alloy tension bars shall be 6061-T6 or 6063-T6 alloy (see Specification B 221M or B 221M).

8.4 Steel or fiberglass tension bars used to connect  $1\frac{3}{4}$  in. [44.5 mm] and 2 in. [50 mm] mesh fabric to end, gate and corner posts shall be a minimum of  $\frac{3}{16}$  in. [4.8 mm] by  $\frac{5}{8}$  in. [15.9 mm] for fabric heights up to 5 ft [1.52 m] and a minimum of  $\frac{3}{16}$  in. [4.9 mm] by  $\frac{3}{4}$  in. [19.1 mm] for fabric heights over 5 ft [1.52 m]. Steel, fiberglass, or aluminum alloy tension bars used to connect 1 in. [25.4 mm] mesh fabric to end, gate and corner posts shall be a minimum of  $\frac{1}{4}$  in. [6.4 mm] by  $\frac{3}{8}$  in. [9.5 mm].

8.5 Aluminum alloy tension bars used to connect  $1\frac{3}{4}$  in. [44.5 mm] and 2 in. [50 mm] mesh fabric to end, gate and corner posts shall be a minimum of  $\frac{1}{4}$  in. [6.4 mm] by  $\frac{3}{4}$  in. [19.1 mm].

8.6 Minimum lengths of tension bar shall be 2 in. [50 mm] less than the full height of the chain link fabric.

## 9. Truss Rod Assembly

9.1 Steel truss rods shall be fabricated from  $\frac{5}{16}$  in. [7.9 mm] merchant quality rod and it and all related devices shall be hot-dip galvanized after threading with a minimum of  $1.2 \text{ oz/ft}^2$  [ $366 \text{ g/m}^2$ ] of zinc coating of surface area.

9.2 Aluminum alloy truss rods shall be fabricated from  $\frac{3}{8}$  in. [9.5 mm] alloy 6061-T6 (see Specification B 211 or B 211M or B 221 or B 221M). Aluminum truss rod tighteners shall be alloy 356-T6 or 713-T5 (see Specifications B 26/B 26M or B 28) or alloy 6061-T6 (see Specification B 211 or B 221).

9.3 Truss rod and tightener shall be capable of withstanding a tension of 2000 lb [907 kg].

## 10. Barbed Wire Arms

10.1 Barbed wire arms shall be fabricated from pressed steel or cast iron, and hot-dip galvanized with a minimum of  $1.2 \text{ oz/ft}^2$  [ $366 \text{ g/m}^2$ ] of zinc coating of surface area, or from Aluminum alloy 360 (see Specification B 85), or 356-T6 (see Specification B 26/B 26M and B 108). Aluminum Barb Arm Blades shall be fabricated from aluminum alloy 3003-H14, 5052-H32 or 6061-T6 extruded bar or sheet having a minimum thickness of 0.080 in. [2 mm] (see Specifications B 209, B 209M, B 211, B 211M, B 221, and B 221M).

10.2 Barbed wire arms shall be of the following types as specified:

10.2.1 *Type I*—Single slanted arm, for three barbed wire strands;

10.2.2 *Type II*—Single vertical arm for three barbed wire strands;



10.2.3 *Type III*—V-shaped arm, for six barbed wire strands;  
or

10.2.4 *Type IV*—A-shaped arm, for five barbed wire strands.

10.3 Barbed wire arms shall be fitted with clips or slots for attaching the barbed wire to the arms.

10.4 In the installed position, Type I, III and IV barbed wire arms shall project at an angle of 45° (+5°) from the vertical plane of the fence line.

10.5 When the base of the barbed wire arm has been securely clamped in a testing device, the arm shall be capable of supporting a vertical 250 lb [113 kg] load placed where the outer strand of barbed wire would connect to the arm, without causing any permanent deflection of the arm.

### 11. Color Coating of Fittings

11.1 The color coating of fittings shall match the color coating of the fabric when so specified. Standard colors shall be green, olive green, brown, or black as described in Munsell Units specified by Specification F 934.

11.2 The exterior surface of the fittings shall be polymer coated with a minimum 0.006-in. [0.152-mm], maximum 0.015-in. [0.381-mm] thickness when so specified. Color

coating material and thickness may be at the option of the manufacturer, when so specified by the buyer. Ferrous fittings shall be hot-dip galvanized prior to application of color coating material.

11.3 The color coating material shall be without voids on all visually exposed surfaces when viewed in the as-installed attitude, without tears or cuts that reveal the substrate and adhere to the fitting without peeling when scratched with a pick device or knife blade point.

### 12. Terminology Fitting Size Terminology

12.1 Descriptive sizes of fittings for the various shapes of posts and rail commonly used for chain-link fence shall be as listed in Table 1.

### 13. Illustrations

13.1 See Terminology F 552 for illustrations of various types of fittings.

### 14. Keywords

14.1 fittings; fence; high security

**TABLE 1 Fitting Sizes**

Trade Size, in.	Nominal Size, in.	Actual Size, in.	Outside Diameter, mm
<i>Pipe and Tube Sections:</i>			
1 $\frac{3}{8}$	1	1.315	33.40
1 $\frac{5}{8}$	1 $\frac{1}{4}$	1.660	42.16
2	1 $\frac{1}{2}$	1.900	48.26
2 $\frac{1}{2}$	2	2.375	60.33
3	2 $\frac{1}{2}$	2.875	73.03
3 $\frac{1}{2}$	3	3.500	88.90
4	3 $\frac{1}{2}$	4.000	101.60
4 $\frac{1}{2}$	4	4.500	114.30
6 $\frac{3}{8}$	6	6.625	168.28
8 $\frac{5}{8}$	8	8.625	219.06
<i>Formed Steel Sections:</i>			
C-Rail	1.625	1.625 by 1.250	41.28 by 31.75
Standard C	1.900	1.875 by 1.625	47.63 by 41.28
Heavy C	2.250	2.250 by 1.700	57.15 by 43.18
Terminal	3.500	3.500 by 3.500	88.90 by 88.90
<i>H Section:</i>			
2 $\frac{1}{4}$	...	2.250 by 1.700	57.15 by 43.18
<i>Square Sections:</i>			
2	...	2.000 by 2.000	50.80 by 50.80
2 $\frac{1}{2}$	...	2.500 by 2.500	63.50 by 63.50
3	...	3.000 by 3.000	76.20 by 76.20



## F 626 – 96a (2003)

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# Standard Specification for Residential Chain Link Fence Gates<sup>1</sup>

This standard is issued under the fixed designation F 654; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon ( $\epsilon$ ) indicates an editorial change since the last revision or reapproval.

## 1. Scope

1.1 This specification covers detail requirements for residential chain link fence gates, gate posts, and accessories.

## 2. Referenced Documents

### 2.1 ASTM Standards:

A 780 Practice for Repair of Damaged and Uncoated Areas of Hot-Dip Galvanized Coatings<sup>2</sup>

F 1043 Specification for Strength and Protective Coatings on Metal Industrial Chain Link Framework<sup>2</sup>

F 626 Specification for Fence Fittings<sup>2</sup>

## 3. Classification

3.1 Residential chain link fence gates are classified as follows:

3.1.1 *Type I*—Single Swing

3.1.2 *Type II*—Double Swing

3.2 No gate leaf over 6 ft [1.829 m] in height or over 6 ft [1.829 m] in width shall be classified as residential, regardless of use or location.

## 4. Manufacture

4.1 Zinc-coated steel frames shall be zinc-coated in accordance with the zinc coating specified for the fence framework. Welded joints shall have suitable rust preventive coating applied to the welds.

4.2 Aluminum gate frame shall be the same base material and alloy as specified for the fence framework. Aluminum gate frames may be assembled with corner fittings.

4.3 Polymer-coated steel or aluminum frame shall be polymer coated as specified for framework. Polymer-coated steel frames may be assembled with corner fittings. Welded joints shall have suitable preventive coating applied to the welds.

NOTE 1—The word polymer is used to describe all types of heat set organic exterior coatings and is not applicable to metallic coatings, such as zinc or aluminum.

<sup>1</sup> This specification is under the jurisdiction of ASTM Committee F14 on Fences and is the direct responsibility of Subcommittee F14.40 on Chain Link Fence and Wire Accessories.

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<sup>2</sup> Annual Book of ASTM Standards, Vol 01.06.

## 5. Gate Frames, Fabric, Attachment, and Finish

5.1 *Gate Frames* shall be of aluminum or steel tubing, round or square, and assembled by means of corner fittings or welded, or formed by bending. The bend should be smooth and continuous.

5.1.1 *Corner Fitted and Welded Gates* shall have vertical and horizontal interior members spaced so that no horizontal dimension between outside members shall be greater than 5 ft [1.524 m], and no vertical dimension between members shall be greater than 5 ft [1.524 m].

5.2 *Fabric* shall match that of the line fabric adjacent to the gate opening or as required by specifications or drawings, or both. However, fabric having a breaking strength equivalent to or greater than the fabric used in the line of fence may be used.

5.3 *Attachment of Fabric to Gate Frame*—Stretch the fabric so it is taut and fastened to frames by one of the following methods:

5.3.1 Place a round rod or flat bar through the fabric and fasten with clips or bands, at a maximum spacing of 12 in. [305 mm] on center, of sufficient strength to hold fabric taut between the vertical frame members. Clips or bands shall conform to the profile of the frame members.

5.3.2 Place a round rod or flat bar through the fabric and fasten with a J-bolt through the holes in the frame.

5.3.3 Fasten all fabric to horizontal frame members and to any interior frame members by means of clips, tie wires, or bands suitable to retain the fabric to the frame members. Spacing should be at a maximum of 18 in. [450 mm] apart.

## 6. Dimensions and Weights (of Gate Frames and Gate Posts)

### 6.1 Dimension (Height):

6.1.1 The vertical dimension (height) of the gate should be 2 in. [60 mm] less than the specified height of the adjacent fence.

6.1.2 Where interior members are required, they shall be evenly spaced between outside members.

6.2 *Dimension (Width)*—Gate opening sizes are figured on the inside dimensions between gate posts. The actual width of the gate panel shall be equal to the opening minus the space required for free operation of hinges and latches.

6.3 *Diameter and Weight of Frames*—See Table 1.

**TABLE 1 Fence Frames (Minimum Requirements)**

	Outside Dimension Pipe, in. [mm]	Wall Thickness, in. [mm]	Nominal Weight, lb/ft [kg/m]
Steel:			
Round tube	1.315 [33.4]	0.065 [1.65]	0.8681 [1.29]
Square tube	1.25 by 1.25 [31.75 by 31.75]	0.065 [1.65]	1.05 [1.56]

**TABLE 2 Gate Posts (for Gate Leaf Width of 48 in. [1.219 m] or Less)**

	Outside Dimension Pipe, in. [mm]	Wall Thickness, in. [mm]	Nominal Weight, lb/ft [kg/m]
Round Post:			
Steel	1.90 [48.3]	0.15 [1.15]	1.27 [1.89]
Square Post:			
Steel	2 by 2 [50.8 by 50.8]	0.080 [2.032]	2.09 [3.11]

**TABLE 3 Gate Posts (for Gate Leaf Width over 48 in. [1.201 m] to 72 in. [1.829 m])<sup>A</sup>**

	Outside Dimension Pipe, in. [mm]	Wall Thickness, in. [mm]	Nominal Weight, lb/ft [kg/m]
Round Post:			
Steel	2.375 [60.3]	0.095 [2.93]	2.31 [3.44]
Square Post:			
Steel	2.5 by 2.5 [63.5 by 63.5]	0.083 [2.11]	2.73 [4.06]

<sup>A</sup> Gate posts for gate leaf width up to 60 in. [1.524 m] may use a round steel post 2.375 in. [60.3 mm] in diameter with a wall thickness of 0.065 in. [1.651 mm].

6.4 *Gate Post Dimensions and Weights*—See Table 2 and Table 3.

## 7. Gate Hardware

7.1 All gate hardware shall be of sufficient strength and durability to support the gate and repeated open-close cycles.

### 7.2 *Single and Double Gate Latches:*

7.2.1 *Single Gate Latches* shall be of lockable design.

7.2.2 *Double Gate Latches* shall be equipped with a center drop rod or bar, and suitable fork or gravity latch to retain both gates in a parallel position while closed, or a positive locking device with suitable attachment to retain both gates in parallel position while closed.

7.3 *Center Stops*— When required for drop rods or bars, center stops may be of manufactured design of aluminum or steel and suitable for attachment to slab or installed in concrete or may be a hole drilled into existing concrete slab.

7.4 *Gate Holdbacks* are optional to the purchaser.

7.5 *Accessories* are optional as required by specifications, drawings, or to match the line adjacent to the gates.

## 8. Workmanship

8.1 Gates shall be produced in accordance with good commercial practices. Defects in welds, chain link fabric, bracing and truss rods, and accessories shall be noted and, if present to any considerable extent, shall provide a basis for rejection.

## 9. Inspection

9.1 The manufacturer shall afford the inspector representing the purchaser all reasonable facilities to satisfy him that the material being furnished is in accordance with this specification. Unless otherwise specified, all tests and inspection shall be made at the place of manufacture, prior to shipment, and shall be so conducted as not to interfere unnecessarily with the operation of the work.

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# Standard Specification for Polyvinyl Chloride (PVC) and Other Organic Polymer-Coated Steel Chain-Link Fence Fabric<sup>1</sup>

This standard is issued under the fixed designation F 668; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon ( $\epsilon$ ) indicates an editorial change since the last revision or reapproval.

## 1. Scope

1.1 This specification covers polyvinyl chloride and other conforming organic polymer-coated steel chain-link fabric, coated before weaving. Polyvinyl chloride and other organic polymer coating hereinafter will be designated as polymer coating.

1.2 Fabric produced from three classes of wire coatings are covered as follows:

1.2.1 *Class 1* consists of polymer coatings extruded over zinc-coated, aluminum-coated, or zinc-5 % aluminum-mischmetal alloy-coated, or zinc-5 % aluminum-mischmetal alloy-coated steel wire.

1.2.2 *Class 2a* consists of polymer coating extruded and adhered to zinc-coated, aluminum-coated, or zinc-5 % aluminum-mischmetal alloy-coated steel wire.

1.2.3 *Class 2b* consists of polymer coating fused and adhered to zinc-coated, aluminum-coated, or zinc-5 % aluminum-mischmetal alloy-coated steel wire.

1.3 The values stated in inch-pound units are to be regarded as the standard. The values given in parentheses are provided for information only.

## 2. Referenced Documents

### 2.1 ASTM Standards:

A 90/A 90M Test Method for Weight [Mass] of Coating on Iron and Steel Articles with Zinc or Zinc-Alloy Coatings<sup>2</sup>

A 370 Test Methods and Definitions for Mechanical Testing of Steel Products<sup>3</sup>

A 428/A 428M Test Method for Weight of Coating on Aluminum-Coated Iron or Steel Articles<sup>2</sup>

D 1499 Practice for Operating Light- and Water-Exposure Apparatus (Carbon-Arc Type) for Exposure of Plastics<sup>4</sup>

D 1535 Practice for Specifying Color by the Munsell System<sup>5</sup>

<sup>1</sup> This specification is under the jurisdiction of ASTM Committee F-14 on Fences and is the direct responsibility of Subcommittee F14.40 on Chain Link Fence and Wire Accessories.

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<sup>2</sup> *Annual Book of ASTM Standards*, Vol 01.06.

<sup>3</sup> *Annual Book of ASTM Standards*, Vol 01.03.

<sup>4</sup> *Annual Book of ASTM Standards*, Vol 08.01.

<sup>5</sup> *Annual Book of ASTM Standards*, Vol 06.01.

D 1729 Practice for Visual Evaluation of Color Differences of Opaque Materials<sup>5</sup>

F 552 Terminology Relating to Chain Link Fencing<sup>2</sup>

G 23 Practice for Operating Light-Exposure Apparatus (Carbon-Arc Type) With and Without Water for Exposure of Nonmetallic Materials<sup>6</sup>

G 26 Practice for Operating Light-Exposure Apparatus (Xenon-Arc Type) With and Without Water for Exposure of Nonmetallic Materials<sup>6</sup>

### 2.2 U.S. Federal Standard:

Fed. Std. No. 123 Marking for Shipments (Civil Agencies)<sup>7</sup>

### 2.3 U.S. Military Standards:

MIL-STD-129 Marking for Shipment and Storage<sup>7</sup>

MIL-STD-163 Steel Mill Products, Preparation for Shipment and Storage<sup>7</sup>

## 3. Terminology

3.1 *Definitions*—For definitions of terms such as chain-link fence fabric, selvage, knuckle, twist, and diamond count, see Terminology F 552.

## 4. Ordering Information

4.1 Orders for chain-link fence fabric purchased to this specification shall include the following information:

4.1.1 Quantity.

4.1.2 Class of polymer coating to be applied to the metallic-coated core wire.

4.1.3 Color of coating (see Table 1).

4.1.4 Size of mesh (see Table 2).

4.1.5 Finished outside diameter of metallic-coated core wire or minimum breaking strength, or both (see Tables 2-4).

4.1.6 Height of fabric (see Table 1).

4.1.7 Type of selvage if nonstandard (see 12.1 and 12.2).

4.1.8 Diamond count if nonstandard (see 9.1 and Table 3).

4.1.9 Certification, if required.

4.2 Any tests required other than those specifically covered in this specification must be stipulated by the purchaser in the order or contract.

<sup>6</sup> *Annual Book of ASTM Standards*, Vol 14.02.

<sup>7</sup> Available from the procuring activity or as directed by the contracting office or from Standardization Documents Order Desk, Bldg. 4 Section D, 700 Robbins Ave., Philadelphia, PA 19111-5094, Attn: NPODS.

**TABLE 1 Standard Polymer Colors**

NOTE 1—Values are in Munsell units (see Test Method D 1535 and Practice D 1729).

	Green	Olive Green	Brown	Black
Hue	8.8G	2.0G	7YR	1.8PB
Value	2.63	3.02	2.4	1.26
Chroma	5.8	2.35	1.75	0.5

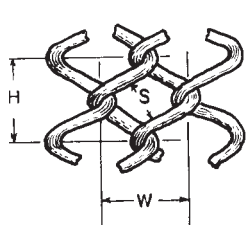
**TABLE 2 Sizes of Wire and Mesh<sup>A</sup>**

NOTE 1—For custom fabric heights, see Section 11.

Specified Diameter of Core Wire, in.	Size Core Wire Gage	Size of Mesh, in.	Height of Fence Fabric, in.
0.192	6	2	36, 42, 48, 60, 72, 84, 96, 108, 120, 144
0.192	6	1¾	36, 42, 48, 60, 72, 84, 96, 108, 120, 144
0.148	9	2	36, 42, 48, 60, 72, 84, 96, 108, 120, 144
0.148	9	1¾	96, 108, 120, 144
0.148	9	1	36, 42, 48, 60, 72, 84, 96, 108, 120, 144
0.120	11	2½	36, 42, 48, 60, 72,
0.120	11	2	36, 42, 48, 60, 72, 84, 96, 108, 120, 144
0.120	11	1¾	36, 42, 48, 60, 72, 84, 96, 108, 120, 144
0.120	11	1	36, 42, 48, 60, 72, 84, 96, 108, 120, 144
0.120	11	¾	36, 42, 48, 60, 72, 84, 96, 108, 120, 144
0.120	11	½	36, 42, 48, 60, 72, 84, 96, 108, 120, 144
0.120	11	⅜	36, 42, 48, 60, 72, 84, 96, 108, 120, 144
0.105 <sup>B</sup>	12	⅝	36, 42, 48, 60, 72, 84, 96, 108, 120, 144
0.105 <sup>B</sup>	12	½	36, 42, 48, 60, 72, 84, 96, 108, 120, 144
0.105 <sup>B</sup>	12	⅜	36, 42, 48, 60, 72, 84, 96, 108, 120, 144
0.080 <sup>B</sup>	14	⅝	36, 42, 48, 60, 72, 84, 96, 108, 120, 144
0.080 <sup>B</sup>	14	½	36, 42, 48, 60, 72, 84, 96, 108, 120, 144
0.080 <sup>B</sup>	14	⅜	36, 42, 48, 60, 72, 84, 96, 108, 120, 144

<sup>A</sup>See Table X1.1 for metric equivalents.

<sup>B</sup>These wire sizes should only be used on ⅝ in., ½ in., and ⅜ in. mesh fabrics. See Fig. 1 for criteria on mesh dimensions.



S	H	W
¾ in. MESH	¾ in.	¾ in.
½ in. MESH	15/16 in.	15/16 in.
⅝ in. MESH	1 1/8 in.	1 1/8 in.

**FIG. 1 Mesh Dimensions for ⅝-in., ½-in., and ¾-in. Fabric**

4.3 All rolls of fabric accepted by the purchaser shall be billed to him on the basis of the original footage of the rolls before sampling, unless changed by contractual agreement.

**5. Materials**

5.1 *Base Metal*—The base metal shall be steel of such quality and purity that, when drawn to the size of wire specified and coated with an organic polymer, the finished fencing shall be of uniform quality and have properties and characteristics as prescribed in the specification.

5.2 Wire used for the manufacture of fabric shall meet the requirements of this specification and shall be capable of being woven into fabric without the polymer coating cracking or peeling. The polymer coating shall be formulated and produced properly to conform to the requirements of this specification.

**6. Manufacture**

6.1 Class 1 polymer-coated wire shall have the polymer coating extruded onto wire that conforms to the requirements as shown in Table 4.

6.2 Class 2a polymer-coated wire shall have the polymer coating extruded and adhered to wire that is zinc-coated by the hot-dip method, zinc-coated by the electrolytic process, or aluminum-coated by the hot-dip method.

6.3 Class 2b polymer-coated wire shall have the polymer coating fused and adhered to wire that is zinc-coated by the hot-dip method, zinc-coated by the electrolytic process, or aluminum-coated by the hot-dip method. The use of a primer prior to the application of a polymer coating may be recommended by the polymer manufacturer.

NOTE 1—Under current practice, the fusion bonded process for PVC wire coating requires the use of a primer to attain chemical bonding to the substrate, in any event, the polymer manufacturer’s recommendation should be followed.

6.4 Type of metallic coating on the steel wire substrate shall be the choice of the producer unless otherwise specified.

**7. Weave**

7.1 The wire shall be woven throughout in the form of approximately uniform square mesh, having parallel sides and horizontal and vertical diagonals of approximately uniform dimensions. The top and bottom of the fabric shall be knuckled or twisted as specified in Section 12.

**8. Size of Mesh**

8.1 The size of mesh shall conform to the requirements as shown in Table 2.

8.2 The permissible variation from the specified size of mesh shall be ± ⅛ in. (3.2 mm) for all mesh sizes over 1 in. (25 mm) and ± 1/16 in. (1.6 mm) for all mesh sizes 1 in. (25 mm) and under.

8.3 Size of mesh shall be determined by unrolling a roll of fabric on a flat surface and exerting tension in accordance with the requirements of 18.2, then measuring the minimum clear distance between the wires forming the parallel sides of the mesh.

**9. Diamond Count**

9.1 Typical diamond count for each standard height is shown in Table 3. Other diamond counts are permissible, provided that they are consistent within a lot. The purchaser has the option to specify the typical diamond count of 4.1.8.

**10. Size of Wire**

10.1 Chain-link fabric shall be fabricated from wire diameters as necessary to meet the requirements of Table 2. The diameter shall be determined as the average of two readings taken at right angles to each other on the straight portion of the parallel sides of the mesh and measured to the nearest 0.001 in. (0.03 mm).

10.2 The permissible variation from the specified diameter of the core wire over 0.105 in. (2.67 mm) shall be ± 0.005 in. (0.13 mm). The permissible variation for the specified diameter on core wires 0.105 in. (2.67 mm) or less shall be ± 0.004 in. (0.10 mm).

**TABLE 3 Typical Diamond Count<sup>A</sup>**

NOTE 1—Other diamond counts are permitted (see Section 9 on Diamond Count).

NOTE 2— For fabric heights over 144 in., see Section 9.

Nominal Diameter Core Wire, in.	Size of Mesh, in.	Height of Fence Fabric, in.									
		36	42	48	60	72	84	96	108	120	144
0.192	2	10½	12½	13½	17½	20½	24½	27½	31½	34½	41½
0.148	2	10½	12½	13	17½	20½	24½	27½	31½	34½	41½
0.120	2	10½	12½	14½	17½	20½	24½				
0.120	2½	9½	11½	13½	16½	19½					
0.120	1¾	11½	13½	15½	19½	23½	27½	31½	35½	39½	47½
0.120	1	20	23	27	33	45	53	61	67	69	
0.120	5/8										
0.120	½										
0.120	3/8										
0.105	5/8										
0.105	½	see Fig. 1									
0.105	3/8										
0.080	5/8										
0.080	½										
0.080	3/8										

<sup>A</sup>See Table X1.1 for metric equivalents.

**TABLE 4 Breaking Strength of Core Wire**

Specified Diameter of Core Wire, in. (mm)	Minimum Breaking Strength	
	lbf	(N)
0.192 (4.88)	2170	(9650)
0.148 (4.76)	1290	(5740)
0.120 (3.05)	850	(3780)
0.105 (2.67)	650	(2890)
0.080 (2.03)	380	(1690)

**11. Height of Fabric**

11.1 Chain-link fabric, unless otherwise specified by the purchaser, shall be furnished in the standard heights shown in Table 2. Custom order fabric is available in heights to and including 240 ft. (6.56 m). The height of the fabric shall be the overall dimension from the ends of twists or knuckles. Permissible variations from the specified height shall be ±1 in. (25 mm) for standard selvage on fabric with mesh sizes 1 in. (25 mm) and over and ±½in. (13 mm) for all fabric with mesh sizes less than 1 in. (25 mm).

**12. Selvage**

12.1 Fabric with 2-in. (50.8-mm) or 2 ⅛-in. (54.0-mm) mesh, in heights less than 72 in. (1829 mm), shall be knuckled at both selvages. Fabric 72 in. (1829 mm) high and over shall be knuckled at one selvage and twisted at the other. These are the standard selvages. Other selvage combinations will be supplied only if specified by the purchaser.

NOTE 2—**Caution:** Twisted selvages for fences under 72 in. (1829 mm) in height are not recommended because of consumer safety considerations.

12.2 The selvages of fabrics with meshes of less than 2 in. (50.8 mm) shall be knuckled on both edges.

**13. Breaking Strength**

13.1 Wire constituting the fabric shall meet the minimum breaking strength shown in Table 4, as determined in accordance with Test Methods and Definitions A 370.

13.2 Specimens to establish conformance to this requirement shall comprise individual pickets from a section of the fence fabric. The specimens shall be of sufficient length so as to be firmly gripped in the testing machine after straightening. Polymer coating may be removed from the sample by chemical or mechanical means before testing. The actual gage length (distance between jaws) of the specimen shall be limited to the undeformed length of wire between the two adjacent bends.

**14. Weight of Zinc, Aluminum, or Zinc-5 % Aluminum-Mischmetal Alloy Coatings**

14.1 The weight of zinc or aluminum coating shall conform to Table 5.

14.2 The weight of coating shall be determined on an individual piece of wire removed from the fabric. This specimen may be any length of wire over 12 in. (305 mm) and shall include both bends and straight sections, but shall not include either twists or knuckles.

14.3 The weight of zinc or zinc-5 % aluminum-mischmetal alloy coating shall be determined by the method contained in Test Method A 90/A 90M after stripping the polymer coating as outlined in Section 15.

14.4 The weight of aluminum coating shall be determined by the method contained in Test Method A 428, after stripping the polymer coating as outlined in Section 15.

**15. Thickness of Polymer Coating**

15.1 The thickness of the polymer coating shall be in accordance with Table 6.

**TABLE 5 Weight of Zinc, Aluminum, or Zinc-5 % Aluminum-Mischmetal Alloy Coatings**

Specified Diameter of Core Wire, in. (mm)	Minimum Weight of Zinc or Zinc-5 % Aluminum- Mischmetal Alloy Coating, oz/ft <sup>2</sup> (g/m <sup>2</sup> )	Minimum Weight of Aluminum Coating, oz/ft <sup>2</sup> (g/m <sup>2</sup> )
0.192 (4.88)	0.40 (122)	0.20 (61)
0.148 (3.76)	0.30 (92)	0.20 (61)
0.120 (3.05)	0.30 (92)	0.20 (61)
0.105 (2.67)	0.30 (92)	0.20 (61)
0.080 (2.03)	0.25 (76)	0.20 (61)

**TABLE 6 Thickness of Polymer Coating**

	Class 1, Class 2a, in. (mm)	Class 2b, in. (mm)
Minimum thickness at any point	0.015 (0.38)	0.006 (0.15)
Maximum thickness at any point	0.025 (0.64)	0.010 (0.25)

15.2 The thickness of polymer coating shall be determined on an individual piece of wire removed from the fabric. This specimen may be any length of wire over 12 in. (305 mm) and shall include both bends and straight sections, but shall not include either twists or knuckles.

15.3 For Class 1 and Class 2a material, mechanically strip the polymer coating from the wire and measure the minimum and maximum thickness of the polymer coating with a suitable micrometer.

15.4 For Class 2b material, strip the polymer coating by chemical or mechanical means and determine the diameter of the bare wire. Scrape the coating from one side of the wire and measure the reduced diameter with a micrometer. The thickness of coating at this point is the difference between the measurement thus obtained and the measured diameter of the bare wire. In a similar manner, determine the thickness of coating at right angles to the first determination.

15.5 When removing polymer coating by scraping, take care not to remove any of the metallic surface.

## 16. Properties of Polymer-Coated Wire

16.1 The polymer-coated wire from which the fabric is woven shall have a demonstrated ability to conform to the following requirements:

### 16.2 Adhesion Tests:

16.2.1 Class 2a must conform to the requirements of 16.2.2. Class 2b must conform to the requirements of 16.2.3.

16.2.2 Three specimens from each lot shall be tested. Measure a distance of  $\frac{3}{4}$  in. (19 mm) from the end of the specimen. With a regular hand grip wire stripper, exert maximum hand pull parallel to the axis of the wire. Attempt to remove the measured portion of the vinyl sleeve from the core wire. The lot shall be acceptable if the polymer sleeve is not capable of being removed from the core wire on all three samples.

16.2.3 Three specimens from each lot shall be tested. Make two cuts parallel to the axis of the wire through the coating, approximately  $\frac{1}{16}$  in. (1.6 mm) apart, at least  $\frac{1}{2}$  in. (12.7 mm) long. With a knife peel back a section of the coating between  $\frac{1}{8}$  in. (3.2 mm) and  $\frac{1}{4}$  in. (6.4 mm) long to produce a tab. Attempt to remove the  $\frac{1}{16}$  in. (1.6 mm) strip of coating by pulling the tab. The lot shall be acceptable if the coating breaks rather than separates from the core wire on all three specimens.

16.3 *Accelerated Aging*—Polymer-coated wire from which the fabric is woven shall withstand exposure for 1000 h without failure at a black panel temperature of 145°F (63°C) when tested in accordance with Practice D 1499. Type D, E, or F apparatus described in Practice G 23 or Type BH apparatus described in Practice G 26 shall be used for the test. The product shall be construed to have failed the test if:

16.3.1 The wire fails to withstand the mandrel bend test described in 16.4.

16.3.2 Shrinkage of the polymer coating is greater than  $\frac{1}{16}$  in./ft (5.2 mm/m) of wire.

16.3.3 There is a significant change in color or gloss of the polymer surface as determined by visual inspection.

### 16.4 Mandrel Bend:

16.4.1 Polymer-coated wire when subjected to a single bend at  $-20^{\circ}\text{F}$  ( $-29^{\circ}\text{C}$ ) around a mandrel no larger than ten times the diameter of the wire shall not exhibit breaks or cracks in the polymer coating.

16.4.2 The mandrel bend test shall be performed on an individual piece of wire removed from the fabric. This specimen may be any length of wire over 12 in. (305 mm) and shall include both bends and straight sections but shall not include either twists or knuckles.

### 16.5 Color:

16.5.1 Unless otherwise stipulated by the purchaser, the color of the polymer shall be in accordance with the standard colors contained in Table 1.

16.5.2 Compliance with this requirement shall be determined by comparison of specimens of the polymer-coated wire to standard flat specimens of fused film of approximately the thickness specified for the polymer coating to be applied to the wire, and measuring at least  $1\text{-}\frac{1}{2}$  by  $1\text{-}\frac{1}{2}$  in. (38 by 38 mm).

16.5.3 Standard flat specimens for the evaluation of color of Class 1 and Class 2a coatings shall be prepared by milling, calendaring, or compression molding polymer pellets, using temperatures approximating those to be used in the extrusion.

16.5.4 Standard flat specimens for the evaluation of Class 2 coatings shall be prepared by thermally fusing polymer powder onto a suitable base, using temperatures approximating those to be used in the powder coating process.

16.5.5 The color of the standard flat specimens shall be determined in accordance with Test Method D 1535 and Practice D 1729.

## 17. Workmanship

17.1 Chain-link fence fabric shall be produced by methods recognized as good commercial practices. The polymer coating shall be without voids. The polymer-coated wire shall be woven into fabric without tears or cuts that reveal the substrate.

## 18. Standard Length of Rolls

18.1 The standard length of roll shall be 50 ft (15.24 m)  $\pm$  1 % except as otherwise agreed upon at the time of purchase.

18.2 The length of roll shall be determined by unrolling a roll of fabric on a flat surface and exerting tension by appropriate means to remove all slack. The tension applied shall not reduce the actual height of the fabric by more than  $\frac{1}{16}$  in./ft (5.2 mm/m) of height or by more than  $\frac{1}{2}$  in. (12.7 mm), whichever is less.

## 19. Field Sampling and Number of Tests

19.1 The purchaser may select at random one roll from every 50 rolls or fraction thereof for test purposes, except in no case shall fewer than two rolls be sampled.

19.2 Sample rolls thus selected shall be checked for weave (Section 7), size of mesh (Section 8), diamond count (Section 9), wire size (Section 10), height of fabric (Section 11), selvage (Section 12), and length (Section 18).



19.3 Test specimens taken from the outside end of the sample rolls shall be tested for breaking strength (Section 13), weight of zinc, aluminum, or zinc-5 % aluminum-mischmetal alloy coating (Section 14), and thickness of polymer coating (Section 15).

19.4 If any specimen tested fails to conform to the specified requirements, the roll represented by the specimen shall be rejected and two additional rolls shall be tested, both of which shall meet the requirements in every respect; otherwise the lot represented by the samples may be rejected.

19.5 Unless otherwise stipulated by the purchaser, tests for breaking strength (Section 13), weight of zinc, aluminum, or zinc-5 % aluminum-mischmetal alloy coating (Section 14), thickness of polymer coating (Section 15), and properties of polymer-coated wire (Section 16) made on the wire prior to weaving may be substituted for tests made on the wire from the finished fabric.

## 20. Inspection

20.1 The seller is responsible for the performance of all inspection and test requirements as specified herein. The seller may use his own or other suitable facilities for inspection and testing unless the purchaser does not approve at the time the order is placed. Purchaser has the right to make any of the inspection and tests outlined where such are deemed necessary.

## 21. Certification and Reports

21.1 Upon the request of the purchaser in the contract or order, a manufacturer's certification that the material was produced in accordance with the specification shall be furnished.

## 22. Packaging, Marking, and Loading for Shipment

22.1 Each length of fabric shall be tightly rolled and firmly tied. Each shipment of fabric shall be identified as to the class of polymer coating, the color, the size of mesh, the finished outside size of the wire, the height and length of fabric in each roll, ASTM Designation F 668, and the name or mark of the manufacturer. These requirements apply unless otherwise specified.

22.2 When specified in the contract or order, and for direct procurement by or direct shipment to the U. S. government, when Level A is specified, preservation, packaging, and packing shall be in accordance with the Level A requirements of MIL-STD-163.

22.3 When specified in the contract or order, and for direct procurement by or direct shipment to the U. S. government, marking for shipment, in addition to requirements specified in the contract or order, shall be in accordance with MIL-STD-129 for U. S. military agencies and in accordance with Fed. Std. No. 123 for U. S. government civil agencies.

## 23. Keywords

23.1 chain-link fence, steel; coatings, polyvinyl chloride (PVC); fence/fencing materials, chain-link; organic polymer coating; organic polymer-coated chain-link fabric; organic polymers; polyvinyl chloride (PVC) coated chain link fence fabric; polyvinyl chloride (PVC) coating on iron and steel articles; polyvinyl chloride (PVC) plastics

## APPENDIX

### (Nonmandatory Information)

### X1. METRIC EQUIVALENTS

**TABLE X1.1 Approximate Metric Equivalents for Tables 2 and 3**

Size of Wire and Mesh, in. (mm)	Height of Fence Fabric, in. (mm)
Wire	
0.192 (4.88)	36 (910)
0.148 (3.76)	42 (1070)
0.120 (3.05)	48 (1220)
0.105 (2.67)	60 (1520)
0.080 (2.03)	72 (1830)
	84 (2130)
	96 (2440)
Mesh	
3/8 (10)	108 (2740)
1/2 (13)	120 (3050)
5/8 (16)	144 (3660)
1 (25)	
1 1/4 (44)	
2 (50)	
2 1/8 (54)	

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# Standard Specification for Industrial and Commercial Swing Gates<sup>1</sup>

This standard is issued under the fixed designation F 900; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon ( $\epsilon$ ) indicates an editorial change since the last revision or reapproval.

## 1. Scope

1.1 This specification covers detailed requirements for chain link fence gates, gate posts and accessories for both single and double swing-type gates for industrial and commercial application.

## 2. Referenced Documents

### 2.1 ASTM Standards:

A 780 Practice for Repair of Damaged and Uncoated Areas of Hot-Dip Galvanized Coatings<sup>2</sup>

F 1043 Specification for Strength and Protective Coatings on Metal Industrial Chain Link Fence Framework<sup>2</sup>

F 1083 Specification for Pipe, Steel, Hot-Dipped Zinc-Coated (Galvanized) Welded, for Fence Structures<sup>2</sup>

## 3. Terminology

### 3.1 Definitions of Terms Specific to This Standard:

3.1.1 *polymer*—in this specification, polymer is used to describe all types of vinyl, poly(vinyl-chloride) (PVC) or similar types of coatings other than zinc or aluminum.

## 4. Materials and Manufacture

4.1 *Materials*—The base materials of the gate frame shall be round or rectangular tubular members, welded at all corners or assembled with corner fittings. Gates assembled with corner fittings shall have adjustable truss rods  $\frac{5}{16}$  in. [7.9 mm] minimum diameter on panels 5 ft [1.5 m] wide or wider. Truss rods shall be the same base metal and finish as the gate frames.

4.1.1 The interior bracing, when needed, shall be the same metal and shape tubular material and finish as the gate frame, but need not be the same size.

4.2 *Manufacture*—Gate frames shall be fabricated and coated where necessary, as described in 4.2.1 through 4.2.3.

4.2.1 *Zinc-Coated Steel Frames* shall be in accordance with Specifications F 1043 or F 1083, or a combination thereof, and shall match that selected for any adjoining fence framework. Welded joints shall be coated in accordance with Practice A 780, employing a zinc-rich paint conforming to 4.2.2 of

Practice A 780 and following only the procedures outlined in A2.1.3 and A2.1.4 of Practice A 780.

4.2.2 *Aluminum Alloy Gate Frames* shall be in accordance with Specification F 1043.

4.2.3 *Polymer-Coated Steel or Polymer-Coated Aluminum Frames* shall be in accordance with Specification F 1043 and shall match that selected for any adjoining fence framework. Welded joints on steel gate frames shall be coated in accordance with Practice A 780, employing a zinc-rich paint conforming to 4.2.2 of Practice A 780 and following only the procedures outlined in A2.1.3 and A2.1.4 of Practice A 780. The painted areas shall then be top-coated to match the frame color.

4.2.4 *Chain Link Gate Fabric*—The fabric shall be as specified for the fence.

4.2.5 *Barbed Wire Top*—When specified, shall have the end members of the gate frame extended in height to accommodate three strands of barbed wire uniformly spaced and positioned so that the top strand is approximately 1 ft [300 mm] above the top horizontal member of the gate frame. Barbed wire shall be attached by suitable means to prevent wire from moving out of position and shall be supported by a gate frame member at maximum intervals of 8 ft.

## 5. Dimensions, Mass, and Permissible Variations

5.1 Size of the gate opening shall be measured from the inside face to inside face of gate posts.

5.2 Dimensions and weights of gate frame members shall be in accordance with Table 1.

5.2.1 Gate frame shall be designed for the width built so that the outer member shall not sag in excess of the lesser of 1 % of the gate leaf width or 2 in. [50.8 mm].

5.2.2 For dimensions and weight of gate posts, see Table 2.

## 6. Gate Accessories

6.1 All gate hardware shall be of sufficient strength and durability to support the gate and repeated open-close cycles.

6.2 *Gate Hinges*—Hinges shall be structurally capable of supporting the gate leaf and allow the gate to open and close without binding. The hinges shall be so designed to permit the gate to swing a full 180°. The user shall specify, one of the following directions of swing:

6.2.1 180° outward,

6.2.2 180° inward,

<sup>1</sup> This specification is under the jurisdiction of ASTM Committee F14 on Fences and is the direct responsibility of Subcommittee F14.40 on Chain Link Fence and Wire Accessories.

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<sup>2</sup> *Annual Book of ASTM Standards*, Vol 01.06.

**TABLE 1 Gate Frame Members, Dimensions, and Weights**

NOTE—Gate leaf shall have vertical interior bracing at maximum intervals of 8 ft and shall have a horizontal interior member if fabric height is 8 ft or more. Additional horizontal, vertical or diagonal member or diagonal truss rods may be needed to comply with requirements of 5.2.1.

Gate Fabric Height	Outside Dimensions, in. [mm]	Minimum Weight, lb/ft [kg/m]
6 ft [1.8 m] or Less:		
Round tubular (steel)	1.66 [42.2]	1.83 [2.72]
Rectangular tubular (steel)	1.50 [38.1]	1.84 [2.74]
Round tubular (aluminum)	1.90 [48.3]	0.91 [1.35]
Rectangular tubular (aluminum)	2.00 [50.8]	0.91 [1.35]
Over 6 ft [1.8 m]:		
Round tubular (steel)	1.90 [48.3]	2.28 [3.39]
Rectangular tubular (steel)	2.00 [50.8]	2.52 [3.75]
Round tubular (aluminum)	1.90 [48.3]	0.91 [1.35]
Rectangular tubular (aluminum)	2.00 [50.8]	0.91 [1.35]
Interior Bracing:		
Round pipe (steel)	1.66 [42.2]	1.83 [3.39]
Rectangular pipe (steel)	1.50 [38.1]	1.84 [2.74]
Round tubular (aluminum)	1.90 [48.3]	0.91 [1.35]
Rectangular tubular (aluminum)	2.00 [50.8]	0.91 [1.35]

**TABLE 2 Dimensions and Weight of Gate Posts**

NOTE—All gate posts shall be of sufficient strength so that the total deflection of the gate frame and the gate post at the end of the gate leaf shall not exceed the lesser of 2 % of the gate leaf width or 4 in. When necessary to meet this requirement due to the total weight of the gate leaf the next larger size post listed in Table 2 shall be used.

Gate Leaf Width		Outside Diameter of Pipe, in. [mm]	Minimum Weight, lb/ft [kg/m]
For Gate Fabric Height of 6 ft [1.8 m] or less:			
Up to and including 4 ft. [1.2 m]	Steel	2.375 [60.3]	3.11 [4.63]
	Aluminum	2.375 [60.3]	1.22 [1.81]
Over 4 to 10 ft [1.2 to 3.7 m]	Steel	2.875 [73.0]	4.64 [6.91]
	Aluminum	2.875 [73.0]	1.94 [2.89]
Over 10 to 18 ft [3.7 to 5.5 m]	Steel	4.000 [101.6]	8.65 [12.88]
	Aluminum	4.000 [101.6]	2.99 [4.45]
For Gate Fabric Height Over 6 ft [1.8 m]:			
Up to and including 6 ft [1.8 m]	Steel	2.875 [73.0]	4.64 [7.04]
	Aluminum	2.875 [73.0]	1.94 [2.89]
Over 6 to 12 ft [1.8 to 3.7]	Steel	4.000 [101.6]	8.65 [12.88]
	Aluminum	4.000 [101.6]	2.99 [4.45]
Over 12 to 18 ft [3.7 to 5.5 m]	Steel	6.625 [168.3]	18.02 [26.82]
Over 18 to 24 ft [5.5 to 7.3 m]	Steel	8.625 [219.1]	27.12 [40.36]

### 6.2.3 90° in and out.

6.3 *Single Gate Latch*—This latch shall be capable of retaining the gate in a closed position and shall have provision for a padlock.

6.4 *Double Gate Latch*—This latch shall be a drop rod or plunger bar arranged to engage the gate stop. Locking devices shall be constructed so that the center drop rod or plunger bar cannot be raised when the gate is locked. The latching devices shall have provision for a padlock.

6.5 *Gate Stops*— Gate stops shall be provided for all double gates and shall be suitable for setting in concrete for the center drop rod or plunger.

6.6 *Keepers*— Keepers shall be provided for each gate leaf over 5 ft [1.5 m] wide. Gate keepers shall consist of a mechanical device for securing the free end of the gate when in full open position.

## 7. Keywords

7.1 drop rod; gate leaf; hinges; keepers; latch; plunger; polymer; truss rods

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# Standard Specification for Standard Colors for Polymer-Coated Chain Link Fence Materials<sup>1</sup>

This standard is issued under the fixed designation F 934; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

## 1. Scope

1.1 This specification covers standard colors for coated chain link fence materials such as chain link fence fabric, tension wire, posts, rails, gate frames, and fittings.

## 2. Referenced Documents

### 2.1 ASTM Standards:

- D 1729 Practice for Visual Appraisal of Colors and Color Differences of Diffusely Illuminated Opaque Materials<sup>2</sup>
- D 2244 Test Method for Calculation of Color Tolerances and Color Differences from Instrumentally Measured Color Coordinates<sup>2</sup>
- G 90 Practice for Performing Accelerated Outdoor Weathering of Nonmetallic Materials Using Concentrated Natural Sunlight<sup>3</sup>

## 3. Color

3.1 Unless otherwise stipulated by the purchaser, determine the color in accordance with the standard contained in Table 1.

<sup>1</sup> This specification is under the jurisdiction of ASTM Committee F14 on Fences and is the direct responsibility of Subcommittee F14.40 on Chain Link Fence and Wire Accessories.

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<sup>2</sup> Annual Book of ASTM Standards, Vol 06.01.

<sup>3</sup> Annual Book of ASTM Standards, Vol 14.04.

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TABLE 1 Standard Polymer Colors

	Dark Green	Olive Green	Brown	Black
L	28.61	32.10	27.76	22.30
A	-12.59	-6.14	3.37	-0.09
B	1.95	3.00	4.28	-0.85
Delta/E	3.0	3.0	3.0	6.0

3.2 Determine compliance with this requirement by comparison of specimens of the coated materials to standard flat specimens of fused film of approximately the thickness specified for the coating to be applied to the materials, and measuring at least 1½ by 1½ in. [38 by 38 mm].

3.3 Prepare standard flat specimens for the evaluation of color coating by duplicating the production process as nearly as possible including temperature, particle size, etc.

3.4 Determine the color of the standard flat specimens in accordance with Test Method D 2244 and Practice D 1729.

3.5 Do not allow the color of the specimens to vary more than 6 Delta E when exposed to 500 000 Langleys accelerated weathering operated in accordance with Practice G 90 with both day and night spray cycles.



# Standard Specification for Rigid Poly (Vinyl Chloride) (PVC) Exterior Profiles Used for Fencing and Railing<sup>1</sup>

This standard is issued under the fixed designation F 964; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon ( $\epsilon$ ) indicates an editorial change since the last revision or reapproval.

## 1. Scope

1.1 This specification establishes requirements for the material properties and physical properties, including dimensional tolerances, extrusion quality, and weatherability, of rigid poly vinyl-chloride (PVC) exterior profiles used for agricultural, commercial, residential fencing and railing. Methods for testing and for identifying exterior profile extrusions that comply with this specification are also provided.

NOTE 1—Information with regard to application, assembly, and installation should be obtained from the manufacturer and/or per ASTM XXXX.

1.2 The material used in these exterior-profiles is limited to rigid poly (vinyl chloride) (PVC) compounds in a single homogeneous extrusion or in a coextrusion of two or more PVC compounds in distinct layers.

1.3 Color-hold guidelines are provided in an appendix for the manufacturer's product development and quality performance use.

1.4 The values stated in inch-pound units are to be regarded as the standard. The values in parentheses are provided for information only.

1.5 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

## 2. Referenced Documents

### 2.1 ASTM Standards:

- D 618 Practice for Conditioning Plastics for Testing<sup>2</sup>
- D 635 Test Method for Rate of Burning and/or Extent and Time of Burning of Self-Supporting Plastics in a Horizontal Position<sup>2</sup>
- D 696 Test Method for Coefficient of Linear Thermal Expansion of Plastics Between  $-30^{\circ}\text{C}$  and  $30^{\circ}\text{C}$ <sup>2</sup>
- D 883 Terminology Relating to Plastics<sup>2</sup>

<sup>1</sup> This specification is under the jurisdiction of ASTM Committee F14 on Fences and is the direct responsibility of Subcommittee F14.30 on Rigid Polymer Fence Systems.

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<sup>2</sup> *Annual Book of ASTM Standards*, Vol 08.01.

D 1435 Practice for Outdoor Weathering of Plastics<sup>2</sup>

D 1600 Terminology for Abbreviated Terms Relating to Plastics<sup>2</sup>

D 1784 Specification for Rigid Poly (Vinyl Chloride) (PVC) Compounds and Chlorinated Poly (Vinyl Chloride) (CPVC) Compounds<sup>2,3</sup>

D 1898 Practices for Sampling of Plastics<sup>2</sup>

D 2244 Test Method for Calculation of Color Differences From Instrumentally Measured Color Coordinates<sup>4</sup>

D 2444 Test Method for Determination of the Impact Resistance of Thermoplastic Pipe and Fittings by Means of a Tup (Falling Weight)<sup>3</sup>

D 4216 Specification for Rigid Poly Vinyl Chloride PVC and Related PVC and Chlorinated Poly Vinyl Chloride CPVC Building Products Compounds<sup>5</sup>

D 4226 Test Methods for Impact Resistance of Rigid Poly Vinyl Chloride PVC Building Products<sup>3</sup>

D 4726 Specification for White Rigid Poly (Vinyl Chloride) (PVC) Exterior-Profile Extrusions Used for Assembled Windows and Doors<sup>3</sup>

## 3. Terminology

3.1 General—Definitions are in accordance with Terminologies D 883 and D 1600, unless otherwise indicated.

### 3.2 Definitions of Terms Specific to This Standard:

3.2.1 *capstock*—the outer layer in a coextrusion exposed to weathering.

3.2.2 *coextrusion*—the process of coextruding profiles from two or more concentric streams of PVC compounds.

NOTE 2—Separate PVC materials may be coextruded to form a multi-layered profile with each layer having different physical characteristics such as strength and weathering.

3.2.3 *reworked material*—material from the manufacturer's facility of known, compatible composition meeting the material requirement of this specification that has been reground, pelletized, or solvated after having been previously processed by molding, extrusion, and so forth.

3.2.4 *single layer profile*—profiles extruded from a single PVC compound. Weathering and other physical characteristics

<sup>3</sup> *Annual Book of ASTM Standards*, Vol 08.04.

<sup>4</sup> *Annual Book of ASTM Standards*, Vol 06.01.

<sup>5</sup> *Annual Book of ASTM Standards*, Vol 08.02.



are uniform throughout the profile.

3.2.5 *substrate*—inner layer(s) of a coextrusion not exposed to weathering.

3.2.6 *temperate northern climate*—in weather testing, a North American metropolitan area testing site located within 73 to 100° W longitude and 37 to 45° N latitude.

3.2.7 *color-hold guidelines*—predictive target color regions within a three-dimensional model which constitute acceptable appearance retention levels of color change resulting from weathering of specific product type and color.

NOTE 3—Commercial products which demonstrate weathering behavior within reasonable conformance to these target guidelines during a 2-year test period can be anticipated to weather without exhibiting unacceptable color changes during the service life of the product.

#### 4. Significance and Use

4.1 The purpose of this specification is to establish a recognized standard of quality for rigid poly vinyl chloride (PVC) exterior profiles for use in assembling agricultural, commercial, and residential fencing and railing. The term “PVC fence” refers to complete fencing and railings systems in which the primary structural members such as posts, rails, spindles, pickets, and gates are made from PVC exterior profiles. Accessory components (not included in this specification), including bolts, screws, hinges, and latches, may be made from PVC and/or non-PVC materials. The information contained in this specification is intended to be helpful to producers, distributors, and users and to promote understanding between purchasers and sellers.

#### 5. Materials and Manufacture

5.1 The rigid poly vinyl chloride (PVC) compound for exterior-profile extrusions meeting the requirements of this specification are categorized by the cell class requirements in accordance with Specification D 4216.

5.2 The PVC compounds used for the products meeting this specification shall meet cell Class 1–10154–33–0000, Class 1–20131–13–0000, or Class 1–40131–13–0000 as defined in Specification D 4216. Compounds that have higher cell classification because one or more properties are superior to those in the specified compound are acceptable.

5.3 *Color*—The color of the profiles shall be as agreed upon between the purchaser and the seller. The color specified shall be uniform throughout a single material extrusion or throughout the capstock layer of a coextruded profile for profiles intended to be of uniform color.

5.4 The fence profiles shall be free from visible cracks, holes, foreign inclusions, or other defects.

5.5 The PVC compound, when tested in accordance with Test Method D 635, shall not exceed an average extent of burn of 4 in. (100 mm), with an average time of burn not to exceed 10 s. A sample thickness of  $0.090 \pm 0.009$  in. ( $2.3 \pm 0.2$  mm) shall be used.

NOTE 4—The flammability testing data, conclusions, and recommendations of Test Method D 635 relate solely to the measurement and description of the properties of materials, products, or systems in response to heat and flame under controlled laboratory conditions and should not be used for the description or appraisal of the fire hazard of materials, products, or systems under actual fire conditions.

NOTE 5—No recycled (post consumer waste) may be used in the production of fence profiles.

5.6 *Reworked Material*—Clean reworked material may be used, provided that the fence profiles produced in whole or in part from the reworked materials meet all of the requirements of this specification.

5.7 The PVC compound in extruded section shall maintain uniform color and be free of any visual surface or structural changes, such as peeling, chipping, cracking, flaking, or pitting after weathering for six months and one year for white and for six months, one year, and two years for all other colors in hot, dry climate such as Phoenix, AZ; a hot humid climate, such as Miami, FL; and a temperate northern climate, when tested in accordance with 7.1.1-7.1.4.

5.8 The PVC compound shall have a minimum impact resistance of 0.6 in.-lb/mil (2670 J/m) after weathering six months and one year in a hot, dry climate such as Phoenix, AZ; a hot, humid climate, such as Miami, FL; and a temperate northern climate, when tested in accordance with 7.1.1-7.1.4.

5.9 The PVC compound shall have successfully met the weathering requirements prescribed in 5.7 and 5.8 for six months at each climatic testing site prior to use in production of exterior-profile extrusions, when tested in accordance with 7.1.1-7.1.4.

NOTE 6—The six-month test requirement constitutes a screening process to eliminate catastrophic failure.

#### 6. Physical Requirements

6.1 *Length, Height, and Width*—The specified length, height, and width of the fencing profiles shall be as agreed upon between the purchaser and the seller, or by established internal process control standards. The actual length shall be within  $\pm 1/4$  in. (6.4 mm) of the specified length and the actual height and width shall be within  $1/16$  in. (1.6 mm) of the specified height and width when measured in accordance with 8.4 and 8.5.

6.2 *Weight Tolerance*—Profile extrusion weight shall not be more than 10 % below the specified profile weight indicated in the manufacturer’s specifications.

##### 6.3 Impact Resistance

6.3.1 Round or rectangular profiles with exterior walls of uniform thickness and without internal webs shall be tested in accordance with Test Method D 2444. These profiles will have a minimum impact failure value of 0.75 ft-lbf/mil (40,050 J/m) of thickness of the wall when tested at 32°F (0°C) and 1.5 ft-lbf/mil (80,050 J/m) when tested at 73.4°F (23°C) when tested in accordance with the apparatus section of Test Method D 2444, using the “B” tup and flat plate Holder “B.” The minimum wall thickness for the profile shall determine the required impact level when tested in accordance with 8.6.

6.3.2 All other profiles are to be tested in accordance with test method D 4226, Procedure “B,” using impactor C.125. Flat sections of the profile extrusion shall have a minimum brittle impact failure of 1.2 in. lb/mil (5340 J/m).

6.4 *Warp*—The maximum allowable warp shall be 0.5 % of the length of the fence profile when determined in accordance with 8.7.

6.5 *Dimensional Stability*—The dimensional stability of the profile extrusions shall be determined in accordance with 8.9.



Extrusions shall have a maximum average shrinkage of 2.4 % for all sides measured, with no single value exceeding 3 %.

NOTE 7—Expansion and contraction of the fence profile lengths must be taken in consideration in the design of the fencing system.

6.6 *Coefficient of Linear Expansion*—The fencing profiles shall have a coefficient of linear expansion not greater than  $4.4 \times 10^{-5}$  in./in. · °F ( $7.9 \times 10^{-5}$  mm/mm · °C) when tested in accordance with Test Method D 696.

NOTE 8—Expansion and contraction of the fence profile lengths must be taken in consideration in the design of the fencing system.

6.7 *Thickness of PVC Capstock*—PVC fence profiles produced by coextrusion, which contain two or more layers, shall have an outer layer (capstock) that is no less than 0.015 in. (0.38 mm) thick at any point and that does not exceed 20 % of the total wall thickness at any point.

6.8 *Bond*—For PVC profiles produced by coextrusion, the bond between the layers shall be strong and uniform. It shall not be possible to separate any two layers with a probe or point of a knife blade so that the layers separate at any point.

## 7. Performance Requirements

### 7.1 Weathering

7.1.1 The exposures listed in Table 1 shall be conducted in order to meet the requirements of this specification. All exposures shall be conducted at an angle of 45 degrees South, plywood backed, in accordance with Practice D 1435.

7.1.2 After six months and one year exposure times, the minimum mean impact for 20 measurements conducted on the exposed specimens shall be at least 0.6 in. lb/mil (2670 J/m) in accordance with 8.6 or 8.9 respectively.

7.1.3 After each exposure time, the tested specimens shall maintain a uniform color and be free of any visual surface or structural changes such as peeling, chipping, cracking, flaking, and pitting when tested in accordance with Appendix X1.

NOTE 9—It is recommended that manufacturers utilize the color-hold guidelines in Appendix X1 of D 4726 to ensure quality performance.

7.1.4 Weatherability conformance testing requirements are to reflect performance of a “typical” extrusion system profile representing a specific PVC compound and a specific extrusion technology. In no case is there an implied requirement for testing all the various shaped profiles. The profile extrusion producer shall immediately respond in terms of compound change or extrusion technology change to unsatisfactory weatherability behavior of the profiles under test in any climatic test site at any stage of the weatherability testing.

## 8. Test Methods

8.1 *General*—The inspection and test procedures contained

**TABLE 1 Required Exposures for PVC Extrusions**

Color of PVC Extrusions	Exposure Climate	Required Exposure Times, months <sup>A</sup>
White	hot, dry (Phoenix, AZ)	6 and 12
	hot, humid (Miami, FL)	6 and 12
	northern temperate	6 and 12
Any other color	hot, dry (Phoenix, AZ)	6, 12 and 24
	hot, humid (Miami, FL)	6, 12 and 24
	northern temperate	6, 12 and 24

<sup>A</sup>It is recommended that separate specimens be used for each exposure time.

in this section are used to determine the conformance of products to the requirements of this specification. Each producer who represents his products as conforming to this specification may utilize statistically based sampling plans that are appropriate for each manufacturing process. The producer shall keep the essential records necessary to document with a high degree of assurance his claim that all the requirements of this specification have been met. Additional sampling and testing of the products, as may be agreed upon between the purchaser and the seller at the time of the execution of the sales agreement, are not precluded by this section.

### 8.2 Conditioning and Test Conditions:

8.2.1 Specimens to be tested at  $73.4^\circ \pm 3.6^\circ\text{F}$  ( $23^\circ \pm 2^\circ\text{C}$ ) shall be conditioned in accordance with Practice D 618 for no less than one hour. Specimens to be tested at  $32^\circ \pm 3.6^\circ\text{F}$  ( $0^\circ \pm 2^\circ\text{C}$ ) shall be conditioned in accordance with Practice D 618 for no less than one hour.

8.3 *Sampling*—The selection of sample or samples of fence profiles shall be as agreed upon between the purchaser and the seller. In the absence of any prior agreement, the selection of sample or samples of fence shall be in accordance with the pertinent considerations outlined in Practices D 1898.

8.3.1 *Sample Marking*—Samples being tested at a test laboratory, not at the manufacturer’s location, shall be marked with a verifiable and permanent marking that shall identify the manufacturer.

8.3.2 The number of specimens or the size of the specimen must be sufficient to obtain 20 impact locations of the dropped dart for each weathering interval.

8.3.3 The thickness of any profile tested must not differ from the manufacturer’s published specification of the same profile.

8.4 *Length*—With the sample lying on a flat surface, measure the length to the nearest  $\frac{1}{16}$  in. (1.5 mm) with a steel tape. The average of three samples shall be within  $\pm \frac{1}{4}$  in. (6.3 mm) of the published length with no single sample deviating more than  $\frac{3}{8}$  in. (9.5 mm) from the nominal length.

8.5 *Height and Width*—Lay three samples on a flat surface and measure each to the nearest  $\frac{1}{16}$  in. (1.5 mm) with a steel tape or vernier calipers. The average of the three samples shall be within  $\pm \frac{1}{16}$  in. (1.5 mm) of the nominal height and width with no single sample deviating more than  $\frac{3}{32}$  in. (2.4 mm) from the nominal height and width.

8.6 *Impact Resistance*—Condition ten specimens, not less than 6 in. long ( $152 \pm 1.5$  mm), at either  $73.4^\circ \pm 3.6^\circ\text{F}$  ( $23^\circ \pm 2^\circ\text{C}$ ) or  $32^\circ \pm 3.6^\circ\text{F}$  ( $0^\circ \pm 2^\circ\text{C}$ ) and test with the apparatus described in Test Method D 2444, using a “B” tup and a “B” flat plate holder to the values in 6.3. Seven of ten specimens must pass at whichever test conditioning temperature is used. Specimens shall be temperature conditioned in accordance with 8.2. Any visible cracking, shattering, or breaking shall constitute a failure.

8.6.1 *Retest*—Should more than three specimens fail the initial impact test, select and condition ten more samples and test in accordance with 8.6. If 14 or more samples pass from the combined two samplings, the last shall pass. If seven or more specimens fail, sampling and testing should be conducted backward through the production run until it can be established

that the balance of the production run will pass impact testing.

8.7 *Warp*—Warp should be determined when all sides of the specimen are at the same temperature. Place a full-length specimen on a flat surface alongside a straightedge that is at least as long as the specimen. Measure any space between the specimen and the straightedge to the nearest  $\frac{1}{16}$  in. (1.5 mm).

NOTE 10—Testing in accordance with Section 8 is intended to be done as quality control testing at the time of manufacture to ensure conformance with this specification. Testing performed on profiles after prolonged storage, shipment, or installation may produce results at variance with the values determined at the time of manufacture.

8.8 *Dimensional Stability*—Determine the dimensional stability in accordance with Test Method D 1042, except that the test cycle shall consist of heating the specimens for 30 min in a uniformly heated water bath at a temperature of  $180^{\circ} \pm 1.8^{\circ}\text{F}$  ( $82^{\circ} \pm 1.0^{\circ}\text{C}$ ), then conditioning the specimens for no less than 1 h in accordance with Procedure A of Practice D 618, followed by measurement.

8.9 *Impact Test on Weathered Specimens*—Determine the impact strength in accordance with Test Method D 4226, Procedure B, using the C.125 impactor.

## 9. Retest and Rejection

9.1 If the results of any test(s) do not meet the requirements of this specification, the test(s) may be conducted again in accordance with an agreement between the purchaser and the seller. There shall be no agreement to lower the minimum requirement of the specification by such means as omitting tests that are a part of the specification, substituting or modifying a test method, or by changing the specification limits. In retesting, the product requirements of this specification shall be met, and the test methods designated in this specification shall be followed. If, upon retest, failure occurs, the quantity of product represented by the test(s) shall be rejected.

## 10. Accessories Tests

10.1 Test methods and values for all PVC profile accessories, such as caps, plugs, and rail mounting devices, may or may not be available for the manufacturer and are subject to agreement between the purchaser and the seller.

## 11. Marking of Fence Profiles

11.1 Permanent marking of the fence profiles and accessories are at the option of the manufacturer or subject to agreement between the purchaser and the manufacturer.

11.1.1 Marking, if used, may be in the form of ink printing, decals, or embossing and may be applied internally or externally to the fence profiles. If applied to the external surface of the profile, the marking shall not mar or detract from the appearance of the fence profile.

11.1.2 Injection-molded or fabricated parts may include the manufacturer's name or symbol.

11.1.3 Marking, if used, should include the manufacturer's name and location, code or date of manufacture, and ASTM F 964.

## 12. Marking of Literature and Packaging

12.1 In order that the purchaser may identify PVC fencing profiles that conform to all requirements of this specification, producers and distributors shall include a statement of compliance in conjunction with their name and address on product labels, invoices, sales literature, and the like. The following statement is suggested (not mandatory) when sufficient space is available: "These fencing profiles conform to all of the requirements established in ASTM F 964, developed cooperatively with the industry and published by the American Society for Testing and Materials. Full responsibility for the conformance of this product to the specifications assumed by (name and address of producer or distributor)."

12.2 The following abbreviated statement is suggested when available space on labels or other printed matter is insufficient for the full statement: "Conforms to ASTM. (name and address of producer or distributor)."

12.3 The PVC acronym should be specified for recyclable information.

## 13. Keywords

13.1 capstock; coextrusion; exterior-profile; fencing profiles; poly vinyl chloride; PVC fence

# APPENDICES

## (Nonmandatory Information)

### X1. WEATHERABILITY

X1.1 Weatherability of PVC fence profiles is an important but highly subjective property. Absolute values for weatherability are difficult to assign and weatherability properties are almost always comparative in nature.

X1.2 Laboratory-accelerated weathering methods are available but cannot be equated successfully with outdoor weathering. These tests are valuable aids for process control evaluations and compound development studies but should never be

used for qualification testing purposes.

X1.3 Each manufacturer should establish a practice for qualification testing for PVC compounds in accordance with Practice D 1435 using outdoor weathering panels facing south, angled upward at  $45^{\circ}$ . A practice for laboratory-accelerated ultraviolet testing may also be established for process control testing purposes.

X1.4 A suggested natural weathering program would be as follows:

X1.4.1 Expose extruded specimens of at least 36 in.<sup>2</sup>(914.4 mm<sup>2</sup>) to three widely different climatic areas such as Phoenix, AZ; Miami, FL; and a temperate northern climate sited in the United States. Unexposed samples should be kept for comparison and small strips on the exposure specimens should be shielded for comparison. Changes shall be evaluated at six months and one year aging periods. It is recommended that the exposure of specimens at each climatic site be continued for the warranty period of the product.

X1.5 Laboratory-accelerated ultraviolet testing may be done in commercial equipment provided with ultraviolet light

and humidity controls for process control or development studies. It should always be conducted in conjunction with outdoor weathering studies since no correlation between the two practices has been established.

X1.6 Weathering samples should change color only slightly and uniformly. White PVC will tend to yellow but should not streak or turn brown under exposure in the natural weathering tests.

X1.7 When weatherability testing is conducted without the use of an accelerator (UV cabinet), make exposures in accordance with Practice D 1435.

## **X2. INSTALLATION**

X2.1 This specification is for material performance and purchase specifications only and does not include requirements for engineering designs, climatic changes, and soil conditions or the relationship between soil conditions and the strength or stability of installed posts. However, experience has shown that successful performance of fencing systems, in regard to the posts, depends on soil conditions and care taken in the installation work. The purchaser of the fence profiles specified herein is cautioned that he must properly correlate the field conditions with the fence profile requirements and provide adequate inspection at the job site.

X2.2 PVC fence profile installations will differ from region to region based on climatic conditions, animals to be confined,

and soil conditions. Professional fence installers in their respective locations should be consulted for each individual application.

X2.3 *Manufacturer's Installation Instructions*—Manufacturers shall provide general installation instruction recommendations and may include specific instructions. These are to be used to assist and aid installation, but they should not be considered to be all inclusive. Where recommendations of the installer differ from the manufacturer's printed instructions, consult with the manufacturer before installing fence profiles contrary to the manufacturer's printed recommendations and instructions.

## **X3. SUGGESTED MANUFACTURER'S QUALITY ASSURANCE PROGRAM**

X3.1 Each manufacturer should establish a formal and written procedure for an ongoing quality assurance program. Records of quality assurance tests should be retained for a minimum of two to five years for the benefit of both the customer and the manufacturer.

X3.2 *In-plant Test Frequencies*—Certain tests described in this specification should be done on a qualification basis while others should be performed on a daily basis:

X3.2.1 Cell classification tests should be performed at the initiation of production of fence profiles, when any changes are made in the formulations of the PVC materials, when compounding equipment is replaced or modified, or at least once annually for each material or coextruded materials.

X3.2.2 Coefficient of expansion tests should be performed at the initiation of production of profiles, at the initiation of a

new compound, or when significant changes in filler levels are made in a compound.

X3.2.3 Dimensional tests should be made at the startup of a production run and every 2 h thereafter.

X3.2.4 Flattening, extrusion quality, impact resistance, warp, color comparison with standard color samples, capstock thickness, and bond testing should be done at the startup of a production and once per shift thereafter with a minimum of two tests per 24 h of production.

X3.2.5 Artificial weathering tests should be performed for any new compound or when formulation changes are made in existing compounds. Production from a new or modified compound should be withheld until the samples have successfully passed 30 days of artificial weathering.



## F 964

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# Standard Practice for Construction of Chain-Link Tennis Court Fence<sup>1</sup>

This standard is issued under the fixed designation F 969; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon ( $\epsilon$ ) indicates an editorial change since the last revision or reapproval.

## 1. Scope

1.1 This practice covers fencing around tennis courts, built from various types of chain-link fabric and framework materials, and installation practices for same.

1.2 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

## 2. Referenced Documents

### 2.1 ASTM Standards:

- A 392 Specification for Zinc-Coated Steel Chain-Link Fence Fabric<sup>2</sup>
- A 491 Specification for Aluminum-Coated Steel Chain-Link Fence Fabric<sup>2</sup>
- A 824 Specification for Metallic-Coated Steel Marcellled Tension Wire for Use with Chain-Link Fence<sup>2</sup>
- F 552 Definitions of Terms Relating to Chain Link Fencing<sup>2</sup>
- F 567 Practice for Installation of Chain-Link Fence<sup>2</sup>
- F 626 Specification for Fence Fittings<sup>2</sup>
- F 668 Specification for Poly(Vinyl Chloride) (PVC) and Other Organic Polymer-Coated Steel Chain-Link Fence Fabric<sup>2</sup>
- F 900 Specification for Industrial and Commercial Swing Gates<sup>2</sup>
- F 934 Specification for Standard Colors for Polymer-Coated Chain Link Fence Materials<sup>2</sup>
- F 1043 Specification for Strength and Protective Coatings on Metal Industrial Chain Link Framework<sup>2</sup>
- F 1083 Specification for Pipe, Steel, Hot-Dipped Zinc Coated (Galvanized) Welded for Fence Structures<sup>2</sup>
- F 1345 Specification for Zinc-5% Aluminum-Mischmetal Alloy-Coated Steel Chain-Link Fence Fabric<sup>2</sup>
- F 1664 Specification for Poly(Vinyl Chloride) (PVC) and Other Conforming Organic Polymer-Coated Steel Tension

## Wire Used with Chain-Link Fence<sup>2</sup>

## 3. Terminology

3.1 Definitions—See Definitions F 552 for definitions of terms used in this practice.

## 4. Summary of Practice

4.1 This practice is intended primarily to guide those responsible for or concerned with the design and installation of chain-link fencing around tennis courts.

4.2 This practice does not intend to preclude any practice that has proven equal to or given better performance under varying conditions such as location, weather, intended use, etc.

## 5. Significance and Use

5.1 The intended use of this practice is for 10- or 12-ft (3050 or 3660 mm) high chain-link fencing as complete enclosures around single or multiple tennis courts, or as backstops at either end of tennis courts.

5.2 This practice is not intended for applications where fencing higher than 12 ft (3660 mm) is desired for a special application.

5.3 *Caution Regarding Windscreens*— If wind screens are to be installed at the time of fence erection or at a later time, it is advisable to use stronger framework and parts and closer spacing of posts or back bracing depending upon the type of screening material to be used, area of fence to be covered, and local wind conditions.

## 6. Classification

6.1 The four types of chain-link fencing described in this practice are classified as follows:

6.1.1 *Type I*—Built with aluminum-coated steel chain-link fence fabric as specified in Specification A 491.

6.1.2 *Type II*—Built with zinc-coated steel chain-link fence fabric as specified in Specification A 392, Class 1 coating only.

6.1.3 *Type III*—Built with zinc-5% aluminum-mischmetal alloy-coated steel chain-link fence fabric as specified in Specification F 1345, in a choice of Class 1 or Class 2 coating, as selected.

<sup>1</sup> This practice is under the jurisdiction of ASTM Committee F14 on Fences and is the direct responsibility of Subcommittee F14.10 on Specific Applications.

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<sup>2</sup> *Annual Book of ASTM Standards*, Vol 01.06.

6.1.4 *Type IV*—Built with polymer-coated steel chain-link fence fabric as specified in Specification F 668, in a choice of Class 1, Class 2a, or Class 2b coating, as selected.

## 7. Ordering Information

7.1 Purchase orders, construction specifications, or detailed drawings should include the following information:

7.1.1 Quantity or total measurements in lineal feet of fence and gates.

7.1.2 Type of fence (Type I, II, III or IV) (see 6.1).

7.1.3 Class of fence if Type III (Class 1 or 2) (see 6.1.3).

7.1.4 Class of fence if Type IV (Class 1, 2a, or 2b) (see 6.1.4) and color (see 8.1.2)

7.1.5 If framework, fittings and gates are to be color coated, select color from Specification F 934.

7.1.6 Height of fence (10 or 12 ft [3050 or 3660 mm]).

7.1.7 Number of horizontal rails and location.

7.1.8 Bottom tension wire, if specified.

7.1.9 Depth and diameter of concrete post footings, if other than as indicated in Practice F 567.

7.1.10 Spacing of line posts, if other than as indicated in Practice F 567.

7.1.11 Any details peculiar to the project, such as special finishing of tops of concrete post footings, setting of posts in concrete curbs, etc. (see 9.2.2 and 9.2.3).

NOTE 1—A typical ordering description is as follows: 360 lineal ft (109.7 m) chain-link tennis court fence to make a full enclosure 60 by 120 ft (18.3 by 36.6 m) with 3 ft (914 mm) gate at one corner, Type I, 12 ft (3660 mm) high, 3 horizontal rails (top, middle, and bottom), furnished and erected as shown on the enclosed drawing, and in accordance with ASTM F 969.

7.2 A detailed drawing or drawings showing the complete layout of the fence line, together with typical elevations, details of pavement around post footings, etc., should be a part of the purchase order or construction contract.

## 8. Materials

### 8.1 Chain-Link Fabric:

8.1.1 If Type III is selected, indicate whether Class 1 or 2 is desired.

8.1.2 If Type IV is selected, indicate whether Class 1, 2a, or 2b is desired, and select color of fabric coating in accordance with Specification F 934.

8.1.3 Size of wire shall be 0.120 in. (3.05 mm) 11 gage. If Type IV is selected, this shall be the size of the metallic-coated core wire.

8.1.4 Size of fabric mesh shall be 1¾ in. (44 mm).

8.1.5 Height of fabric shall be 10 or 12 ft (3050 or 3660 mm), as selected.

8.1.6 Fabric selvage shall be knuckled top and bottom.

### 8.2 Posts:

8.2.1 Posts shall be as selected from Specifications F 1043 and F 1083. If polymer-coated, specify type of coating and color.

8.2.2 The posts shall not be splice-welded.

### 8.3 Horizontal Rails:

8.3.1 Horizontal rails shall be as selected from Specifications F 1043 and F 1083. If polymer-coated, specify type of coating and color.

8.3.2 All fences shall have a top rail. Fences 12 ft (3660 mm) in height shall have a continuous middle rail. Additional rails at mid-points or at the bottom of the fence may be specified.

### 8.4 Bottom Tension Wire:

8.4.1 Bottom tension wire shall be used except where continuous bottom rail is specified.

8.4.2 Bottom tension wire shall be in accordance with Specification A 824 for metallic coated chain link fabric and Specification F 1664 for polymer-coated chain link fabric.

### 8.5 Fittings:

8.5.1 All fittings shall conform to Specification F 626. If Type IV fabric is selected and polymer-coated posts and rails are also selected, all fittings shall be polymer coated as specified in Specification F 626, Section 11.

### 8.6 Gates:

8.6.1 All gates shall be fabricated in accordance with Specification F 900.

8.6.2 Minimum width of gate opening shall be 3 ft (914 mm).

8.6.3 All single walk gates shall be 7 ft (2133 mm) high with a transom panel above the gate extending to full height of the fence.

8.6.4 Gates shall have hinges to provide a full 180° swing from the closed to the open position.

8.6.5 Gate latch shall have provision for secure locking with a padlock.

8.6.6 Gate latch shall have a built-in provision to permit the gate to open outward only.

## 9. Installation

9.1 Lay out the fence lines as shown in Fig. 1, Fig. 2, or Fig. 3.

9.2 Installation shall be in accordance with Practice F 567 with the following additional provisions or exceptions:

9.2.1 Unless otherwise specified, the chain-link fabric shall be placed on the playing side of the fence enclosure or backstops.

9.2.2 If fence is installed in concrete curbs around the perimeter of the tennis court(s), provide sleeves in the curbs for this purpose, then set the posts as indicated in Practice F 567.

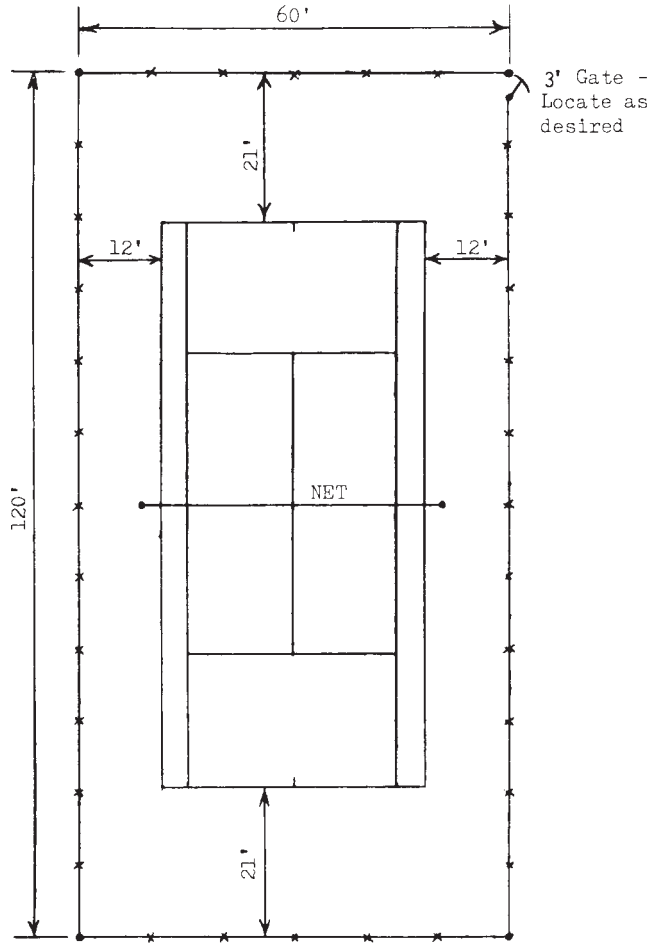
9.2.3 Since in most cases it is impractical to pave the courts after setting the posts, it becomes necessary to cut through the finished pavement and excavate the post holes. The contract specifications shall indicate whether the concrete footings around the posts should be brought up to finished grade and trowelled to a crown, or whether they should be left 2 in. (50 mm) below finished grade to allow for cover with black top as described in Practice F 567. If the latter method is selected, the contract specifications shall stipulate who is responsible for installing the black top cover over the footings.

9.2.4 Install chain-link fabrics with bottom 1 in. (25 mm) maximum above finished pavement.

9.2.5 Where bottom tension wire is used, it shall be attached to the bottom diamond of the chain-link fabric.

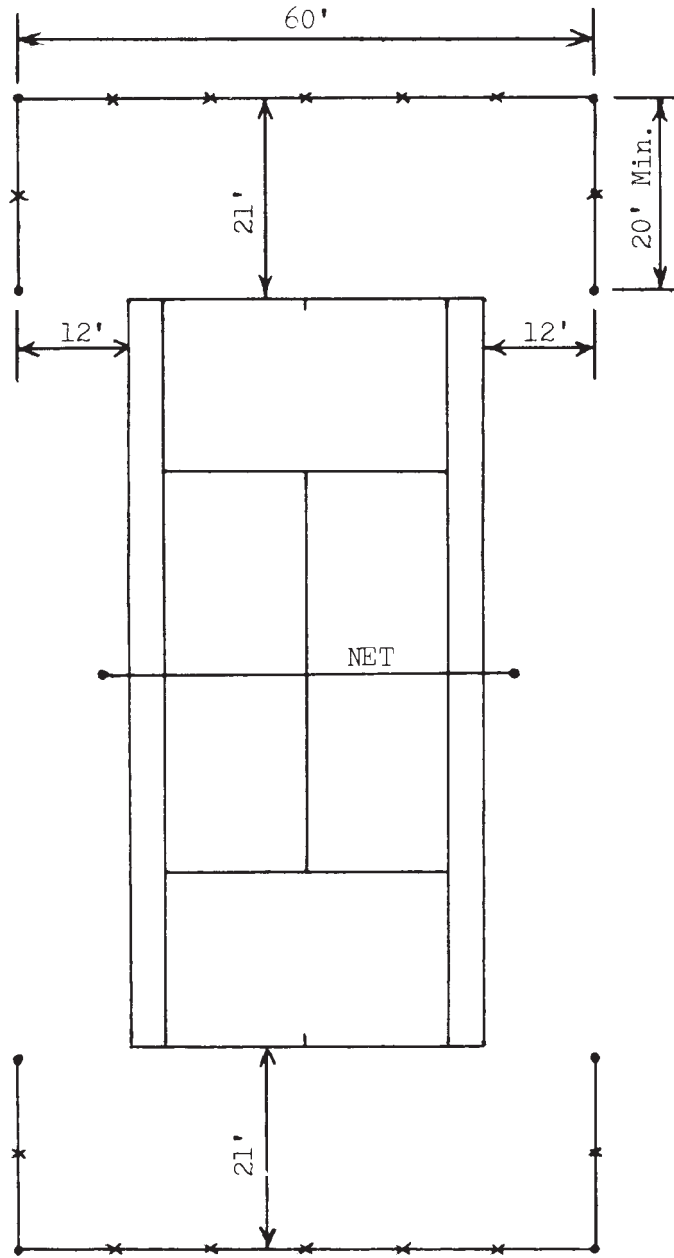
## 10. Keywords

10.1 tennis court fence; chain link; tension wire; bottom rail; 1¾ in. (44 mm) chain link mesh



NOTE—See Table 1 for SI equivalents.

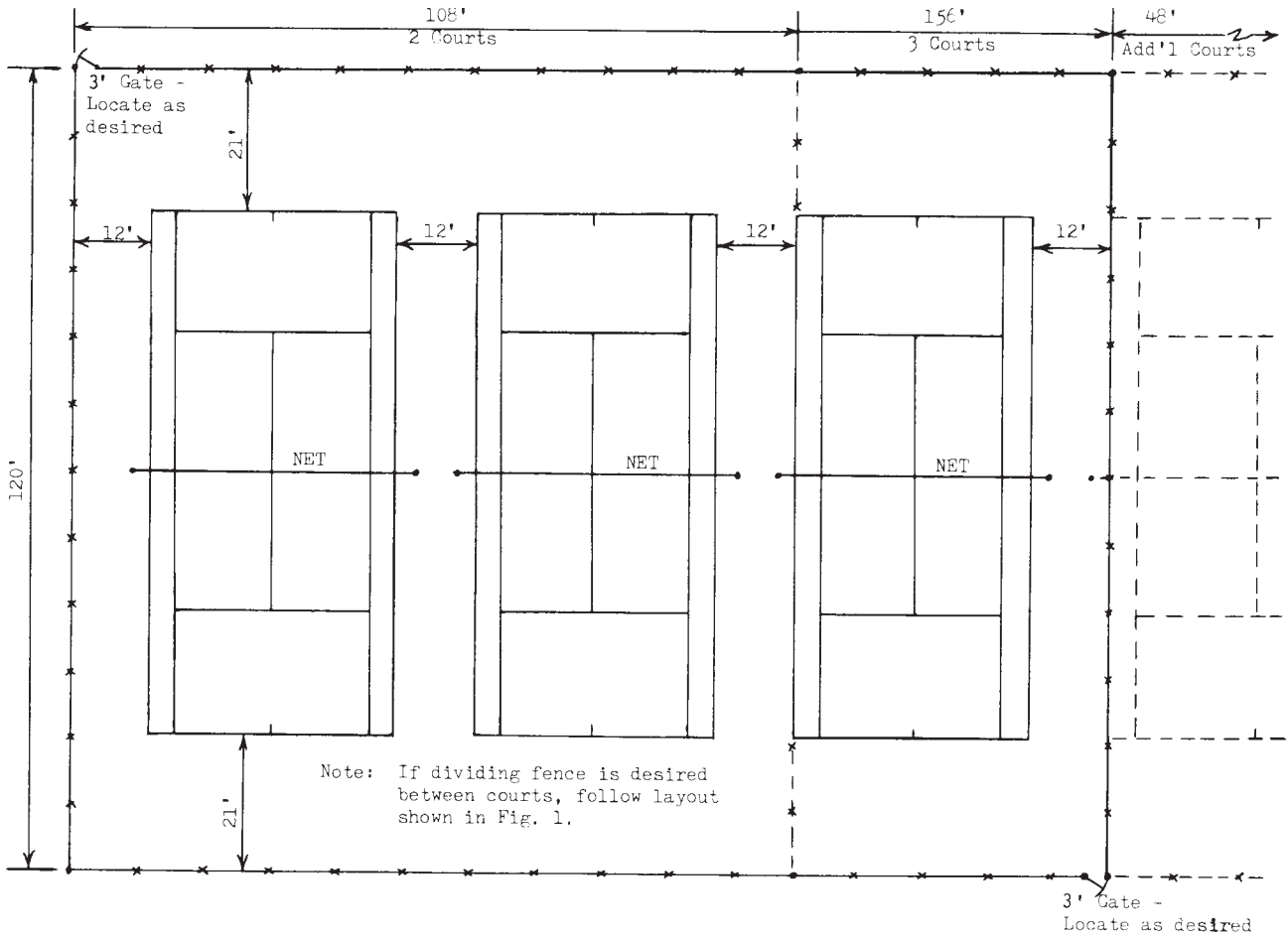
**FIG. 1 Typical Fence Layout for Complete Enclosure of One Standard 36 by 78 ft (11 m by 23.8 m) Doubles Court**



NOTE—See Table 1 for SI equivalents.

FIG. 2 Typical Fence Layout for Backstops at Either End of One Standard 36 by 78 ft (11 m by 23.8 m) Doubles Court





NOTE—See Table 1 for SI equivalents.

FIG. 3 Typical Fence Layout for Complete Enclosure of Two or More Standard 36 by 78 ft (11 m by 23.8 m) Doubles Courts

**TABLE 1 SI Reference Chart**

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12 ft 0 in.	= 3.7 m (3 660 mm)
21 ft 0 in.	= 6.4 m (6 400 mm)
48 ft 0 in.	= 14.6 m (14 630 mm)
60 ft 0 in.	= 18.3 m (18 288 mm)
108 in. 0 in.	= 32.9 m (32 918 mm)
120 ft 0 in.	= 36.6 m (36 576 mm)
156 ft. 0 in.	= 47.5 m (47 540 mm)

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# Standard Specification for Strength and Protective Coatings on Steel Industrial Chain Link Fence Framework<sup>1</sup>

This standard is issued under the fixed designation F 1043; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

## 1. Scope

1.1 This specification covers the strength and protective coating requirements for industrial steel chain link fence framework. Maximum allowable heights of framework and post spacing are to be based on chain link fence fabric mesh size and gages, and specified wind loads. Post spacings are not to exceed 10 ft. (For additional information, see CLFMI Guide WLG2445).

1.1.1 *Caution Regarding Windload*—If additives to the fence, such as windscreens, inserts or signage, are required, it is advisable to use stronger framework and fittings, to reduce the on-center spacing of posts or to add back bracing. Factors to consider when determining windload include the type of screening material to be used, area of fence to be covered, and local wind conditions.

1.2 Posts and rails may have any cross-sectional shape meeting the requirements herein. The shapes may be formed and welded, cold formed, hot rolled, or extruded.

1.3 The values in inch-pound units are to be regarded as the standard. The values stated in SI units are for information purposes only.

NOTE 1—For aluminum-alloy extruded structural pipe and tube please refer to Specification B 429.

## 2. Referenced Documents

### 2.1 ASTM Standards:

- A 90/A 90M Test Method for Weight [Mass] of Coating on Iron or Steel Articles with Zinc or Zinc Alloy Coatings<sup>2</sup>
- A 123/A 123M Specification for Zinc (Hot-Dip Galvanized) Coatings on Iron or Steel Products<sup>2</sup>
- A 653/A 653M Specification for General Requirements for Steel Sheet, Zinc-Coated (Galvanized) or Zinc-Iron Alloy-Coated (Galvannealed) by the Hot-Dip Process<sup>2</sup>
- A 875/A 875M Specification for Steel Sheet, Zinc-5 % Aluminum Alloy Metallic-Coated by the Hot-Dip Process<sup>2</sup>

- A 1011 Specification for Steel, Sheet and Strip, Hot-Rolled, Carbon, Structural, High-Strength Low-Alloy and High-Strength Low Alloy with Improved Formability<sup>3</sup>
- B 6 Specification for Zinc (Slab Zinc)<sup>4</sup>
- B 308/B 308M Specification for Aluminum Alloy 6061 T6 Standard Structural Steel<sup>5</sup>
- B 429 Specification for Aluminum-Alloy Extruded Structural Pipe and Tube<sup>4</sup>
- B 750 Specification for Zinc-5 % Aluminum-Mischmetal; Alloy in Ingot Form for Hot-Dip Coatings<sup>6</sup>
- D 1499 Practice for Filtered Open-Flame Carbon-Arc Exposures of Plastics<sup>7</sup>
- D 3359 Test Methods for Measuring Adhesion by Tape Tests<sup>8</sup>
- E 8 Test Methods for Tension Testing of Metallic Materials<sup>9</sup>
- E 376 Practice for Measuring Coating Thickness by Magnetic-Field or Eddy-Current (Electromagnetic) Test Methods<sup>10</sup>
- F 552 Terminology Relating to Chain Link Fencing<sup>2</sup>
- F 934 Specification for Standard Colors for Polymer Coated Chain Link Fence<sup>2</sup>
- F 1083 Specification for Pipe, Steel, Hot-Dipped Zinc Coated (Galvanized), Welded, for Fence Structures<sup>2</sup>
- F 1553 Guide for Specifying Industrial and Commercial Chain Link Fence<sup>2</sup>
- G 23 Practice for Operating Light-Exposure Apparatus (Carbon-Arc Type) With and Without Water for Exposure of Nonmetallic Materials<sup>11</sup>
- G 26 Practice for Operating Light-Exposure Apparatus (Xenon-Arc Type) With and Without Water for Exposure of Nonmetallic Materials<sup>12</sup>

<sup>1</sup> This specification is under the jurisdiction of ASTM Committee F14 on Fences and is the direct responsibility of Subcommittee F14.40 on Chain Link Fence and Wire Accessories.

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<sup>2</sup> *Annual Book of ASTM Standards*, Vol 01.06.

<sup>3</sup> *Annual Book of ASTM Standards*, Vol 01.03.

<sup>4</sup> *Annual Book of ASTM Standards*, Vol 02.03.

<sup>5</sup> *Annual Book of ASTM Standards*, Vol 02.02.

<sup>6</sup> *Annual Book of ASTM Standards*, Vol 02.04.

<sup>7</sup> *Annual Book of ASTM Standards*, Vol 08.01.

<sup>8</sup> *Annual Book of ASTM Standards*, Vol 06.01.

<sup>9</sup> *Annual Book of ASTM Standards*, Vol 03.01.

<sup>10</sup> *Annual Book of ASTM Standards*, Vol 03.03.

<sup>11</sup> Discontinued. See 1997 *Annual Book of ASTM Standards*, Vol 14.02. Replaced by Practices G 152 and G 153.

<sup>12</sup> Discontinued. See 1997 *Annual Book of ASTM Standards*, Vol 14.02. Replaced by Practice G 155.

2.2 CLFMI Guide:  
WLG2445 Guide for the Selection of Line Post Spacings<sup>13</sup>

3. Terminology

3.1 Definitions:

3.1.1 posts—vertical members of the fence.

3.1.1.1 Discussion—End, corner, and pull posts are posts at which chain link fabric terminates. Gateposts are posts to which gates are either attached or latched. Line posts are posts that occur in a line of fence in which the chain link fabric passes and to which it is tied.

3.1.2 rails—horizontal members of the fence.

3.1.2.1 Discussion—May be top, bottom, intermediate or brace rails.

3.1.3 The dimensional terminology is shown in Fig. 1.

3.1.4 The relationship of measured dimension (used throughout) to trade and industry usage is shown in Table 1.

3.1.5 open sections—non-tubular framework sections (such as H-posts, C-posts, roll-formed top rail, and terminal posts).

3.1.6 polymer coatings—examples of some polymer coatings are acrylic urethane, polyurethane, polyvinyl chloride (PVC), polyester, and polyolefin elastomer.

3.1.7 See Terminology F 552 for definitions of other terms.

4. Ordering Information

4.1 Orders for steel fence framework purchased to this specification shall include the following information:

<sup>13</sup> Available from Chain Link Fence Manufacturers Institute, 10015 Old Columbia Road, Suite B-215, Columbia, MD 21046; or website <http://www.chainlinkinfo.org/>.

TABLE 1 Size Terminology

Trade Size, in. [mm]	Designator, NPS [Metric]	Actual Outside Diameter	
		in.	mm
1 3/8 [34.9]	1 [25]	1.315	33.4
1 1/2 [41.3]	1 1/4 [32]	1.660	42.2
2 [50.8]	1 1/2 [40]	1.900	48.3
2 1/2 [63.5]	2 [50]	2.375	60.3
3 [76.2]	2 1/2 [65]	2.875	73.0
3 1/2 [88.9]	3 [80]	3.500	88.9
4 [101.6]	3 1/2 [90]	4.000	101.6

- 4.1.1 Number of posts and rails by size and length,
- 4.1.2 Type of outside and inside coating (Section 7) and class of material,
- 4.1.3 Color, if applicable, in accordance with Specification F 934,
- 4.1.4 Material group (IA, IC, IC-L, II, II-L, III, III-L) (Table 2),
- 4.1.5 Certification, if required, and
- 4.1.6 Exception(s) to this specification, or special requirements, if any.

NOTE 2—These details may be covered in whole or in any part by accompanying the orders with design drawings and notations thereon.

TABLE 2 Definitions of Fence Framework Materials Design

Material	Description of Material
Group IA Round Steel Pipe	Steel pipe shall be produced to conform to Specification F 1083, standard weight (Schedule 40).
Group IB Aluminum Pipe	Aluminum pipe shall be produced of alloy Aluminum Pipe 6063 and shall conform to Specification B 429.
Group IC Round Steel Pipe (Electric Resistance Welded Pipe)	Steel pipe shall be produced in accordance with commercial standards. Minimum yield strength shall be 50 000 psi [344 MPa]. Such products shall include, without seeking to limit to, cold-formed and welded pipe. The minimum weight shall be not less than 90 % of the nominal weight.
Group IIA Roll-Formed Steel Shapes (C-Sections)	Roll formed steel shapes shall be produced to commercial standards. Minimum yield strength shall be 45 000 psi [310 MPa]. The minimum weight shall be not less than 90 % of the nominal weight. The formed lip shall be of the same thickness as the flat elements and shall project no less than 1/3 the width of the flat element being stiffened. Group II products shall be designated such that the strong axis is perpendicular to the line of fence.
Group IIB Aluminum Shapes	Aluminum shapes shall be produced of alloy 6061-T6 and shall conform to Specification B 308/B 308M.
Group III Hot-Rolled Shapes (H Beams)	Hot-rolled shapes shall meet the criteria and exhibit a minimum yield strength of 45 000 psi [310 MPa]. The minimum weight shall be not less than 90 % of the nominal weight.
Group IV Alternate Design	Any suitable design can be delivered, provided it meets the strength and stiffness criteria of Fig. 2 (Industrial) or Fig. 3 (Light Industrial/Commercial) and the producer has supplied, in a form acceptable to the purchaser, data that demonstrates conformance with the specification. At the producer's option the methods in either Section 6 or 6.4 may be used.

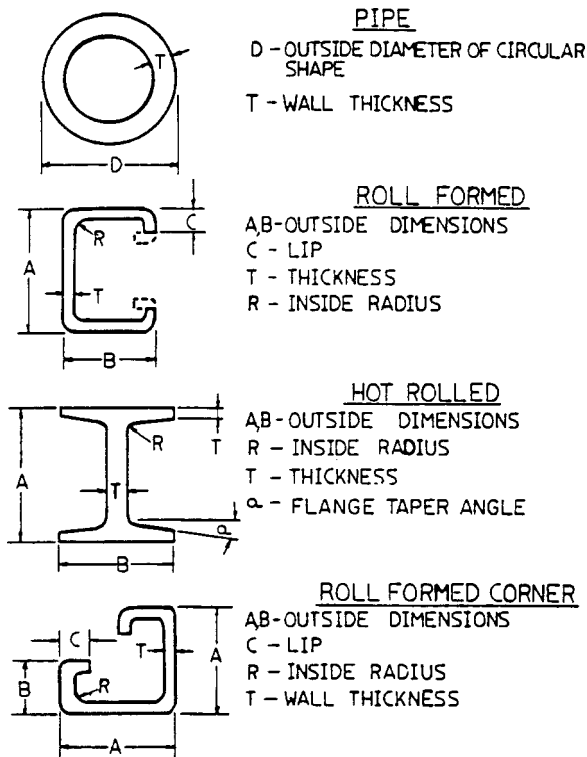


FIG. 1 Definitions of Dimensional Terms

**5. Strength Requirements**

5.1 It is the intent of this specification to permit the continuance of historically proved practice in the installation of chain link fence systems, and to provide strength requirements for alternative shapes and materials. Two categories are described. Heavy industrial fence represents the most rigid and mechanically durable of the commonly installed framework. Light industrial/commercial fence, as provided herein, exhibits approximately 80 % of the load bearing capability of heavy industrial fence. The summary requirements and options for heavy industrial fence are given in Fig. 2 and those of light industrial/commercial fence in Fig. 3.

5.2 *Historical Practice*—Experience has shown that galvanized steel performs satisfactorily as fence posts and rails if furnished to the standard weight (Schedule 40) and nominal sizes listed in Specification F 1083. Therefore, fence posts and rails consisting of standard weight (Schedule 40) galvanized steel in the nominal sizes and weight per foot listed in Specification F 1083 shall be considered in compliance with this specification.

5.2.1 Experience has also shown that several additional products performed satisfactorily provided certain additional requirements are met. The nominal dimensions, minimum yield strength (Y), and nominal weight/ft are also listed in Figs. 2 and 3. These satisfactory designs are classified in accordance with products and special requirements as described in Table 2.

**6. Strength Calculations**

6.1 The strength of a structural member can generally be predicted from established engineering principles. The intent

of this section is to provide criteria by which alternate designs can be judged to provide adequate strength without premature failure by local buckling. Accordingly, the criteria of 6.2 and 6.3 shall be satisfied even though, in general, only one will govern a particular design.

6.2 The elastic bending strength equals the yield strength times the section modulus of the entire cross section.

6.2.1 The yield strength may be considered to be either: (1) the minimum specified yield strength for material used to form a part, or (2) the value determined from tension tests performed in accordance with Test Method E 8. The specimen may be cut either from material before forming or from the part after fabrication.

6.3 Accepted engineering practice indicates that the full bending strength of a structure can be realized if the additional dimensional restrictions shown below are satisfied.

6.3.1 For circular shapes the ratio of the diameter to the thickness may not exceed 0.1  $E/Y$ .

6.3.2 For cross-sectional shapes composed of flat elements, the ratio of width to thickness for elements supported along two parallel edges may not exceed 1.2  $(E/Y)^{1/2}$ , and ratio of width to thickness for elements supported along one edge may not exceed 0.34  $(E/Y)^{1/2}$ .

6.3.3 In these formulas,  $Y$  is the yield strength of the material and  $E$  is the modulus of elasticity of the material. A formed lip shall be considered to provide support only if the radius of gyration of the lip about the mid-thickness of the flat element from which it projects is not less than 1/5 the width of the flat element. For simple rectangular lips of the same thickness as the flat element, this requirement is satisfied when

Description	Pipe			Roll-Formed				Hot-Formed				Performance Criteria for Future Products IV			
	IA	IB	IC	II				III							
Material	Steel	Aluminum	Steel	Steel				Steel				Bending Strength Z x Y Stiffness E x I			
Reference Specification	F 1083	B 429	A 653, A924, A 569	A 570 Grade 45, Others											
Minimum Yield Strength psi (Mpa)	30,000 (205)	25,000 (170)	50,000 (344)	45,000 (310)				45,000 (310)							
Structural				A	B	C	R	A	B	R	a				
Top Rail	D = 1.660 in. (42 mm) t = 0.140 in. (3.6 mm) 2.27 lb/ft (3.38 kg/m)	D = 1.660 in. (42 mm) t = 0.140 in. (3.6 mm) 0.786 lb/ft (1.17 kg/m)	D = 1.660 in. (42 mm) t = 0.111 in. (2.8 mm) 1.82 lb/ft (2.71 kg/m)	1 1/4	1 1/8	3/8	3/16	t = 0.080 in. (2.0 mm) 1.35 lb/ft (2.01 kg/m)					7100 lbf-in (802 N-m) t <sub>min</sub> = 0.075 in. (1.9 mm)	3 x 10 <sup>6</sup> lbf-in. <sup>2</sup> (8.6 kPa-m <sup>4</sup> )	
Line post	D = 2.375 in. (60 mm) t = 0.154 in. (3.9 mm) 3.65 lb/ft (5.43 kg/m)	D = 2.375 in. (60 mm) t = 0.154 in. (3.9 mm) 1.264 lb/ft (1.88 kg/m)	D = 2.375 in. (60 mm) t = 0.130 in. (3.3 mm) 3.12 lb/ft (4.64 kg/m)	2 1/4	1 1/8	3/8	1/4	t = 0.121 in. (3.1 mm) 2.78 lb/ft (4.13 kg/m)	2 1/4	1 1/8	1 1/4	10	t = 0.125 in. (3.2 mm) 3.26 lb/ft (4.85 kg/m)	19600 lbf-in (2200 N-m) t <sub>min</sub> = 0.115 in. (2.9 mm)	16 x 10 <sup>6</sup> lbf-in. <sup>2</sup> (46 kPa-m <sup>4</sup> )
End corner and pull post	D = 2.875 in. (73 mm) t = 0.203 in. (5.2 mm) 5.79 lb/ft (8.62 kg/m)	D = 2.875 in. (73 mm) t = 0.203 in. (5.2 mm) 2.004 lb/ft (2.98 kg/m)	D = 2.875 in. (73 mm) t = 0.160 in. (4.1 mm) 4.64 lb/ft (6.9 kg/m)	3 1/2	1 1/2	1	3/16	t = 0.135 in. (3.5 mm) 5.10 lb/ft (7.6 kg/m)					37200 lbf-in (4200 N-m) t <sub>min</sub> = 0.125 in. (3.2 mm)	35 x 10 <sup>6</sup> lbf-in. <sup>2</sup> (100 kPa-m <sup>4</sup> )	

A = outside dimension  
 B = outside dimension  
 C = lip  
 D = outside diameter  
 R = radius at surface (max)  
 a = flange taper angle  
 t = thickness (wall)

See Fig. 1 for drawings of shapes

Y = yield strength, min  
 Z = section modulus  
 I = moment of inertia  
 E = modulus of elasticity

NOTE—Engineering calculations should be used to determine post requirements for fences based on load and installation requirements.

FIG. 2 Summary of Requirements for Industrial Fence

Description	Pipe	Roll-Formed				Hot-Formed				Performance Criteria for Future Products IV	
	IC	II				III				Bending Strength	Stiffness
Material	Steel	Steel				Steel					
Reference Specification	A 653, A924, A 569	A 570 Grade 45, Others									
Minimum yield strength, psi (Mpa)	50,000 (344)	45,000 (310)				45,000 (310)					
		A	B	C	R	A	B	R	a		
Top Rail	D = 1.660 in. (42 mm) t = 0.085 in. (2.1 mm) 1.43 lb/ft (2.12 kg/m)	1 1/4	1 3/8	3/8	3/16					7100 lbf-in (802 N-m)	3 x 10 <sup>4</sup> lbf-in. <sup>2</sup> (8.6 kPa-m <sup>4</sup> )
Line post	D = 2.375 in. (60 mm) t = 0.095 in. (2.4 mm) 2.31 lb/ft (3.44 kg/m)	1 7/8	1 3/4	3/16	1/8	2 1/4	1 11/16	1/4	10	19600 lbf-in (2200 N-m)	16 x 10 <sup>4</sup> lbf-in. <sup>2</sup> (46 kPa-m <sup>4</sup> )
End corner and pull post	D = 2.875 in. (73 mm) t = 0.110 in. (2.8 mm) 3.25 lb/ft (4.84 kg/m)	3 1/2	1 1/2	1	3/16					37200 lbf-in (4200 N-m)	35 x 10 <sup>4</sup> lbf-in. <sup>2</sup> (100 kPa-m <sup>4</sup> )

A = outside dimension  
B = outside dimension  
C = lip

D = outside diameter  
R = radius at surface (max)  
a = flange taper angle  
t = thickness (wall)

See Fig. 1 for drawings of shapes

Y = yield strength, min  
Z = section modulus  
I = moment of inertia  
E = modulus of elasticity

NOTE—Engineering calculations should be used to determine post requirements for fences based on load and installation requirements.

FIG. 3 Summary of Requirements for Light Industrial/Commercial Fence

the projecting distance of the lip is not less than 1/3 the width of the flat element being stiffened.

6.4 Strength Tests:

6.4.1 At the producer’s option, the producer may provide data from appropriate bending tests, to demonstrate compliance with Fig. 2 or Fig. 3. The producer shall provide test data from cantilever tests that have a 6-ft [1.83-m] span from the fixed end to the application of load.

6.4.2 Having once provided evidence of the validity of the designs, the producer’s responsibility shall thereafter be limited to the quality control provisions of Section 9.

7. Coating Requirements

NOTE 3—The order of designation of these coating types is not to be construed as a measure of their effectiveness.

7.1 External Coatings (See Table 3):

7.1.1 Type A—Zinc, 1.8 oz/ft<sup>2</sup> [550 g/m<sup>2</sup>] minimum average in accordance with Specification F 1083 for pipe; roll-formed shapes shall be coated in accordance with Specification A 123/A 123M except with a 2.0 oz/ft<sup>2</sup> [610 g/m<sup>2</sup>] minimum average zinc coating; or zinc coated in accordance with

Specification A 653/A 653M for roll-formed shapes with a 4.0 oz/ft<sup>2</sup> [1220 g/m<sup>2</sup>], total both sides.

7.1.2 Type B—Zinc with organic overcoat, 0.9 oz/ft<sup>2</sup> [275 g/m<sup>2</sup>] minimum zinc coating with a verifiable polymer film.

7.1.3 Type C—Zinc-5 % aluminum-mischmetal alloy in accordance with Specification B 750 and a 1.8 oz/ft<sup>2</sup> [550 g/m<sup>2</sup>] total both sides, minimum coating in accordance with Specification A 875/A 875M.

7.2 Internal Coatings (See Table 3):

7.2.1 Type A—Zinc, 1.8 oz/ft<sup>2</sup> [550 g/m<sup>2</sup>] minimum average in accordance with Specification F 1083 for pipe; roll-formed shapes shall be coated in accordance with Specification A 123/A 123M except with a 2.0 oz/ft<sup>2</sup> [610 g/m<sup>2</sup>] minimum average zinc coating; or zinc coated in accordance with Specification A 653/A 653M for roll-formed shapes with a 4.0 oz/ft<sup>2</sup> [1220 g/m<sup>2</sup>], total both sides.

7.2.2 Type B—Zinc-0.9 oz/ft<sup>2</sup> [275 g/m<sup>2</sup>] minimum.

7.2.3 Type C—Zinc-5 % aluminum-mischmetal alloy in accordance with Specification B 750, and a 1.8 oz/ft<sup>2</sup> [550 g/m<sup>2</sup>], total both sides, minimum coating in accordance with Specification A 875/A 875M.

7.2.4 Type D—81 % nominal zinc pigmented coating, 0.3-mils [0.0076-mm] minimum thickness.

7.3 Optional Supplemental Color Coating—Polymer coating, PVC or polyolefin elastomer 10-mils [0.254-mm] minimum or polyester 3-mils [0.0076-mm] minimum coating can be specified in conjunction with all metallic coatings and is applied to the exterior surface of tubular shapes, and to the exterior and interior surfaces of roll-formed open-sided shapes. Unless otherwise specified, color of the coating shall be in accordance with Specification F 934.

TABLE 3 Cross Reference of Industrial Fence Products with Commercially Available Coatings<sup>A</sup>

Outside Surface Coatings from 7.1	Inside Surface Coatings from 7.2	Material Description <sup>B</sup>
Type A	Type A	Group IA, II, III
Type B	Type B	Group IC
Type B	Type D	Group IC
Type C	Type C	Group IC, II

<sup>A</sup> Any other combination of interior or exterior coatings is not available.

<sup>B</sup> Refer to Table 2 for material design definition.

7.4 *Welded Section*—Zinc-coated framework produced from precoated steel sheet meeting Specification A 653/A 653M shall have exterior weld surface recoated with the same type of material and thickness as the basic coating.

## 8. Additional Coating Requirements

### 8.1 *Coating Materials*:

8.1.1 Zinc used for coating shall be any grade of zinc conforming to the requirements of Specification B 6 and shall be applied by the hot-dip method.

8.1.2 Zinc-5 % aluminum-mischmetal alloy coating shall meet the requirements of Specification B 750 and shall be applied by the hot-dip method.

8.1.3 PVC, polyester polymer, or polyolefin elastomer coating shall be of a color conforming to Specification F 934. The PVC, polyester, or polyolefin elastomer coating shall not fade, crack, blister, or split under normal use. It shall have demonstrated the ability to withstand exposure in a weatherometer apparatus for 1000 h without failure when tested with Practice D 1499.

### 8.1.4 Adhesion shall be tested as follows:

8.1.4.1 *PVC or Polyolefin Elastomer* —At three separate locations, using a sharp blade, cut two parallel lines 1/8-in. [3.2-mm] apart and 1-in. [25.4-mm] long through the coating. At one end of the parallel cut, attempt to pull away the coating from the surface. The coating should break and not peel back in two of the three tests.

8.1.4.2 *Polyester*—Use cross hatch test in accordance with Test Methods D 3359, Method B.

8.1.4.3 One hundred percent adhesion is generally not possible due to variations of the undercoating.

8.1.5 Zinc-pigmented coating shall yield a dry film with a 0.3-mil [0.0076-mm] minimum total thickness.

8.1.6 *Clear Polymeric*—Clear polymeric coatings shall be a clear film applied in a manner assuring good adhesion. The existence of a clear film coating shall be verified by a 15-second contact with a copper sulfate solution (specific gravity 1.186) at three separate locations on a specimen. Copper sulfate will react with zinc to form a black deposit of copper anywhere the zinc is not protected by the clear polymeric coating. The clear exterior coating shall have a demonstrated ability to withstand exposure for 500 h without failure at a black panel temperature of 145°F [63°C] when tested in accordance with Practice D 1499. (See Practice G 26, xenon Type BH apparatus; or Practice G 23, carbon-arc Type HH apparatus).

## 9. Quality Control Provisions

9.1 *Group IA, IC, and IC-L*—When requested, producers shall furnish, at the time of delivery, the following information for each size ordered:

- 9.1.1 Statement of conformance,
- 9.1.2 Nominal diameter,
- 9.1.3 Minimum weight per foot, and
- 9.1.4 Coating requirements.

9.2 *Group II, II-L, III, and III-L*—When requested, producers shall furnish, at the time of delivery, the following information for each size ordered:

- 9.2.1 Statement of conformance,

- 9.2.2 Minimum yield strength,
- 9.2.3 Representative yield strength,
- 9.2.4 Minimum weight per foot,
- 9.2.5 Nominal cross-sectional dimensions, and
- 9.2.6 Coating requirements.

9.3 *Group IV (Alternate Designs)*—The producers may elect either of the methods of 9.3.1 or 9.3.2 to provide insurance of conformity with this specification.

9.3.1 *Strength Tests*—The primary criterion, minimum elastic bending strength is measurable in a number of standard tests.

9.3.1.1 Required documents are as follows:

- (1) Statement of conformance,
- (2) Required minimum elastic bending strength,
- (3) Required maximum total deflection,
- (4) Actual elastic bending strength, and
- (5) Actual total deflection.

9.3.2 *Strength Calculation*—Conformance may be demonstrated by calculation.

9.3.2.1 The elastic bending strength is the yield strength ( $Y$ ) times the section modulus ( $Z$ ).

9.3.2.2 The buckling criterion of 6.4 shall be satisfied.

9.3.2.3 *Required Documents*—Producers electing to use this section shall provide, at the time of delivery:

- (1) A statement of conformance,
- (2) Minimum yield strength,
- (3) Yield strength,
- (4) Minimum cross section to meet all requirements,
- (5) Actual cross section,
- (6) Corresponding minimum weight per foot, and
- (7) Conformance to coating requirements of Section 7.

### 9.4 *Inspection*:

9.4.1 *Sampling*—The purchaser may select one sample from each lot. A lot shall consist of the smaller of 500 pieces or all pieces delivered at the same time. This sample will then be tested for any or all attributes specified in this specification.

9.5 *Retest*—In case of failure of the initial test, two additional samples shall be taken and tested, each of which shall conform to the requirements specified. In the event of failure of either test, the entire lot may be rejected.

9.6 The method of determining weight or thickness of coating shall be as follows:

9.6.1 For zinc coated or zinc-5 % aluminum-mischmetal alloy coated, the weight of the coating shall be determined in accordance with Test Method A 90/A 90M.

9.6.2 Specified organic coating thickness, exclusive of the metallic coating, shall be determined in accordance with Practice E 376.

## 10. Workmanship, Finish and Appearance

10.1 *Posts and Rails*—Finished posts and rails shall show good workmanship and be reasonably free of defects. Coatings shall be uniform and free of voids or excessive roughness.

## 11. Certification and Reports

11.1 *Posts and Rails*—When specified by the purchaser in the contract or order, a manufacturer's certification that the material was manufactured, sampled, tested, and inspected in accordance with this specification, or an independent test lab

certification that the material has been found to meet the requirements of this specification, or both shall be furnished. When specified in the contract or purchase order, a report of the test results shall be furnished.

## **12. Keywords**

12.1 coatings, protective; fence, chain link; framework, fence; posts, fence; rails, fence; strength, fence posts; strength, fence rails

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# Standard Specification for Pipe, Steel, Hot-Dipped Zinc-Coated (Galvanized) Welded, for Fence Structures<sup>1</sup>

This standard is issued under the fixed designation F 1083; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon ( $\epsilon$ ) indicates an editorial change since the last revision or reapproval.

## 1. Scope

1.1 This specification covers hot-dipped galvanized welded steel pipe in NPS 1 (Note 1) to NPS 8, inclusive, with nominal (average) wall thickness as given in Table 1 and Table 2. Pipe having other dimensions (Note 2) may be furnished provided such pipe complies with all other requirements of this specification. Pipe ordered under this specification is intended for use as a structural support for fencing in accordance with Specification F 1043, Group 1A.

NOTE 1—The dimensionless designator NPS (nominal pipe size) has been substituted in this specification for such traditional terms as nominal diameter, size, and nominal size.

NOTE 2—A comprehensive listing of standardized pipe dimensions is contained in ANSI B 36.10.

1.2 The values stated in inch-pound units are to be regarded as the standard. The values given in parentheses are for information only.

## 2. Referenced Documents

### 2.1 ASTM Standards:

A 53 Specification for Pipe, Steel, Black and Hot-Dipped, Zinc-Coated Welded and Seamless<sup>2</sup>

A 90/A 90M Test Method for Weight of Coating on Zinc-Coated (Galvanized) Iron or Steel Articles<sup>3</sup>

A 700 Practices for Packaging, Marking, and Loading Methods for Steel Products for Domestic Shipment<sup>4</sup>

B 6 Specification for Zinc (Slab Zinc)<sup>5</sup>

E 8 Test Methods for Tension Testing of Metallic Materials<sup>6</sup>

E 29 Practice for Using Significant Digits in Test Data to Determine Conformance with Specifications<sup>7</sup>

F 1043 Specification for Strength and Protective Coatings on Metal Industrial Chain Link Fence Framework<sup>3</sup>

<sup>1</sup> This specification is under the jurisdiction of Committee F14 on Fences and is the direct responsibility of Subcommittee F14.40 on Chain Link Fence and Wire Accessories.

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<sup>2</sup> Annual Book of ASTM Standards, Vol 01.01.

<sup>3</sup> Annual Book of ASTM Standards, Vol 01.06.

<sup>4</sup> Annual Book of ASTM Standards, Vol 01.05.

<sup>5</sup> Annual Book of ASTM Standards, Vol 02.04.

<sup>6</sup> Annual Book of ASTM Standards, Vol 03.01.

<sup>7</sup> Annual Book of ASTM Standards, Vol 14.02.

### 2.2 ANSI Standard:

B 36.10 Welded and Seamless Wrought Steel Pipe<sup>8</sup>

## 3. Ordering Information

3.1 Orders for material under this specification shall include the following as required, to describe the desired material adequately:

3.1.1 Specification designation,

3.1.2 Quantity (feet, metres, or number of lengths),

3.1.3 Name of material (steel pipe),

3.1.4 Method of manufacture (electric-resistance welded or furnace welded),

3.1.5 Type (Table 1 or Table 2),

3.1.6 Size (NPS designator and weight class; or outside diameter and nominal wall),

3.1.7 Length (see Section 14),

3.1.8 Certification (see 18.1), and

3.1.9 Selection of applicable level of preservation and packaging required, if other than in accordance with Practices A 700 (see 19.1).

## 4. Process

4.1 The steel for welded pipe shall be made by one or more of the following processes: electric-furnace, open hearth, or basic-oxygen. The steel for welded pipe shall be of soft weldable quality.

4.2 Welded pipe NPS 4 and under may be butt-welded, unless otherwise specified. Welded pipe over NPS 4 shall be electric-welded.

## 5. Coating

5.1 Pipe shall be coated with zinc inside and outside by the hot-dip process.

5.2 The zinc used for the coating shall be any grade of zinc conforming to Specification B 6.

## 6. Tensile Requirements

6.1 Pipe furnished to this specification shall meet the following minimum tensile requirements when tested in accordance with Test Methods E 8.

<sup>8</sup> Available from American National Standards Institute (ANSI), 25 W. 43rd St., 4th Floor, New York, NY 10036.

**TABLE 1 Dimensions, Nominal Weights (Plain Ends) for Standard Weight Pipe (Schedule 40)**

NOTE 1—Pipe furnished in accordance with this table will be standard pipe.

NOTE 2—The wall thickness is expressed in three decimal places, the fourth decimal place being carried forward or dropped, in accordance with Practice E 29.

NPS	Designator		Outside Diameter		Wall Thickness		Weight	
	Metric		in.	[mm]	in.	[mm]	lb/ft	[kg/m]
1	[25]		1.315	[33.4]	0.133	[3.38]	1.68	[2.5]
1¼	[32]		1.660	[42.2]	0.140	[3.56]	2.27	[3.4]
1½	[40]		1.900	[48.3]	0.145	[3.68]	2.72	[4.0]
2	[50]		2.375	[60.3]	0.154	[3.91]	3.65	[5.4]
2½	[65]		2.875	[73.0]	0.203	[5.16]	5.80	[8.6]
3	[80]		3.500	[88.9]	0.216	[5.49]	7.58	[11.3]
3½	[90]		4.000	[101.6]	0.226	[5.74]	9.12	[13.6]
4	[100]		4.500	[114.3]	0.237	[6.02]	10.80	[16.1]
6	[150]		6.625	[168.3]	0.280	[7.11]	18.99	[28.3]
8	[200]		8.625	[219.1]	0.322	[8.18]	28.58	[42.5]

**TABLE 2 Dimensions, Nominal Weights (Plain Ends) for Extra Strong Pipe (Schedule 80)**

NOTE 1—Pipe furnished in accordance with this table will be extra-strong pipe.

NOTE 2—The wall thickness is expressed in three decimal places, the fourth decimal place being carried forward or dropped, in accordance with Practice E 29.

NPS	Designator		Outside Diameter		Wall Thickness		Weight	
	Metric		in.	[mm]	in.	[mm]	lb/ft	[kg/m]
1	[25]		1.315	[33.4]	0.179	[4.55]	2.17	[3.23]
1¼	[32]		1.660	[42.2]	0.191	[4.85]	3.00	[4.47]
1½	[40]		1.900	[48.3]	0.200	[5.08]	3.63	[5.41]
2	[50]		2.375	[60.3]	0.218	[5.54]	5.03	[7.48]
2½	[65]		2.875	[73.0]	0.276	[7.01]	7.67	[11.41]
3	[80]		3.500	[88.9]	0.300	[7.62]	10.26	[15.27]
3½	[90]		4.000	[101.6]	0.318	[8.08]	12.52	[18.63]
4	[100]		4.500	[114.3]	0.337	[8.56]	15.00	[22.32]
6	[150]		6.625	[168.3]	0.432	[10.97]	28.60	[42.56]
8	[200]		8.625	[219.1]	0.500	[12.70]	43.43	[64.64]

6.1.1 *Tensile Strength*—Minimum tensile strength shall be 48 000 psi [330 MPa].

6.1.2 *Yield Strength*—Minimum yield strength shall be 30 000 psi [205 MPa].

## 7. Weight of Coating

7.1 The weight of zinc coating shall be not less than 1.8 oz/ft<sup>2</sup> [550 g/m<sup>2</sup>], as determined from the average results of the two specimens taken for test in accordance with 10.1 and not less than 1.6 oz/ft<sup>2</sup> [490 g/m<sup>2</sup>] for either of these specimens. The weight of coating expressed in ounces per square foot shall be calculated by dividing the total weight of zinc, inside plus outside, by the total area, inside plus outside, of the surface coated. Each specimen shall have not less than 1.3 oz/ft<sup>2</sup> [400 g/m<sup>2</sup>] of zinc coating on each surface, calculated by dividing the total weight of zinc on the given surface (outside or inside) by the area of the surface coated (outside or inside).

## 8. Weight of Coating Test

8.1 Determine the weight of zinc coating by a strip test in accordance with Test Method A 90/A 90M. The total zinc on each specimen shall be determined in a double stripping operation.

## 9. Test Specimens

9.1 Test specimens for determination of weight of coating shall be cut approximately 4 in. [102 mm] in length. Specimens

of toprail and brace material shall be taken from the ends of mill lengths. Specimens of post material shall be cut from the length from which the post is to be cut. Under no circumstances shall specimens of post material be taken after the post is cut from the mill length.

9.2 Tensile and yield samples shall be of sufficient length to prepare specimens for testing in accordance with Test Methods E 8.

## 10. Number of Tests

10.1 Two test specimens for the determination of weight of coating shall be taken, one from each end of one length of galvanized pipe, selected at random from each lot of 500 lengths or fraction thereof of each size.

10.1.1 For purposes of testing, a lot shall consist of not more than 500 lengths of pipe of the same type, grade, size, and weight.

10.1.2 For electric-resistance welded pipe, one tensile test shall be made on one length of pipe from each lot of 500 lengths, or fraction thereof, of each size. A length is defined as the length as ordered, except that in the case of orders for cut lengths shorter than single random, the term lot shall apply to the lengths as rolled, prior to cutting to the required short lengths.

10.1.3 For continuous-welded pipe, one tensile test shall be made on one length of pipe from each lot of 25 tons, or fraction

thereof, of pipe NPS 1½ and smaller, and from each lot of 50 tons, or fraction thereof, of pipe NPS 2 and larger.

### 11. Retests

11.1 If the weight of coating of any lot does not conform to the requirements specified in Section 7, retests of two additional pipes from the same lot shall be made, each of which shall conform to the requirements specified.

### 12. Standard Weights

12.1 The standard weights with the corresponding wall thickness for pipe of various nominal outside diameters are prescribed in Table 1 and Table 2.

NOTE 3—A system of standard pipe sizes has been approved by the American National Standards Institute as B 36.10 that dispenses with the double-extra-strong weight and reclassifies the standard and extra-strong weights, substituting, therefore, schedules of wall thicknesses based on minimum pressure-stress ratios. Wall thicknesses corresponding to most of these now listed as standard weight and extra-strong are incorporated in Schedules 40 and 80, respectively, of B 36.10.

### 13. Dimensions, Mass, and Permissible Variations

13.1 *Weight*—The weight of the pipe covered by Table 1 and Table 2 shall not vary by more than  $\pm 10\%$  from that prescribed.

NOTE 4—The weight tolerance of  $\pm 10\%$  is determined from the weights of the customary lifts of pipe as produced for shipment by the mill, divided by the number of feet of pipe in the lift. On pipe sizes over NPS 4 where individual lengths may be weighed, the weight tolerance is applicable to the individual length.

13.2 *Diameter*—For pipe NPS 1½ and under, the outside diameter at any point shall not vary more than  $\frac{1}{64}$  in. [0.4 mm] over nor more than  $\frac{1}{32}$  in. [0.8 mm] under the standard specified. For pipe NPS 2 and over, the outside diameter shall not vary more than  $\pm 1\%$  from the standard specified.

13.3 *Thickness*—The minimum wall thickness at any point shall not be more than 12.5 % under the nominal wall thickness specified.

### 14. Lengths

14.1 Lengths of top rail may be of random lengths, for example, 16 ft [4.9 m] to 24 ft [7.3 m], unless otherwise specified. Post lengths shall be as noted in the purchase order or producer plans and specifications with a tolerance of  $\pm 1$  in. [25.4 mm].

### 15. Workmanship, Finish, and Appearance

15.1 The finished pipe shall be galvanized and reasonably straight and free of defects. Any imperfection that is deeper than 12½ % of the wall thickness or violates the minimum wall shall be considered a defect. All burrs at the ends of the pipe shall be removed.

15.2 The zinc coating shall be free of voids or excessive roughness.

15.3 End finish shall be plain end square cut.

15.4 Posts and rails shall be one piece free of welded sections.

### 16. Inspection and Certification

16.1 All tests and inspection shall be made at the place of manufacture prior to shipment, unless otherwise specified, and shall be so conducted as not to interfere unnecessarily with the operation of the works.

16.2 Responsibility for inspection, unless otherwise specified in the contract or purchase order, rests upon the producer. This includes performance of all inspection and test requirements specified herein. Except as otherwise specified in the contract order, the producer may use their own or any other suitable facilities for the performance of the inspection and test requirements specified herein unless disapproved by the purchaser. The purchaser shall have the right to perform any of the inspections and tests set forth in this specification where such inspections are deemed necessary to ensure that material conforms to prescribed requirements.

### 17. Rejection

17.1 Each length of pipe received from the manufacturer may be inspected by the purchaser and, if it does not meet the requirements of this specification based on the inspection and test method as outlined in this specification, the length may be rejected and the manufacturer shall be notified. Disposition of rejected pipe shall be a matter of agreement between the manufacturer and the purchaser.

17.1.1 Pipe found in fabrication or installation to be unsuitable for the intended use, under the scope and requirements of this specification, may be set aside and the manufacturer notified. Such pipe shall be subject to mutual investigation as to the nature and severity of the deficiency and the forming or installation, or both, conditions involved. Disposition shall be a matter for agreement.

### 18. Certification


18.1 The producer or supplier shall, upon request, furnish to the purchaser a certificate of inspection stating that the material has been sampled, tested, and inspected in accordance with this specification, and has been found to meet the requirements.

### 19. Packaging, Marking, and Loading

19.1 When specified on the purchase order, packaging, marking, and loading for shipment shall be in accordance with Practices A 700.

### 20. Keywords

20.1 fence; posts, fence; strength; strength, fence posts; top rails, fence

 **F 1083 – 97 (2003)**

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# Standard Specification for Industrial and Commercial Horizontal Slide Gates<sup>1</sup>

This standard is issued under the fixed designation F 1184; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon ( $\epsilon$ ) indicates an editorial change since the last revision or reapproval.

## 1. Scope

1.1 This specification covers detailed requirements for cantilever and overhead slide chain link fence gates, gate posts, and accessories for industrial and commercial applications.

1.2 The values stated in inch-pound units are to be regarded as the standard. The values given in parentheses are for information only.

## 2. Referenced Documents

### 2.1 ASTM Standards:

A 780 Practice for Repair of Damaged and Uncoated Areas of Hot-Dip Galvanized Coatings<sup>2</sup>

F 567 Practice for Installation of Chain-Link Fence<sup>2</sup>

F 1043 Specification for Strength and Protective Coatings on Metal Industrial Chain Link Fence Framework<sup>2</sup>

F 1083 Specification for Pipe, Steel, Hot-Dipped Zinc-Coated (Galvanized) Welded, for Fence Structures<sup>2</sup>

## 3. Terminology

### 3.1 Definitions of Terms Specific to This Standard:

3.1.1 *polymer*—as used in this specification, describes poly(vinyl chloride) (PVC) or polyester.

## 4. Classification

4.1 Horizontal slide gates covered by this specification shall be of the types described in 4.1.1 and 4.1.2.

4.1.1 *Type I—Overhead Slide*—Any horizontal slide gate supported only from above.

4.1.2 *Type II—Cantilever Slide*—Any horizontal slide gate spanning an opening lacking a top or bottom support within that opening. Type II gates shall be supplied in one of two classes:

4.1.2.1 *Class 1*—Steel frame gates and aluminum frame gates using external rollers.

4.1.2.2 *Class 2*—Steel frame gates and aluminum frame gates using internal rollers.

## 5. Materials and Manufacture

5.1 *Materials*—The base materials of the gate frame shall be round or rectangular tubular members, welded at all corners. However, bolted or riveted, or both, field assemblies of modular panels are permitted.

5.1.1 The interior vertical or horizontal bracing, when needed, shall be the same metal tubular material and finish as the gate frame, but need not be the same size.

5.2 *Manufacture*—Gate frames shall be fabricated, and coated where necessary, as described in 5.2.1 through 5.2.3.

5.2.1 *Zinc-Coated Steel Frames* shall be in accordance with Specifications F 1043 or F 1083, or a combination thereof, and shall match that selected for any adjoining fence framework. Welded joints shall be coated in accordance with Practice A 780, employing a zinc-rich paint conforming to 4.2.2 of Practice A 780 and following only the procedures outlined in A 2.1.3 and A 2.1.4 of Practice A 780.

5.2.2 *Aluminum Alloy Gate Frames* shall be in accordance with Specification F 1043 and shall meet the performance criteria described in this specification.

5.2.3 *Polymer-Coated Steel or Polymer-Coated Aluminum Frames* shall be in accordance with Specification F 1043 and shall match that selected for any adjoining fence framework. Welded joints on steel gate frames shall be coated in accordance with Practice A 780, employing a zinc-rich paint conforming to 4.2.2 of Practice A 780 and following only the procedures outlined in A 2.1.3 and A 2.1.4 of Practice A 780. The painted areas shall then be top-coated to match the frame color.

5.2.4 *Chain Link Gate Fabric*—The fabric shall be as specified for the adjoining fence.

5.2.5 *Barbed Wire Top*—When specified, the barbed wire top shall have extensions to the gate frame to accommodate three strands of barbed wire uniformly spaced and positioned so that the top strand is approximately 1 ft [0.305 m] above the top horizontal member of the gate frame. Barbed wire shall be attached by suitable means to prevent wire from moving out of position and shall be supported by the gate frame extensions at maximum intervals of 10 ft [3.05 m].

<sup>1</sup> This specification is under the jurisdiction of ASTM Committee F14 on Fences and is the direct responsibility of Subcommittee F14.40 on Chain Link Fence and Wire Accessories.

Current edition approved January 10, 2003. Published March 2003. Originally approved in 1988. Last previous edition approved in 2000 as F 1184 94(2000).

<sup>2</sup> *Annual Book of ASTM Standards*, Vol 01.06.

## 6. Dimensions

6.1 Width of gate opening shall be measured from one inside face to the other inside face of the gate posts.

6.2 Height of gate shall be measured from the finished grade line to the top edge of the gate frame, to match the height of the adjoining fence as measured from the finished grade line to the top edge of the top rail or fabric.

## 7. Gate Accessories

7.1 All gate hardware shall be of sufficient strength and durability to support the gate and repeated open-close cycles.

7.2 In addition, latches shall have a provision for locking devices.

## 8. Additional Specifications for Type I Gates

8.1 The specifications given in 8.1.1 through 8.1.7 shall apply only to Type I (overhead slide) gates with opening widths up to 40 ft [12.2 m].

8.1.1 *Materials and Manufacture*—In addition to the welded construction specified in 5.1, the gate frame may be alternatively assembled with corner fittings. Gates assembled with corner fittings shall have adjustable truss rods of  $\frac{5}{16}$  in. [7.9 mm] minimum diameter on panels 5 ft [1.52 m] wide or wider. Truss rods shall be of the same base metal and finish as the gate frame.

8.1.2 *Shape and Size*—Shape and size of the gate frame shall conform to procurement drawings or shall be of the shape and size as specified. The gate frame width shall be the width of the gate opening plus the diameter of one gate post.

8.1.3 *Dimension and Weight*—Gate frame members shall have dimensions and weights as described in Table 1.

8.1.4 *Gate Posts*—Gates having an opening width of up to 10 ft [3.05 m] and an overhead clearance of up to 14 ft [4.27 m] shall be supported by steel posts with a nominal outside diameter of 2.875 in. [73.02 mm] and a minimum weight of 4.64 lb/linear ft [6.91 kg/m]. Gates having an opening width larger than 10 ft [3.05 m] but up to 24 ft [7.32 m] with an overhead clearance of up to 22 ft [6.71 m] shall be supported

by steel posts with a nominal outside diameter of 4.00 in. [101.6 mm] and a minimum weight of 6.56 lb/linear ft [9.77 kg/m]. Gates having an opening width larger than 22 ft [6.7 m] but up to 40 ft [12.2 m] and an overhead clearance of up to 22 ft [6.71 m] shall be supported by a double set of steel posts with a nominal outside diameter of 4.00 in. [101.6 mm] and a minimum weight of 6.56 lb/linear ft [9.77 kg/m], or a single set of steel posts with a nominal outside diameter of 6.625 in. [168.3 mm] and a minimum weight of 18.97 lb/linear ft [28.27 kg/m]. For post lengths over 24 ft [7.32 m], a single weld butt joint reinforced by an internal sleeve at least 2 ft [0.61 m] in length will be permitted. Gate posts shall be installed in accordance with Practice F 567.

8.1.5 *Gate Support Member*—The overhead track support member shall be as indicated in the project specifications. The support member shall extend over the gate opening span and the adjacent span at the specified ground clearance. The support member shall be of adequate length to ensure a clear opening. The track and member shall have proper corrosion protection.

8.1.6 *Roller Assembly*—The gate shall be suspended from the overhead track member by means of suitable internal or external roller assemblies. These roller assemblies shall consist of at least two swivel type trucks having sealed lubricant ball bearing wheels, or roller bearing wheels with grease fittings, and include a means to assure that the trucks remain properly aligned in or on the track during all normal operations of the gate.

8.1.7 *Gate Extensions*—Gate extensions, which consist of vertical members which span the distance between the top of the gate and the overhead track, shall be attached to the gate frame by means of a threaded or bolted coupling, or a combination of both.

8.1.8 *Gate Extension Bracing*—Suitable diagonal or horizontal bracing, or both, shall be provided to ensure proper rigidity of the gate during normal operation.

## 9. Additional Specifications for Type II Gates

9.1 The specifications given in 9.1.1 through 9.1.8 shall apply only to Type II (cantilever slide) gates with opening widths up to 30 ft [9.1 m] and heights (see 5.2) up to 8 ft [2.4 m].

9.1.1 *Shape and Size*—Shape and size of the gate frame shall conform to procurement drawings or shall be of the shape and size as specified. The gate frame width shall be the width of the opening plus the diameter of one gate post, plus an overhang or counterbalance panel of at least 40 % of the width of the opening. Only the size of the opening need be filled with fabric or other specified material. Class 1 and Class 2 gates with tubular steel frames shall conform to the dimensions and weights in Table 2.

9.1.2 *Gate Posts*—Gates having an opening width of up to 12 ft [3.7 m] shall be supported by steel posts with a nominal outside diameter of 2.875 in. [73.03 mm] and a minimum weight of 4.64 lb/linear ft [6.91 kg/m]. Gates having an opening width larger than 12 ft [3.7 m] shall be supported by steel posts with a nominal outside diameter of 4.00 in. [101.6 mm] and a minimum weight of 6.56 lb/linear ft [9.77 kg/m]. Gate posts shall be installed in accordance with Practice F 567.

**TABLE 1 Type I Gates—Gate Frame Members, Dimensions and Weights**

Gate Fabric Weight	Outside Dimensions		Nominal Weight <sup>A</sup>	
	in.	[mm]	lb/ft	[kg/m]
6 ft [1.8 m] or less				
Round tubular (steel)	1.66	[42.2]	1.83	[2.72]
Rectangular tubular (steel)	1.50	[38.1]	1.84	[2.74]
Round tubular (aluminum)	1.90	[48.3]	0.91	[1.35]
Rectangular tubular (aluminum)	2.00	[50.8]	0.91	[1.35]
Over 6 ft [1.8 m]				
Round tubular (steel)	1.90	[48.3]	2.28	[3.39]
Rectangular tubular (steel)	2.00	[50.8]	2.52	[3.75]
Round tubular (aluminum)	1.90	[48.3]	0.91	[1.35]
Rectangular tubular (aluminum)	2.00	[50.8]	0.91	[1.35]
Interior bracing <sup>B</sup>				
Round pipe (steel)	1.66	[42.2]	1.83	[3.39]
Rectangular pipe (steel)	1.50	[38.1]	1.84	[2.74]
Round tubular (aluminum)	1.90	[48.3]	0.91	[1.35]
Rectangular tubular (aluminum)	2.00	[50.8]	0.91	[1.35]

<sup>A</sup>Weight tolerance,  $\pm 5\%$ .

<sup>B</sup>The gate shall have vertical interior bracing at maximum intervals of 8 ft [2.4 m], and shall have a horizontal interior member if fabric height is 8 ft [2.4 m] or more.

**TABLE 2 Gate Frame Members, Dimensions and Weights Type II, Class 1 or Class 2 Gates with Tubular Steel Frames**

Gate Opening Width and Height	Outside Diameter of Pipe		Nominal Minimum Weight of Pipe	
	in.	[mm]	lb/ft	[kg/m]
Frame Size				
4 ft [1.2 m] width or less	1.90	[48.26]	2.28	[3.40 kg/m]
6 ft [1.8 m] height or less				
Over 4 ft [1.2 m] width	2.375	[60.325]	3.11	[4.63 kg/m]
All heights				
Interior bracing				
All gates	1.90	[48.26]	2.28	[3.40 kg/m]
Diagonal bracing				
All gates	1.90	[48.26]	2.28	[3.40 kg/m]

9.1.3 *Guide Posts (for Class 1 Gates Only)*—Guide posts for all Class 1 gates equal to the height of the gate shall be installed adjacent to each gate support post (see Fig. 1). The gate shall slide between the gate support posts and the guide posts. Guide posts shall be the same as, or one pipe diameter smaller than, the gate support posts and shall have a minimum weight of 3.11 lb/ft [4.63 kg/m].

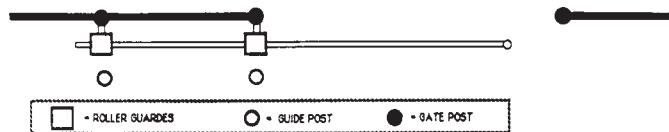
9.1.4 *Roller Assembly:*

9.1.4.1 External rollers for Class 1 gates shall be galvanized, malleable iron riding on a caged cylindrical roller or needle bearing. The bearing shall extend a minimum of 90 % of the width of the inside of the roller wheel, turn on a steel axle shaft and be housed within a steel bearing race or sleeve. The bearing shall not ride on any surface of the iron casting. The roller shall be drilled, tapped and equipped with a grease fitting. Roller assemblies shall be secured to the gate posts with a minimum of two 5/8 in. [15.9 mm] diameter “U” bolts, nuts, and lock washers for each assembly.

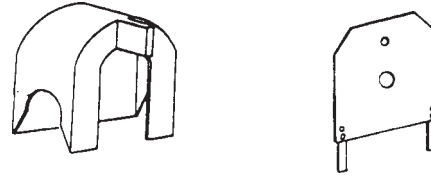
9.1.4.2 Internal rollers for Class 2 gates shall consist of two swivel type trucks having sealed lubricant ball bearing wheels and a means to assure that the trucks remain properly aligned in the track during all normal operations of the gate.

9.1.4.3 *Top Roller Guards*—Top external rollers for Class 1 gates shall be covered by top roller guards (see Fig. 2). Top roller guards shall be designed to help lessen pinch points, thereby helping eliminate possible injuries from top external rollers. The top roller guards shall be installed to help provide a safe opening from the bottom edge of the guard to the top edge of the gate frame. The maximum opening between the gate frame and the guard shall be 0.25 in. [6.4 mm].

9.1.4.4 *Bottom Protective Plates*—Bottom external rollers for Class 1 gates shall have a bottom roller protective plate attached (see Fig. 2). The bottom protective plate shall be



**FIG. 1 Post Configuration and Roller Guards**



**TOP ROLLER GUARD      BOTTOM PROTECTIVE PLATE**  
**FIG. 2 Top Roller Guard and Bottom Protective Plate**

secured behind the cotter pin (or behind the nut and cotter pin, if used) on the roller axle.

9.1.5 *Performance Criteria*—All Class 2 gates shall perform to the minimum criteria outlined in Table 3 and shall be installed to manufacturer’s specifications. All minimum performance criteria for the fabric or other filler material and other accessories installed shall be met, including a gate operator where specified.

9.1.6 *Field Adjustment*—All gates shall be designed with a means to adjust the vertical alignment of the gate in the field.

9.1.7 *Latching*—All gates shall be designed with sufficient lateral stability to assure that the gate will enter a catcher which has a 12 in. [305 mm] width (6 in. [152 mm] on each side from center) under wind loads as indicated and using the particular means of operation as indicated in the project specifications.

9.1.8 Assembly and installation instructions which clearly outline the proper procedure for all required assembly and proper installation and tuning of the gate shall be included with all gate shipments.

**10. Keywords**

10.1 cantilever slide; external rollers; gate posts; internal rollers; overhead slide; roller assembly

**TABLE 3 Minimum Performance Criteria, Type II, Class 2 Gates**

Performance Factor	Maximum Allowable Distances	
	Opening Width Up to 21 ft [6.4 m]	Opening Widths , 21 ft to 30 ft [6.4 m to 9.1 m]
	in. [mm]	in. [mm]
Downward deflection (unloaded) <sup>A</sup>	1/2 [12.7]	1 [25.4]
Downward deflection (loaded) <sup>A</sup>	2 [50.8]	3 [76.2]
Vertical chord <sup>B</sup>	1/2 [12.7]	1 [25.4]
Lateral chord (camber) <sup>C</sup>	1/2 [12.7]	1 [25.4]

<sup>A</sup>*Downward deflection, unloaded and loaded*—Measure the gate within 6 in. [152.4 mm] of being fully closed, and without support by devices at the latch end. The measurement is made twice, once with the gate totally unencumbered by any foreign weight, and once with a 200-lb [907-kg] dead weight attached to the front of the gate. The critical measurement is made at the maximum vertical distance between the extension of a straight line drawn at the top of the gate between the two internal truck assemblies, at the point of the two center bolts and the top of the gate at the outermost point of the latch end of the gate.

<sup>B</sup>*Vertical chord*—Measure the maximum vertical distance between a straight line drawn between the two top ends of the gate and any point on the top of the gate.

<sup>C</sup>*Lateral chord (camber)*—Measure the maximum lateral distance between a straight line drawn between the two top or the two bottom outside points of the vertical members of the gate and the corresponding lateral member.

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# Standard Specification for Zinc-5 % Aluminum-Mischmetal Alloy-Coated Steel Chain- Link Fence Fabric<sup>1</sup>

This standard is issued under the fixed designation F 1345; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon ( $\epsilon$ ) indicates an editorial change since the last revision or reapproval.

## 1. Scope

1.1 This specification covers zinc-5 % aluminum-mischmetal (Zn-5A1-MM) alloy-coated steel chain-link fence fabric, Zn-5A1-MM alloy-coated, before weaving.

1.2 The values stated in inch-pound units are to be regarded as the standard.

## 2. Referenced Documents

### 2.1 ASTM Standards:

A 90 Test Method for Weight of Coating on Zinc-Coated (Galvanized) Iron or Steel Articles<sup>2</sup>

A 491 Specification for Aluminum-Coated Steel Chain-Link Fence Fabric<sup>2</sup>

A 700 Practices for Packaging, Marking and Loading Methods for Steel Products for Domestic Shipment<sup>3</sup>

A 817 Specification for Metallic-Coated Steel Wire for Chain Link Fence Fabric<sup>2</sup>

### 2.2 Federal Standard:

Fed. Std. No. 123 Marking for Shipment, Civil Agencies<sup>4</sup>

### 2.3 Military Standards:

MIL-STD-129 Marking for Shipment and Storage<sup>4</sup>

MIL-STD-163 Steel Mill Products, Preparation for Shipment and Storage<sup>4</sup>

## 3. Terminology

### 3.1 Definitions of Terms Specific to This Standard:

3.1.1 *chain link fence fabric*—a fencing material made from steel wire helically wound and interwoven in such a manner as to provide a continuous mesh without knots or ties except in the form of knuckling, or of twisting the ends of the wires to form the selvage of the fabric.

3.1.2 *diamond count*—the number of diamond openings from one edge of the fabric to the other. The diamond count of a given fabric shall begin at the first completed diamond at one edge and continue to the unfinished half or full opening at the other edge.

3.1.3 *knuckling*—a term used to describe the type of selvage obtained by interlocking adjacent pairs of wire ends and then bending the wire ends back into a loop. The loop shall be closed or nearly closed to a measurement less than the diameter of the wire.

3.1.4 *twisting*—a term used to describe the type of selvage obtained by twisting adjacent pairs of wire ends together in a close helix of 1½ machine turns, which is equivalent to three full twists, and cutting the wire ends at an angle. The wire ends beyond the twist shall be at least ¼ in. [6.4 mm] long. This type of selvage is not used on fabric with a mesh size of less than 2 in. [50.8 mm].

## 4. Ordering Information

4.1 Orders for chain-link fence fabric purchased to this specification shall include the following information:

- 4.1.1 Quantity (Section 13),
- 4.1.2 Size of mesh (Section 7),
- 4.1.3 Size of wire (Section 8),
- 4.1.4 Height of fabric (Section 9),
- 4.1.5 Diamond count, if specified (Section 6),
- 4.1.6 Type of selvage (Section 10),
- 4.1.7 Certification if required (Section 16),
- 4.1.8 Class of Coating (Section 11), and
- 4.1.9 ASTM designation and year of issue.

4.2 All rolls of fencing accepted by the purchaser shall be billed on the basis of the original footage of the rolls before sampling, unless changed by contractual arrangement.

NOTE 1—A typical ordering description is as follows: 25 rolls, 50 ft each, chain-link fence fabric, Zn-5A1-MM alloy-coated, 2 in. mesh, 0.148 in. wire, 60 in. high, knuckled both selvages, class 2 coating to Specification F 1345.

<sup>1</sup> This specification is under the jurisdiction of ASTM Committee F14 on Fences and is the direct responsibility of Subcommittee F14.40 on Chain Link Fence and Wire Accessories.

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<sup>2</sup> *Annual Book of ASTM Standards*, Vol 01.06.

<sup>3</sup> *Annual Book of ASTM Standards*, Vol 01.05.

<sup>4</sup> Available from Standardization Documents Order Desk, Bldg. 4 Section D, 700 Robbins Ave., Philadelphia, PA 19111-5094, Attn: NPODS.

**5. Materials**

5.1 The wire from which the fabric is woven shall conform to all requirements of Specification A 817 for Type III coating, in the class of coating specified (Class 1 or Class 2).

**6. Weave**

6.1 The wire shall be woven throughout in the form of approximately uniform square mesh, having parallel sides and horizontal and vertical diagonals of approximately uniform dimensions. The top and bottom of the fabric shall be knuckled or twisted as specified in Section 10.

6.2 Typical diamond count for each standard height is shown in Table 1. Other diamond counts are permissible provided that they are consistent within a lot. The purchaser has the option to specify the diamond count (4.1.5).

**7. Size of Mesh**

7.1 The size of mesh shall be as indicated in Table 2.

7.2 The permissible variation from the specified size of mesh shall be  $\pm 1/8$  in. [ $\pm 3.2$  mm] for all mesh sizes except 1 in., and  $\pm 1/16$  in. [ $\pm 1.6$  mm] for 1 in. mesh size.

7.3 The size of mesh shall be determined by measuring the minimum clear distance between the wires forming the parallel sides of the mesh and determined as the average of two readings taken at right angles to each other.

**8. Size of Wire**

8.1 Chain-link fabric shall be fabricated from wire diameters as listed in Specification A 817, with a permissible variation from the specified diameter of the coated wire of  $\pm 0.005$  in. [ $\pm 0.13$  mm].

**9. Height of Fabric**

9.1 Chain-link fabric shall be furnished in the standard heights shown in Table 2. The height of fabric shall be the overall dimension from ends of twists or knuckles. The permissible variation from the specified height shall be  $\pm 1$  in. [ $\pm 25$  mm] for standard selvage.

**10. Selvage**

10.1 Unless otherwise specified by the purchaser, fabrics with 2- or 2 1/8-in. [50- or 54-mm] mesh, in heights 60 in. [1520 mm] and under shall be knuckled at both selvages. Fabric 72 in. [1830 mm] high and over shall be knuckled at one selvage and twisted at the other.

**TABLE 2 Sizes of Wire and Mesh<sup>A</sup>**

Specified Diameter of Coated Wire, in.	Size, Coated Wire Gage	Size of Mesh, in.	Height of Fence Fabric, in.
0.192	6	2	36, 42, 48, 60, 72, 84, 96, 108, 120, 144
0.148	9	2	36, 42, 48, 60, 72, 84, 96, 108, 120, 144
0.148	9	1	36, 42, 48, 60, 72, 84, 96, 108, 120, 144
0.120	11	2	36, 42, 48, 60, 72, 84
0.120	11	1 3/4	96, 108, 120, 144
0.120	11	1	36, 42, 48, 60, 72, 84, 96, 108, 120, 144
0.113	1 1/2	2 1/8	36, 42, 48, 60, 72

<sup>A</sup>See Appendix X1 for SI equivalents.

10.2 The selvages of fabrics with meshes of less than 2 in. [50 mm] shall be knuckled.

NOTE 2—**Caution:** Twisted selvages for fence fabric under 72 in. [1830 mm] in height are not recommended because of consumer safety considerations.

**11. Weight of Coating**

11.1 The weight of Zn-5A1-MM alloy coating on the fabric may be ordered in two coating weight classes as follows, in accordance with Specification A 817.

11.1.1 *Class 1*—The weight of Zn-5A1-MM alloy coating shall not be less than 0.6 oz/ft<sup>2</sup> [183 g/m<sup>2</sup>] of uncoated wire surface.

11.1.2 *Class 2*—The weight of Zn-5A1-MM alloy coating shall not be less than 1.0 oz/ft<sup>2</sup> [305 g/m<sup>2</sup>] of uncoated wire surface.

11.2 The weight of coating shall be determined in accordance with Test Method A 90.

**12. Workmanship**

12.1 Chain-link fence fabric shall be produced by methods recognized as good commercial practices.

12.2 Excessive roughness, blisters, and flaking shall be noted. These and other defects, if present to any considerable extent, shall provide a basis for rejection.

NOTE 3—Rust formations on the cut ends of the wire at the fabric selvages are inherent characteristics of this material and do not warrant rejection of the fabric.

**13. Standard Length of Rolls**

13.1 The standard length of roll shall be 50 ft [15.24 m]  $\pm 1\%$  except as otherwise agreed upon at the time of purchase.

**TABLE 1 Typical Diamond Count<sup>A</sup>**

Nominal Diameter of Coated Wire, in.	Size of Mesh, in.	Height of Fence Fabric, in.									
		36	42	48	60	72	84	96	108	120	144
0.192	2	10 1/2	12 1/2	13 1/2	17 1/2	20 1/2	24 1/2	27 1/2	31 1/2	34 1/2	4 1/2
0.148	2	10 1/2	12 1/2	13 1/2	17 1/2	20 1/2	24 1/2	27 1/2	31 1/2	34 1/2	41 1/2
0.148	1	20	23	27	33	39	45	53	61	67	79
0.120	2	10 1/2	12 1/2	14 1/2	17 1/2	20 1/2	24 1/2				
0.120	1 3/4							31 1/2	35 1/2	39 1/2	47 1/2
0.120	1	20	23	27	33	39	45	53	61	67	79
0.113	2 1/8	9 1/2	11 1/2	13 1/2	16 1/2	19 1/2					

<sup>A</sup>See Appendix X1 for SI equivalents.



13.2 The length of roll shall be determined by unrolling a roll of fabric on a flat surface and exerting tension by appropriate means to remove all slack. The tension applied shall not reduce the actual height of the fabric by more than 1/16 in./ft [5.3 mm/m] of height or by more than 1/2 in. [12.7 mm], whichever is less.

**14. Sampling and Number of Tests**

14.1 One roll from every 50 rolls or fraction thereof in a lot shall be taken at random as a sample for test purposes. In no case shall less than two samples be tested, except when the lot is less than 10 rolls, only one roll shall be selected for the sample.

14.2 Sample rolls selected shall be inspected for weave (Section 6), size of mesh (Section 7), diamond count (6.2), wire size (Section 8), height of fabric (Section 9), selvage (Section 10) and length (Section 13).

14.3 If any specimen tested fails to meet the requirements of this specification, the roll represented by the specimen shall be rejected and two additional rolls shall be inspected, both of which shall meet the requirements in every respect; otherwise, the lot represented by the samples may be rejected.

**15. Inspection**

15.1 Unless otherwise specified in the purchase order or contract, the manufacturer is responsible for the performance of all inspection and test requirements specified in this specification. Except as otherwise specified in the purchase order or contract, the manufacturer may use his own or any other suitable facilities for the performance of the inspection and test requirements unless disapproved by the purchaser at the time the order is placed. The purchaser shall have the right to perform any of the inspection and tests set forth in this

specification when such inspections and tests are deemed necessary to ensure that the material conforms to prescribed requirements.

**16. Certification**

16.1 When specified in the purchase order or contract, a producer's or supplier's certification shall be furnished to the purchaser that the material was manufactured, sampled, tested, and inspected in accordance with this specification and has been found to meet the requirements. When specified in the purchase order or contract a report of the test results shall be furnished.

**17. Packaging, Marking, and Loading**

17.1 Each length of chain-link fence fabric shall be tightly rolled and firmly tied. Each roll shall carry a tag showing the type of coating, the specified wire size, mesh size, the specified length and height of fabric in the roll, Specification A 491, and the name or mark of the manufacturer.

17.2 Unless otherwise specified, packaging, marking and loading for shipment shall be in accordance with recommended Practices A 700.

17.3 When specified in the contract or order, and for direct procurement by or direct shipment to the U.S. government, when Level A is specified, preservation, packaging, and packing shall be in accordance with Level A requirements of MIL-STD-163.

17.4 When specified in the contract or order, and for direct procurement by or direct shipment to the U.S. government, marking for shipment, in addition to the requirements specified in the contract or order, shall be in accordance with MIL-STD-129 for U.S. military agencies and in accordance with Fed. Std. No. 123 for civil agencies.

**APPENDIX**

(Nonmandatory Information)

**X1. APPROXIMATE SI EQUIVALENTS**

**TABLE X1.1 Approximate SI Equivalents for Tables 1 and 2**

Sizes of Wire and Mesh		Height of Fence Fabric	
in.	mm	in.	mm
0.192	4.88	36	910
0.148	3.76	42	1070
0.120	3.05	48	1220
0.113	2.87	60	1520
1	25	72	1830
1 3/4	44	84	2130
2	50	96	2440
2 1/8	54	108	2740
		120	3050
		144	3660

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## Standard Terminology Relating to Barbed Tape<sup>1</sup>

This standard is issued under the fixed designation F 1379; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon ( $\epsilon$ ) indicates an editorial change since the last revision or reapproval.

### 1. Scope

1.1 This terminology is intended for use by barbed tape specifiers and end-users to give a general understanding of the types, sizes, and configuration of barbed tape.

### 2. Terminology

**attachment points,  $n$** —points where alternate pairs of coil loops are joined around the circumference creating the concertina effect. (1992)

**barb length,  $n$** —measured from the barb point to the center line of the barb cluster. (1992)

**barb length classification,  $n$** —commonly used barbed types describing length and shape; such as long barb, medium barb, and short barb. (1995)

**barb spacing,  $n$** —the circumferential or linear distance between the center lines of the barb clusters. (1992)

**barbed tape,  $n$** —strip of metal, machined to produce clusters of sharp points. (1992)

**clip,  $n$** —a mechanical means of joining two loops. (1992)

**coil loop,  $n$** —one complete rotation ( $360^\circ$ ) of barbed tape. (1995)

**coil rotation,  $n$** —the spiraling effect that occurs as the concertina coils are deployed. (1993)

**concertina,  $n$** —a pattern formed by attaching adjacent loops of helical coils to one another at specified points on the circumference, resulting in an accordion-like configuration. (1992)

**concertina spacing,  $n$** —distance between adjacent concertina attachments in a concertina configuration, as measured down the length of the extended coil (also called *concertina attachment spacing*). (1992)

**cross section,  $n$** —shows the width and thickness of material, including the center section's shape, core diameter, and core wrap. (See Figs. 1-3 for types.) (1993)

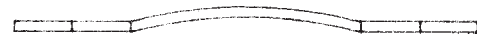


FIG. 1 Cross Section

**deployed length,  $n$** —the coils as extended for use. It is specified by the coverage where:

Helical coverage = number of coil loops per unit  $\times$  helical loop spacing

Concertina coverage = number of coil loops divided by 2  $\times$  concertina loop spacing. (1992)

**diameter,  $n$** —specified size diameters shall be measured across the center line of the packaged coil with a tolerance of  $\pm 2$  in.; installed diameters are always less than the packaged diameter of the coil. (1992)

**double coil,  $n$** —a configuration where a smaller diameter coil is placed inside a larger diameter coil. The assembled rolls may be either concertina style or helical style. (1993).

DISCUSSION— 1. Concertina style, for example, the 24 and 30-in. [61 and 76-mm] diameter coils are attached together at both ends for installation purposes.

DISCUSSION— 2. Helical style, for example, the 24 and 30-in. [61 and 76-mm] diameter coils are alternately attached together throughout the roll in four places around the circumference. In addition, one coil is fabricated in reverse helix to the companion coil.

**double loop ties,  $n$** —twistable ties used to secure the barbed tape at the tie point (also known as *bag ties*). (1993)

**flange,  $n$** —the extension of the wrap beyond the core wire or stiffening groove. See Fig. 4. (1993)

**helical,  $n$** —the most simple pattern in a barbed tape coil where there are no concertina attachments and each coil loop is left free in its natural spiral (also called *spiral*). (1992)



FIG. 2 Cross Section



FIG. 3 Cross Section

<sup>1</sup> This terminology is under the jurisdiction of ASTM Committee F14 on Fences and is the direct responsibility of Subcommittee F14.40 on Chain Link Fence and Wire Accessories.

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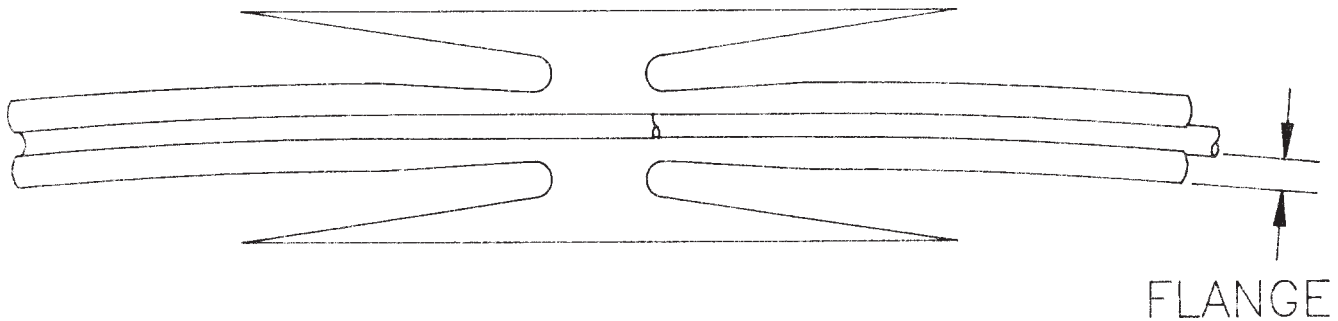


FIG. 4 Flange



FIG. 5 Off Set Barbs

**helical loop spacing, *n***—average distance between each coil loop in a helical coil configuration. (1992)

**long barb, *n***—barbs having an average length of  $1.2 \pm 5\%$ . (1995)

**loop spacer wire, *n***—wire that is attached loop-to-loop (or on consecutive attachment points) on the barbed tape to preset the loop spacing. (1992)

**medium barb, *n***—barbs having an average length of  $0.4 \pm 5\%$ . (1995)

**off set barbs, *n***—angling of the barb cluster from the center line of the tape in opposite directions. See Fig. 5. (1993)

**short barb, *n***—barbs having an average length of  $0.1875 \pm 5\%$ . (1995)

**single coil, *n***—a configuration where there is one coil with one

diameter, the coil being either helical or concertina style. (1992)

**spot welds, *n***—means of permanently joining two adjacent coil loops by fusing them through a heat or electrical process. (1993)

**splice connections, *n***—joining of consecutive coils. (1993)

**splicing tail, *n***—the barb clusters extending beyond the last attachment at both ends of the coil. (1993)

**tie points, *n***—the location where ties are placed securing the coils to brackets, wires, or cables including fence fabric, at the specified spacing. (1993)

**wire rings (hog rings), *n***—wires formed to make attachments during splicing or under certain conditions to serve as an alternate to the tie wires (see *double loop ties*). (1993)

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# Standard Guide for Specifying Industrial and Commercial Chain Link Fence<sup>1</sup>

This standard is issued under the fixed designation F 1553; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

## 1. Scope

1.1 This guide covers the recommended criteria for specifying the various elements of a chain link fence for industrial or commercial use and lists the available choices of components from the current ASTM standards.

1.2 No recommendation is made or implied concerning the merits of any particular product. The choice of product components of the chain link fence should be made by the writers of the project specification, based on their own perception of the merits of the products for the particular application.

1.3 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

## 2. Referenced Documents

### 2.1 ASTM Standards:

- A 121 Specification for Metallic-Coated Carbon Steel Barbed Wire<sup>2</sup>
- A 392 Specification for Zinc-Coated Steel Chain-Link Fence Fabric<sup>2</sup>
- A 491 Specification for Aluminum-Coated Steel Chain-Link Fence Fabric<sup>2</sup>
- A 824 Specification for Metallic-Coated Steel Marcellled Tension Wire for Use with Chain Link Fence<sup>2</sup>
- F 552 Terminology Relating to Chain Link Fencing<sup>2</sup>
- F 567 Practice for Installation of Chain-Link Fence<sup>2</sup>
- F 626 Specification for Fence Fittings<sup>2</sup>
- F 668 Specification for Poly(Vinyl Chloride) (PVC)-Coated Steel Chain-Link Fence Fabric<sup>2</sup>
- F 900 Specification for Industrial and Commercial Swing Gates<sup>2</sup>
- F 934 Specification for Standard Colors for Polymer Coated Chain Link Fence Materials<sup>2</sup>
- F 969 Practice for Construction of Chain-Link Tennis Court Fence<sup>2</sup>
- F 1043 Specification for Strength and Protective Coatings on Metal Industrial Chain Link Fence Framework<sup>2</sup>

- F 1083 Specification for Pipe, Steel, Hot-Dipped Zinc-Coated (Galvanized) Welded, for Fence Structures<sup>2</sup>
- F 1183 Specification for Aluminum Alloy Chain Link Fence Fabric<sup>2</sup>
- F 1184 Specification for Industrial and Commercial Horizontal Slide Gates<sup>2</sup>
- F 1345 Specification for Zinc-5 % Aluminum-Mischmetal Alloy-Coated Steel Chain Link Fence Fabric<sup>2</sup>
- F 1379 Terminology Relating to Barbed Tape<sup>2</sup>
- F 1664 Specification for Poly (Vinyl Chloride) (PVC)-Coated Steel Tension Wire Used With Chain-Link Fence<sup>2</sup>
- F 1665 Specification for Poly (Vinyl Chloride) (PVC)-Coated Steel Barbed Wire Used With Chain Link Fence<sup>2</sup>
- F 1712 Specification for Steel Chain Link Fencing Materials Used in Detention and Correctional Facilities<sup>2</sup>
- F 1910 Specification for Long Barbed Tape Obstacles<sup>2</sup>
- F 1911 Practice for Installation of Barbed Tape<sup>2</sup>
- F 2000 Guide for Fences for Ballfields and Other Sports Facilities<sup>2</sup>
- F 2049 Guide for Fences/Barriers for Public, Commercial, and Multi-Family Residential Use Outdoor Play Areas<sup>2</sup>
- 2.2 *CSI Standard:*<sup>3</sup>  
Master Format

## 3. Terminology

3.1 *Definitions*—See Terminology F 552 for definitions of terms relating to chain link fencing. See Terminology F 1379 for definitions of terms relating to barbed tape.

## 4. Summary of Practice

4.1 Many standard specifications for chain link fence are presently in existence. These include, but are not limited to, specifications of the federal, state, and municipal governments and their various agencies, as well as trade groups and organizations. Most of these specifications either reference existing ASTM standards or are duplications of some of these standards. This guide references only existing ASTM standards for this reason, since these standards encompass most standard components of a typical chain link fence installation.

4.2 A large percentage of construction specifiers use MasterFormat, a publication of the Construction Specifications Institute (CSI) for writing their project specifications. MasterFormat is divided into 16 divisions, and chain link fence is

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<sup>2</sup> *Annual Book of ASTM Standards*, Vol 01.06.

<sup>3</sup> Available from Construction Specifications Institute, 601 Madison St., Alexandria, VA 22314-1791.

listed as Section 02830 under Division 2—Site Work. The standard format for each section is in three parts: Part 1—General; Part 2—Products; and Part 3—Execution. This guide is written in a manner that will lend itself to following that format.

## 5. Part 1—General

5.1 List the work included, related work, erector qualification, referenced documents, criteria for shop drawings, and product data submittals, when required.

## 6. Part 2—Products

6.1 *Acceptable Manufacturers*—When desired, list the acceptable manufacturers of any components of the chain link fence.

### 6.2 *Materials:*

6.2.1 *Chain Link Fabric*—Select the material and type of coating from one of the following:

6.2.1.1 *Zinc-Coated Steel In Accordance With Specification A 392*—If zinc-coated steel, select Class 1 or Class 2 coating.

6.2.1.2 *Aluminum-Coated Steel In Accordance With Specification A 491*.

6.2.1.3 *Zinc-5 % Aluminum-Mischmetal (Zn-5Al-MM) Alloy-Coated Steel In Accordance With Specification F 1345*—If Zn-5Al-MM alloy-coated steel, select Class 1 or Class 2 coating.

6.2.1.4 *Aluminum Alloy In Accordance With Specification F 1183*.

6.2.1.5 *PVC-Coated Steel In Accordance With Specification F 668*:

(1) If PVC-coated steel, select Class 1, Class 2a, or Class 2b PVC coating.

(2) If PVC-coated steel, select the color from Specification F 934.

### 6.2.2 *Fence Posts, Rails, and Braces:*

6.2.2.1 Select the shapes and type of material (that is, steel or aluminum alloy) from Specifications F 1043 or F 1083 as applicable.

6.2.2.2 If steel, select the protective coating from Specification F 1043.

6.2.2.3 If optional supplemental color coated polymer coated steel, select polymer coating in accordance with Specification F 1043.

6.2.2.4 *Zinc-5 % Aluminum-Mischmetal (Zn-5Al-MM) Alloy-Coated Steel In Accordance With Specification A 824, Type III*—If Zn-5Al-MM alloy-coated steel, select Class 1 or Class 2 coating.

6.2.3 *Barbed Wire*—If barbed wire is desired, select the type of coating from one of the following:

6.2.3.1 If metallic coated steel in accordance with Specification A 121, select Design Number and coating Type A (aluminum coated steel), Z (zinc-coated steel) or ZA (zinc-5 % aluminum-mischmetal alloy coated steel).

(1) For Type Z or Type ZA, select the Class of coating from Specification A 121, Table 2 or 3.

6.2.3.2 If PVC or other polymer coated steel, select Coating Class 1, Class 2a or Class 2b in accordance with Specification F 1664, and select color in accordance with Specification F 934.

6.2.4 *Barbed Tape Obstacles*—select in accordance with the product descriptions in Specification F 1910.

6.2.5 *Tension Wire*—If tension wire is desired, select the type of coating from one of the following:

6.2.5.1 If metallic coated steel in accordance with Specification A 824, select coating Type I (aluminum coated steel), Type II (zinc-coated steel) or Type III (zinc-5 %-aluminum-mischmetal alloy coated steel).

(1) For Type II, select coating Class 1, Class 2, or Class 3;

(2) For Type III, select coating Class 1 or Class 2.

6.2.5.2 If PVC or other polymer coated steel, select core wire diameter, type of metallic coating, and Coating Class 1, Class 2a or Class 2b in accordance with Specification F 1665 and select color in accordance with Specification F 934.

6.2.6 *Fittings*—Indicate that the fittings are to be in accordance with Specification F 626, and list any choices, additions, or exceptions to that specification. In general, the type of material and any protective coating selected for the fittings should match that selected for the fence posts, rails and braces (See 6.2.2.).

6.2.7 *Swing Gates*—Indicate that the swing gates are to be in accordance with Specification F 900. Select single or double gates.

6.2.8 *Slide Gates*—Indicate that the slide gates are to be in accordance with Specification F 1184, and select Type I, overhead slide, or Type II, cantilever slide. Select single or double gates.

6.2.8.1 If Type II, cantilever slide, select Class 1 or Class 2.

### 6.3 *Components and Sizes:*

6.3.1 *Chain Link Fabric*—Select the size of mesh, size of wire, height of fabric, type of top selvage, and type of bottom selvage from Specifications A 392, A 491, F 668, F 1183, or F 1345.

NOTE 1—If the fence is for a tennis court, note special provisions for the size of mesh, size of wire, height of fabric, and type of top and bottom selvage listed in Practice F 969.

6.3.2 *Line Posts*—Select the size from Specification F 1043 and F 1083.

6.3.3 *Corner and Terminal Posts*—Select the size from Specifications F 1043 or F 1083.

NOTE 2—If slats, screening or other materials are to be installed in or on the chain link fabric, consideration should be given to selection of larger size line, corner and terminal posts, increasing the size of the post footings, decreasing the spacing of the line posts, decreasing the spacing of the tie wires or other fasteners securing the fabric to the framework, or various combinations of these measures, to withstand the additional wind, and snow or ice load placed on the fence. If the fence is for a tennis court, see 5.3, the section entitled “Caution Regarding Windscreens” in Practice F 969.

6.3.4 *Swing Gate Posts*—Indicate that the sizes of swing gate posts are to be in accordance with Specification F 900, Table 2.

6.3.5 *Slide Gate Posts*—Indicate that the sizes of slide gate posts are to be in accordance with Specification F 1184.

6.3.6 *Horizontal Framework Members*—Materials may be either pipe or roll-formed sections (referred to as *rails*), or tension wire. Select material and type of coating as follows:

6.3.6.1 Determine if the top horizontal member of the fence will be a rail or tension wire. If rail, select from Specification



F 1043. If tension wire, see 6.2.5.

NOTE 3—All fences should have either a top rail or top tension wire.

6.3.6.2 Determine if the fence is to have a mid-height (intermediate) rail. Select from Specification F 1043.

NOTE 4—Tension wire is not used as an intermediate horizontal member. An intermediate rail should always be specified on 12 ft high fence. Fences greater than 14 ft in height may require two or more intermediate rails, spaced at equal intervals between finished grade and the top of the fence. Intermediate rails may be specified on fences less than 12 ft in height when conditions warrant.

6.3.6.3 Determine if the fence is to have a bottom horizontal member. If rail, select from Specification F 1043. If tension wire, see 6.2.5.

NOTE 5—A bottom rail or bottom tension wire is optional but recommended for better security. A bottom horizontal member should be specified on any fence constructed with slats or screening.

6.3.6.4 Brace rails or brace rail and truss rod assemblies may be specified for fences greater than 5 ft in height (see Section 6 of Practice F 567). Select brace rail material from Specification F 1043. Select truss rod material from Specification F 626.

NOTE 6—Brace rails are required on any fences constructed without a top rail.

6.3.7 *Barbed Wire*—Indicate the number of strands (three, five, or six) and the configuration of barbed wire. If three strands, indicate whether the barbed wire is to be slanted inward or outward from the fence line or in a vertical plane above the fence.

6.3.8 *Gates*—Indicate the sizes of all gates (opening width).

6.3.9 If the fence is for a detention or correctional facility, see Specification F 1712 for special provisions on materials, some of which may supersede various provisions specified herein.

## 7. Part 3—Execution

### 7.1 *Installation:*

7.1.1 Indicate that the fence is to be installed per Practice F 567, and list any choices, additions, or exemptions to that practice.

7.1.2 If the fence is for a tennis court, indicate that special provisions for the installation listed in Practice F 969 are to be followed.

7.1.3 Indicate that any manufacturer's instructions for the installation of gate systems are to be followed.

7.1.4 If the fence is for a detention or correctional facility, indicate that special provisions contained in Practice F 1712 are to be followed.

7.1.5 If the fence is to include barbed tape obstacle, indicate that the requirements of Practice F 1911 are to be followed.

7.1.6 If the fence is for a ballfield or other sports facility, indicate that special provisions contained in Guide F 2000 are to be followed.

7.1.7 If the fence is for a public, commercial or multi-family residential use outdoor play area, indicate that any special provisions for the installation listed in Guide F 2049 are to be followed.

## 8. Keywords

8.1 chain link; fence; specifications

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# Standard Specification for Poly(Vinyl Chloride) (PVC) and Other Conforming Organic Polymer-Coated Steel Tension Wire Used with Chain-Link Fence<sup>1</sup>

This standard is issued under the fixed designation F 1664; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon ( $\epsilon$ ) indicates an editorial change since the last revision or reapproval.

## 1. Scope

1.1 This specification covers poly(vinyl chloride) and other conforming organic polymer-coated steel tension wire for use with chain link fence. Poly(vinyl chloride) and other organic polymer coatings hereinafter will be designated as polymer coating.

1.2 Tension wire, produced from three classes of wire coatings, is covered as follows:

1.2.1 *Class 1*, consisting of a polymer coating extruded over zinc-coated or aluminum-coated or zinc-5 % aluminum-mischmetal alloy-coated steel wire;

1.2.2 *Class 2a*, consisting of a polymer coating extruded and adhered to zinc-coated or aluminum-coated or zinc-5 % aluminum-mischmetal alloy-coated steel wire; and

1.2.3 *Class 2b*, consisting of a polymer coating fused and adhered to zinc-coated or aluminum-coated or zinc-5 % aluminum-mischmetal alloy-coated steel wire.

1.3 The values stated in inch-pound units are to be regarded as the standard. The values given in parentheses are for information only.

## 2. Referenced Documents

### 2.1 ASTM Standards:

A 90/A 90M Test Method for Weight [Mass] of Coating on Iron and Steel Articles with Zinc or Zinc-Alloy Coatings<sup>2</sup>

A 370 Test Methods and Definitions for Mechanical Testing of Steel Products<sup>3</sup>

A 428 Test Method for Weight of Coating on Aluminum-Coated Iron or Steel Articles<sup>2</sup>

D 1499 Practice for Operating Light- and Water-Exposure Apparatus (Carbon-Arc Type) for Exposure of Plastics<sup>4</sup>

F 552 Terminology Relating to Chain Link Fencing<sup>2</sup>

F 934 Specification for Standard Colors for Polymer Coated Chain Link Fence Materials<sup>2</sup>

G 23 Practice for Operating Light-Exposure Apparatus

(Carbon-Arc Type) With and Without Water for Exposure of Nonmetallic Materials<sup>5</sup>

G 26 Practice for Operating Light-Exposure Apparatus (Xenon-Arc Type) With and Without Water for Exposure of Nonmetallic Materials<sup>5</sup>

## 3. Terminology

3.1 Definitions—For definitions of terms such as fabric (chain-link fence), tension wire, PVC, and polymer coating, see Terminology F 552.

## 4. Ordering Information

4.1 Orders for tension wire purchased in accordance with this specification shall include the following information:

4.1.1 Quantity (expressed in number of coils);

4.1.2 Class of coating to be applied to metallic-coated steel wire;

4.1.3 Color of coating;

4.1.4 Selection of type of metallic coating on the steel wire substrate, which shall be the choice of the producer unless otherwise specified;

4.1.5 Core diameter of wire or minimum wire breaking strength, or both;

4.1.6 Packaging requirements; and

4.1.7 Certification, if required.

4.2 Any tests required other than those covered specifically in this specification must be stipulated by the purchaser in the order or contract.

NOTE 1—A typical ordering description is as follows: 20 coils polymer-coated steel tension wire, Class 2b coating, olive green color, 7-gage (0.177-in. [4.50 mm]) core wire, in 1000-ft (305-m) coils, certified to ASTM F 1664.

## 5. Materials

5.1 *Base Metal*—The base metal shall be steel of such quality and purity that, when drawn to the size of wire specified and coated with an organic polymer, the finished wire shall be of uniform quality and have properties and characteristics as prescribed in this specification.

5.2 Wire used for the manufacture of tension wire shall meet the requirements of this specification. The polymer coating

<sup>1</sup> This specification is under the jurisdiction of ASTM Committee F14 on Fences and is the direct responsibility of Subcommittee F14.40 on Chain Link Fence and Wire Accessories.

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<sup>2</sup> *Annual Book of ASTM Standards*, Vol 01.06.

<sup>3</sup> *Annual Book of ASTM Standards*, Vol 01.03.

<sup>4</sup> *Annual Book of ASTM Standards*, Vol 08.01.

<sup>5</sup> *Annual Book of ASTM Standards*, Vol 06.01.

shall be formulated and produced properly to conform to the requirements of this specification.

**6. Manufacture**

6.1 Class 1 polymer-coated wire shall have the coating extruded onto wire that conforms to the requirements as given in Table 1.

6.2 Class 2a polymer-coated wire shall have the coating extruded and adhered to wire that conforms to the requirements as given in Table 1.

6.3 Class 2b polymer-coated wire shall have the coating fused and adhered to wire that conforms to the requirements as given in Table 1.

**7. Size of Wire**

7.1 The permissible variation from the specified diameter of the core wire, 0.177 in. (4.50 mm) 7 gage or 0.148 in. (3.76 mm) 9 gage, shall be ±0.005 in. (0.13 mm).

**8. Breaking Strength**

8.1 Tension wire shall meet the minimum breaking strength indicated in Table 2 when tested in accordance with Test Methods and Definitions A 370.

8.2 Specimens to establish conformance with this requirement shall comprise individual pieces from a coil of the tension wire. The specimens shall be of sufficient length so as to be gripped firmly in the testing machine. The polymer coating may be removed from the sample by chemical or mechanical means before testing.

**9. Weight of Metallic Coatings**

9.1 The weight of the metallic coating shall conform to Table 1.

9.2 The weight of the coating shall be determined on an individual piece of wire over 12 in. (305 mm).

9.3 The weight of the zinc or zinc-5 % aluminum mischmetal alloy coating shall be determined by the method contained in Test Method A 90/A 90M after stripping the polymer coating as outlined in Section 10.

9.4 The weight of the aluminum coating shall be determined by the method contained in Test Method A 428 after stripping the polymer coating as outlined in Section 10.

**10. Thickness of PVC Coating**

10.1 The thickness of the coating shall be in accordance with Table 3.

10.2 The thickness of the coating shall be determined on an individual piece of wire. This specimen may be any length of wire over 12 in. (305 mm).

10.3 For Class 1 and Class 2a material, strip the coating mechanically from the wire and measure the minimum and maximum thickness of the coating with a suitable micrometer.

**TABLE 2 Weight of Metallic Coatings**

Specified Diameter of Core Wire, in. (mm)	Minimum Weight of Zinc Coating, oz/ft <sup>2</sup> (g/m <sup>2</sup> )	Minimum Weight of Aluminum Coating, oz/ft <sup>2</sup> (g/m <sup>2</sup> )	Minimum Weight of Zinc-5 % Aluminum-Mischmetal Coating, oz/ft <sup>2</sup> (g/m <sup>2</sup> )
0.177 (4.50)	0.40 (122)	0.20 (61)	0.40 (122)
0.148 (3.76)	0.30 (92)	0.20 (61)	0.30 (92)

**TABLE 3 Thickness of Polymer Coating**

	Class 1 and Class 2a, in. (mm)	Class 2b, in. (mm)
Minimum thickness at any point	0.015 (0.38)	0.006 (0.15)
Maximum thickness at any point	0.025 (0.64)	0.012 (0.30)

10.4 For Class 2b material, strip the coating by chemical means and determine the diameter of the bare wire. Scrape the coating from one side of the wire and measure the reduced diameter with a micrometer. The thickness of the coating at this point is the difference between the measurement thus obtained and the measured diameter of the bare wire. In a similar manner, determine the thickness of the coating at right angles to the first determination.

10.5 Take care not to remove any of the metallic surface when removing polymer coating by scraping.

**11. Properties of Polymer-Coated Tension Wire**

11.1 The polymer-coated tension wire shall have a demonstrated ability to conform to the following requirements:

**11.2 Adhesion Tests:**

11.2.1 Class 2a must conform to the requirements of 11.2.2. Class 2b must conform to the requirements of 11.2.3.

11.2.2 Three specimens from each lot shall be tested. Measure a distance of ¾ in. (19 mm) from the end of the specimen. With a regular hand grip wire stripper, exert maximum hand pull parallel to the axis of the wire. Attempt to remove the measured portion of the polymer sleeve from the core wire. The lot shall be acceptable if the polymer sleeve is not capable of being removed from the core wire on all three samples.

11.2.3 Three specimens from each lot shall be tested. Make two cuts parallel to the axis of the wire through the coating, approximately ¼-in. (1.6-mm) apart, at least ½ in. (12.7 mm) long. With a knife, peel back a section of the coating between ½ and ¾ in. (3.2 and 6.4 mm) long to produce a tab. Attempt to remove the ¼-in. (1.6-mm) strip of coating by pulling the tab. The lot shall be acceptable if the coating breaks rather than separates from the core wire on all three specimens.

11.3 *Accelerated Aging*—The polymer-coated wire shall withstand exposure for 1000 h without failure at a black panel temperature of 145°F (63°C) when tested in accordance with Practice D 1499. Type D, E, or F apparatus described in Practice G 23 or Type BH apparatus described in Practice G 26 shall be used for the test. The product shall be construed to have failed the test if one of the following occurs:

11.3.1 Shrinkage of the polymer coating shall be no greater than ¼ in./ft (1.6 mm/305 mm) of wire, or

11.3.2 There shall be no significant change in color or gloss of the polymer surface as determined by visual inspection.

**TABLE 1 Breaking Strength of Metallic-Coated Core Wire**

Specified Diameter of Core Wire, in. (mm)	Minimum Breaking Strength, lbf (N)
0.177 (4.50)	1950 (8670)
0.148 (3.76)	1290 (5740)

11.4 *Color*—Unless otherwise stipulated by the purchaser, the color of the coating shall be in accordance with the standard colors contained in Specification F 934: green, olive green, brown, and black.

## 12. Workmanship

12.1 The polymer-coated tension wire shall be produced by methods recognized as good commercial practices. The coating shall be without voids. The coated wire shall be manufactured without tears or cuts that reveal the substrate.

## 13. Standard Length of Coils

13.1 The standard length of coils shall be 1000 ft (305 m)  $\pm 1\%$  except as otherwise agreed upon at the time of purchase.

## 14. Field Sampling and Number of Tests

14.1 The purchaser may select at random one coil from every 50 coils or fraction thereof for test purposes, except that in no case shall fewer than two coils be sampled.

14.2 Sample coils thus selected shall be checked for wire size (Section 7).

14.3 Test specimens taken from the outside end of the sample coils shall be tested for the class of polymer coating (Section 6 and Section 11), core wire size (Section 7), breaking strength (Section 8), weight of metallic coating (Section 9), and thickness of polymer coating (Section 10).

14.4 If any specimen tested fails to conform to the specified requirements, the coil represented by the specimen shall be rejected and two additional coils shall be tested, both of which

shall meet the requirements in every respect; otherwise the lot represented by the samples may be rejected.

## 15. Inspection

15.1 The supplier is responsible for the performance of all inspection and test requirements as specified herein. The supplier may use his own or other suitable facilities for inspection and testing unless the purchaser does not approve at the time the order is placed. The purchaser has the right to make any of the inspection and tests outlined where such are deemed necessary.

## 16. Certification and Report

16.1 Upon the request of the purchaser in the contract or order, a manufacturer's certification that the material was produced in accordance with the specification shall be furnished.

## 17. Packaging, Package Marking, and Loading

17.1 Marking shall be by a tag attached securely to each coil of tension wire and shall indicate the identity of the producer, quantity, core wire size, type of coating, class of coating (if applicable), and ASTM designation.

17.2 Packaging of the coils of wire shall be agreed upon between the producer and the purchaser. This agreement may include the coil dimension and weight.

## 18. Keywords

18.1 chain-link fence; polymer-coated steel wire; steel wire; tension wire; wire

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# Standard Specification for Poly(Vinyl Chloride) (PVC) and Other Conforming Organic Polymer-Coated Steel Barbed Wire Used With Chain-Link Fence<sup>1</sup>

This standard is issued under the fixed designation F 1665; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon ( $\epsilon$ ) indicates an editorial change since the last revision or reapproval.

## 1. Scope

1.1 This specification covers poly(vinyl chloride) and other conforming organic polymer-coated steel barbed wire consisting of two polymer-coated strands, with four-point barbs of zinc-coated steel or aluminum alloy wire. Poly(vinyl chloride) and other organic polymer coatings hereinafter will be designated as polymer coating.

1.2 Barbed wire strand wire, produced from three classes of wire coatings, is covered as follows:

1.2.1 *Class 1*, consisting of a polymer coating extruded over zinc-coated or aluminum-coated or zinc-5 % aluminum-mischmetal alloy-coated steel wire;

1.2.2 *Class 2a*, consisting of a polymer coating extruded and adhered to zinc-coated or aluminum-coated or zinc-5 % aluminum-mischmetal alloy-coated steel wire; and

1.2.3 *Class 2b*, consisting of a polymer coating fused and adhered to zinc-coated or aluminum-coated or zinc-5 % aluminum-mischmetal alloy-coated steel wire.

1.3 The values stated in inch-pound units are to be regarded as the standard. The values given in parentheses are for information only.

## 2. Referenced Documents

### 2.1 ASTM Standards:

A 90/A90M Test Method for Weight [Mass] of Coating on Iron and Steel Articles with Zinc or Zinc-Alloy Coatings<sup>2</sup>

A 370 Test Methods and Definitions for Mechanical Testing of Steel Products<sup>3</sup>

A 428 Test Method for Weight of Coating on Aluminum-Coated Iron or Steel Articles<sup>2</sup>

A 700 Practices for Packaging, Marking, and Loading Methods for Steel Products for Domestic Shipment<sup>4</sup>

D 1499 Practice for Operating Light- and Water-Exposure

Apparatus (Carbon-Arc Type) for Exposure of Plastics<sup>5</sup>

F 552 Terminology Relating to Chain Link Fencing<sup>2</sup>

F 934 Specification for Standard Colors for Polymer Coated Chain Link Fence Materials<sup>2</sup>

G 23 Practice for Operating Light-Exposure Apparatus (Carbon-Arc Type) With and Without Water for Exposure of Nonmetallic Materials<sup>6</sup>

G 26 Practice for Operating Light-Exposure Apparatus (Xenon-Arc Type) With and Without Water for Exposure of Nonmetallic Materials<sup>6</sup>

2.2 *Federal Standard*:<sup>7</sup>

Fed. Std. No. 123 Marking for Shipments (Civil Agencies)

2.3 *Military Standards*:<sup>7</sup>

MIL-STD-129 Marking for Shipment and Storage

MIL-STD-163 Steel Mill Products, Preparation for Shipment and Storage

## 3. Terminology

3.1 Definitions—For definitions of terms such as fabric (chain-link fence), PVC, and polymer coating, see Terminology F 552.

## 4. Classification

4.1 Polymer-coated steel barbed wire is supplied in a choice of two types as follows:

4.1.1 *Type I (Standard)*, with barbs spaced on 5-in. (127-mm) centers; and

4.1.2 *Type II (High Security)*, with barbs spaced on 3-in. (76-mm) centers.

## 5. Ordering Information

5.1 Orders for barbed wire purchased in accordance with this specification shall include the following information:

5.1.1 Quantity (expressed in number of spools);

5.1.2 Length of spools (1320 or 1000 ft (402 or 305 m); see 9.4);

<sup>1</sup> This specification is under the jurisdiction of ASTM Committee F14 on Fences and is the direct responsibility of Subcommittee F14.40 on Chain Link Fence and Wire Accessories.

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<sup>2</sup> *Annual Book of ASTM Standards*, Vol 01.06.

<sup>3</sup> *Annual Book of ASTM Standards*, Vol 01.03.

<sup>4</sup> *Annual Book of ASTM Standards*, Vol 01.05.

<sup>5</sup> *Annual Book of ASTM Standards*, Vol 08.01.

<sup>6</sup> *Annual Book of ASTM Standards*, Vol 06.01.

<sup>7</sup> Available from Standardization Documents Order Desk, Bldg. 4 Section D, 700 Robbins Ave., Philadelphia, PA 19111-5094, Attn: NPODS.

- 5.1.3 Class of a polymer coating to be applied to metallic-coated steel strand wire;
- 5.1.4 Color of coating;
- 5.1.5 Type of barbs (galvanized steel or aluminum alloy; see 6.3);
- 5.1.6 Type of barbed wire (Type I or II; see 4.1.1 and 4.1.2);
- 5.1.7 Selection of type of metallic coating on the steel strand wire substrate, which shall be the choice of the producer unless otherwise specified;
- 5.1.8 Packaging requirements;
- 5.1.9 ASTM designation and year of issue; and
- 5.1.10 Certification, if required;
- 5.2 Any tests required other than those covered specifically in this specification must be stipulated by the purchaser in the order or contract.
- 5.3 All spools of barbed wire accepted by the purchaser shall be billed on the basis of the number and original length.

NOTE 1—A typical ordering description is as follows: 20 spools polymer-coated steel barbed wire, 1000-ft (305-m) spools, Class 2b coating, olive green color, aluminum alloy barbs, Type II (high security), on pallets, certified to ASTM F1665.

**6. Materials**

6.1 *Base Metal*—The base metal shall be steel of such quality and purity that, when drawn to the size of wire specified, it shall be of uniform quality and have properties and characteristics as prescribed in this specification.

6.2 Wire used for the manufacture of strand wire shall meet the requirements of this specification. The polymer coating shall be formulated and produced properly to conform to the requirements of this specification.

6.3 *Materials for Barbs:*

6.3.1 *Zinc-Coated Steel Wire*, if used for the barbs, shall be 14 gage, 0.080 in. (2.03 mm), having a Class 3 zinc coating, minimum 0.70 oz/ft (215 g/m) when tested in accordance with Test Method A 90/A 90M.

6.3.2 *Aluminum Alloy Wire*, if used for the barbs, shall be 14 gage, 0.080 in. (2.03 mm), Alloy 5000-H38, 6061-T94, or equal, as agreed upon between the manufacturer and the purchaser at the time of purchase.

6.3.3 The choice of either zinc-coated steel wire or aluminum alloy wire for the barbs shall be that of the manufacturer, unless otherwise specified by the purchaser.

**7. Manufacture**

7.1 Class 1 polymer-coated wire shall have the coating extruded onto the strand wire that conforms to the requirements as given in Table 1.

7.2 Class 2a polymer-coated wire shall have the coating extruded and adhered to the strand wire that conforms to the requirements as given in Table 1.

7.3 Class 2b polymer-coated wire shall have the coating fused and adhered to the strand wire that conforms to the requirements as given in Table 1.

**8. Size and Construction**

8.1 All barbed wire furnished in accordance with this specification shall be fabricated from two strands of 14 gage, 0.080-in. (2.03-mm) metallic-coated core, polymer-coated steel wire, with four-point barbs of 14 gage, 0.080-in. zinc-coated steel or aluminum alloy wire.

**9. Size and Permissible Variations**

9.1 *Line Wire*—The permissible variation from the nominal diameter of the wire shall be ±0.004 in. (0.10 mm).

9.2 *Barbs*—Due to the mechanics of the manufacture when forming the barbs, a certain amount of out-of-roundness can be expected, and this precludes barbs from being subjected to checks for other than nominal diameter and length. Measured from the center of the two strand wires, the barb length shall be 3/8 in. (9.5 mm), minimum.

9.3 *Spacing of Barbs*—Barbs shall be spaced as indicated in 4.1.1 or 4.1.2. The individual barb spacing shall be measured from the edge of one barb at the strand to the corresponding edge of the adjacent barb. Cumulative spacing is established by counting the total number of barbs in a 25-ft (7.6-m) length of barbed wire. Barbs are subject to relocation during fabrication and handling; therefore, a rigid interpretation of the spacing requirement may lead to undue rejections. Any sample with 93.5 % of the individual barb spacings conforming to the specified spacing (±3/4 in. (19 mm)) and containing a minimum of 55 barbs (5-in. (127-mm) spacing) or a minimum of 86 barbs (3-in. (76-mm) spacing) in 25 ft shall be considered acceptable.

9.4 The length of barbed wire in each spool shall be 80 rods (402 m). This is equivalent to one-quarter mile, or 1320 ft. At the option of the manufacturer, 1000-ft (305-m) spools may be offered.

**10. Joints and Workmanship**

10.1 Splicing of individual wires by means of a wrap joint or an electric butt weld is permitted. Not more than three splices or joints shall exist in any spool of barbed wire. Such splices or joints shall be made in a workmanlike manner.

10.2 The strands shall be twisted with a uniform length of lay. The direction of twisting may be either right or left hand. Alternate left and right hand twisting is not permitted.

10.3 The barbs shall be sharp, well-formed, wrapped tightly, and spaced in accordance with 9.3.

**11. Weight of Metallic Coating**

11.1 The minimum weight of zinc coating for the galvanized barbs shall be 0.70 oz/ft (215 g/m). The minimum weight of the strand wire metallic coating shall conform to Table 1 when tested in accordance with Test Method A 90/A 90M or Test Method A 428, as applicable.

**12. Breaking Strength**

12.1 The minimum breaking strength of the stranded barbed wire shall be 760 lbf (3380 N) when tested in accordance with

**TABLE 1 Weight of Strand Wire Metallic Coatings**

Specified Core Diameter of Strand Wire, in. (mm)	Minimum Weight of Zinc Coating, oz/ft (g/m)	Minimum Weight of Aluminum Coating, oz/ft <sup>2</sup> (g/m <sup>2</sup> )	Minimum Weight of Zinc-5 % Aluminum-Mischmetal Coating, oz/ft (g/m)
0.080 (2.03)	0.25 (75)	0.20 (61)	0.25 (75)

Test Methods and Definitions A 370. This breaking strength value reflects that of both strand wires together as one unit.

**13. Properties of Polymer-Coated Barbed Wire**

13.1 The polymer-coated barbed wire shall have a demonstrated ability to conform to the following requirements:

13.2 *Adhesion Tests:*

13.2.1 Class 2a shall conform to the requirements of 13.2.2. Class 2b shall conform to the requirements of 13.2.3.

13.2.2 Three specimens from each lot shall be tested. Measure a distance of 3/4 in. (19 mm) from the end of the specimen. With a regular hand grip wire stripper, exert maximum hand pull parallel to the axis of the wire. Attempt to remove the measured portion of the polymer sleeve from the core wire. The lot shall be acceptable if the polymer sleeve is not capable of being removed from the core wire on all three samples.

13.2.3 Three specimens from each lot shall be tested. Make two cuts parallel to the axis of the wire through the coating, approximately 1/16 in. (1.6 mm) apart, at least 1/2 in. (12.7 mm) long. With a knife, peel back a section of the coating between 1/8 and 1/4 in. (3.2 and 6.4 mm) long to produce a tab. Attempt to remove the 1/16-in. (1.6 mm) strip of coating by pulling the tab. The lot shall be acceptable if the coating breaks rather than separates from the core wire on all three specimens.

13.3 *Accelerated Aging*—The polymer-coated wire shall withstand exposure for 1000 h without failure at a black panel temperature of 145°F (63°C) when tested in accordance with Practice D 1499. Type D, E, or F apparatus described in Practice G 23 or Type BH apparatus described in Practice G 26 shall be used for the test. The product shall be construed to have failed the test if one of the following occurs:

13.3.1 Shrinkage of the polymer coating is greater than 1/16 in./ft (1.6 mm/305 mm) of wire.

13.3.2 There shall be no significant change in color or gloss of the polymer surface as determined by visual inspection.

13.4 *Color*—Unless otherwise stipulated by the purchaser, the color of the polymer shall be in accordance with the standard colors contained in Specification F 934: green, olive green, brown, and black.

**14. Thickness of Polymer Coating**

14.1 The thickness of the polymer coating shall be in accordance with Table 2.

14.2 The thickness of the polymer coating shall be determined on an individual piece of wire. This specimen may be any length of wire over 12 in. (305 mm).

14.3 For Class 1 and Class 2a material, strip the polymer coating mechanically from the wire and measure the minimum and maximum thickness of the polymer coating with a suitable micrometer.

14.4 For Class 2b material, strip the polymer coating by chemical means and determine the diameter of the bare wire.

**TABLE 2 Thickness of Polymer Coating**

	Class 1 and Class 2a, in. (mm)	Class 2b, in. (mm)
Minimum thickness at any point	0.015 (0.38)	0.006 (0.15)
Maximum thickness at any point	0.025 (0.64)	0.010 (0.25)

Scrape the coating from one side of the wire and measure the reduced diameter with a micrometer. The thickness of the coating at this point is the difference between the measurement thus obtained and the measured diameter of the bare wire. In a similar manner, determine the thickness of the coating at right angles to the first determination.

14.5 Take care not to remove any of the metallic surface when removing polymer coating by scraping.

**15. Sampling**

15.1 For the purpose of the tests, one spool from every 50 spools or fraction thereof in a lot shall be selected at random, or a total of seven samples, whichever is less. A lot shall consist of all of the spools of a single type of barbed wire offered for delivery at the same time.

15.2 *Test Specimens*—A 4-ft (1.2-m) length of barbed wire shall be cut from the end of the spool for the tests prescribed in Sections 11 through 14. Each strand wire shall be tested for its metallic and polymer coating. The breaking strength value shall be determined by having the twisted strand tested as a composite.

15.3 Instead of testing wire for its coating and breaking strength from the completed barbed wire in accordance with 15.2, the manufacturer may elect to establish compliance with Sections 11 through 14 by tests made on wire prior to fabrication. If the manufacturer makes this election, the purchaser still reserves the right to test wire from the completed barbed wire for compliance.

15.4 For the purpose of inspection, a maximum of two spools from the lot (as described in 15.1) may be subjected to observations for barb length and spacing, overall length, and general workmanship.

15.5 Instead of inspecting for length by unrolling full spools in accordance with 15.4, the purchaser and the manufacturer may agree on a weight per spool related to the wire size or measuring tools used during manufacturing. The purchaser still reserves the right to confirm the length by actual measurement.

15.6 Inspection for barb spacing is normally performed on the outer 25-ft (7.6-m) length of a spool; this permits repackaging of the spool. Any other selection shall be as agreed upon between the manufacturer and the purchaser.

**16. Retests and Rejection**

16.1 Should one or more of the individual wire specimens fail the coating tests or a strand specimen fail the breaking strength test, the lot shall be subjected to retest. Four additional spools of barbed wire for each 50 spools offered shall be sampled for retest purposes. The lot size then becomes 50, except that this lot size may vary slightly to accommodate pallet count when the barbed wire is palletized.

16.2 *Retesting for Coating*—Should more than two of the individual strand wires of the retest specimens fail to meet the specified coating, the entire lot represented by the retest may be rejected.

16.3 *Retesting for Breaking Strength*—Should any of the retest specimens fail to meet the minimum breaking strength values specified, the entire lot represented by the specimens may be rejected.

16.4 Instead of rejecting the entire lot as provided for in

16.2 and 16.3, the producer or purchaser may test specimens from every spool, as provided for in 15.2, and the purchaser may reject only those spools failing the weight of coating or breaking strength requirements.

16.5 *Reinspection for Barb Spacing, Barb Length, and Overall Length*—Should either of the sample spools fail to meet the requirements of 9.2 through 9.4, two additional spools shall be selected for inspection. The lot may be rejected if either of these spools fails to meet the requirements.

## 17. Inspection

17.1 Unless otherwise specified in the purchase order or contract, the manufacturer is responsible for performance of all inspection and test requirements specified in this specification. Except as otherwise specified in the purchase order or contract, the manufacturer may use his own or any other suitable facilities for performance of the inspection and test requirements unless disapproved by the purchaser at the time the order is placed. The purchaser shall have the right to perform any of the inspection and tests set forth in this specification when such inspections and tests are deemed necessary to ensure that the material conforms to prescribed requirements.

## 18. Certification

18.1 When specified in the purchase order or contract, a producer's or supplier's certification shall be furnished to the

purchaser that the material was manufactured, sampled, tested, and inspected in accordance with this specification and has been found to meet the requirements. When specified in the purchase order or contract, a report of the test results shall be furnished.

## 19. Packaging and Marking

19.1 Unless otherwise specified, packaging, marking, and loading for shipment shall be in accordance with Practices A 700.

19.2 When specified in the contract or order, and for direct procurement by or direct shipment to the U.S. government, when Level A is specified, preservation, packaging, and packing shall be in accordance with the Level A requirement of MIL-STD-163.

19.3 When specified in the contract or order, and for direct procurement by or direct shipment to the U.S. government, marking for shipment, in addition to the requirements specified in the contract or order, shall be in accordance with MIL-STD-129 for U.S. military agencies and in accordance with Fed. Std. No. 123 for U.S. government civil agencies.

## 20. Keywords

20.1 barbed wire; chain-link fence; fencing material; polymer coated steel wire; PVC coated steel wire; wire

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# Standard Specification for Steel Chain-Link Fencing Materials Used in Detention and Correctional Facilities<sup>1</sup>

This standard is issued under the fixed designation F 1712; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon ( $\epsilon$ ) indicates an editorial change since the last revision or reapproval.

## 1. Scope

1.1 This specification covers chain-link fencing material applications for detention and correctional facilities.

1.2 The values stated in inch-pound units are to be regarded as the standard. The SI values given in parentheses are provided for information only.

## 2. Referenced Documents

### 2.1 ASTM Standards:

- A 121 Specification for Zinc-Coated (Galvanized) Steel Barbed Wire<sup>2</sup>
- A 392 Specification for Zinc-Coated Steel Chain-Link Fence Fabric<sup>2</sup>
- A 491 Specification for Aluminum-Coated Steel Chain-Link Fence Fabric<sup>2</sup>
- A 824 Specification for Metallic-Coated Steel Marcellled Tension Wire for Use With Chain Link Fence<sup>2</sup>
- F 626 Specification for Fence Fittings<sup>2</sup>
- F 668 Specification for Poly (Vinyl Chloride) (PVC) and Other Organic Polymer-Coated Steel Chain-Link Fence Fabric<sup>2</sup>
- F 900 Specification for Industrial and Commercial Swing Gates<sup>2</sup>
- F 934 Specification for Standard Colors for Polymer-Coated Chain Link Fence Materials<sup>2</sup>
- F 1043 Specification for Strength and Protective Coatings on Metal Industrial Chain-Link Fence Framework<sup>2</sup>
- F 1184 Specification for Industrial and Commercial Horizontal Slide Gates<sup>2</sup>
- F 1345 Specification for Zinc-5 % Aluminum-Mischmetal Alloy-Coated Steel Chain-Link Fence Fabric<sup>2</sup>
- F 1379 Terminology Relating to Barbed Tape<sup>2</sup>
- F 1664 Specification for Poly (Vinyl Chloride) (PVC) and Other Conforming Organic Polymer-Coated Steel Tension Wire Used with Chain-Link Fence<sup>2</sup>
- F 1665 Specification for Poly (Vinyl Chloride) (PVC) and Other Conforming Polymer-Coated Steel Barbed Wire Used with Chain-Link Fence<sup>2</sup>

F 1910 Specification for Long Barbed Tape Obstacles<sup>2</sup>

F 1911 Practice for Installation of Barbed Tape<sup>2</sup>

F 1916 Specifications for Selecting Chain Link Barrier Systems with Coated Chain Link Fence Fabric and Round Posts for Detention Applications<sup>3</sup>

### 2.2 Other Standard:

UL 325 Door, Drapery, Gate, Louver, and Window Operators and Systems<sup>4</sup>

## 3. Significance and Use

3.1 Typical end users of this specification are detention and correctional facilities.

## 4. Materials and Manufacture

4.1 *Framework*—Shall meet the size and strength requirements in Specification F 1043 for heavy industrial fence framework. Where icing conditions and high wind loads are prevalent or fences are higher than 12 ft (3.7 m), strength requirements shall be determined through engineering calculations. Horizontal top, mid or bottom rails if specified shall be 1.660 in. (42 mm) O.D., or roll-formed section 1¼ by 1⅝ in. (32 by 41 mm). Framework may be polymer-coated and color shall be one of the choices listed in Specification F 934. Framework coatings shall be in accordance with Specification F 1043.

4.2 *Fabric*—Mesh larger than 1 in. (25 mm) shall be 6 gage, 0.192 in. (4.88 mm) or 9 gage, 0.148 in. (3.76 mm): 1-in. mesh shall be 9-gage coated steel wire conforming to Specifications A 392, A 491, or F 1345 as selected if metallic-coated, or conforming to Specification F 668 if polymer-coated. Mesh smaller than 1 in. shall be 11 gage, 0.120 in. (3.05 mm) conforming to Specifications A 491, F 668, or F 1345 as selected.

NOTE 1—The various chain link fabric specifications list fabric heights up to and including 12 ft (3.7 m) height. Some fabrics are available up to 20 ft (6.1 m). Reference Specification F 1916 for fabric installation especially where two fabric heights are spliced horizontally. Chain link fabric shall be installed on the secure side of the fence per Specification F 1916.

<sup>1</sup> This specification is under the jurisdiction of ASTM Committee F14 on Fences and is the direct responsibility of Subcommittee F14.10 on Specific Applications.

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<sup>2</sup> *Annual Book of ASTM Standards*, Vol 01.06.

<sup>3</sup> *Annual Book of ASTM Standards*, Vol 15.08.

<sup>4</sup> Available from Underwriters Laboratories (UL) Corporate Progress, 333 Pfingsten Rd., Northbrook, IL 60062-2096.

4.3 *Fittings*, shall be galvanized steel conforming to Specification F 626.

4.3.1 Fittings may be polymer-coated after galvanizing.

4.3.2 Tie wires shall be 9-gage, 0.148 in. (3.76 mm), metallic-coated steel or polymer-coated over 9-gage, 0.148 in. (3.76 mm), galvanized steel core wire in accordance with Specification F 626. The finish coating shall match the finish coating of the fabric.

4.4 *Barbed Tape Obstacles*—Barbed tape, when specified, shall conform for Specification F 1910. Barbed tape shall be installed in conformance with Practice F 1911. When specifying barbed tape, use descriptions as listed in Terminology F 1379.

4.5 *Barbed Wire*—Metallic-coated barbed wire shall conform to Specification A 121, 12½ gage, 0.099 in. (2.51 mm) diameter strand wire, 14 gage, 0.030 in. (2.02 mm) barbs.

4.5.1 Aluminum-coated, coating Type A, Coating Class 40, Design Number 12–4–3–14R or 12–4–5–14R.

4.5.2 Zinc-coated (galvanized), Coating Type Z, Coating Class 3, Design Number 12-4-5-14R.

4.5.3 5 % Aluminum-mischmetal, Coating Type ZA, Coating Class 60, Design Number 12–4–5–14R.

4.5.4 Polymer-coated barbed wire shall conform to Specification F 1665.

4.6 *Tension Wire*—Metallic tension wire shall conform to Specification A 824.

4.6.1 Type I Aluminum-coated.

4.6.2 Type II Zinc-coated.

4.6.3 Type III Zinc-5 % Aluminum Mischmetal.

4.6.4 Polymer-coated tension wire shall conform to Specification F 1664.

4.7 If a polymer-coated fence system is selected, the color selection shall be in accordance with Specification F 934.

4.8 *Gates*—The gates shall be in accordance with Specification F 900 swing gates or Specification F 1184 slide gates. All bolts used with gates shall be peened to prevent removal of nut per Specification F 1916.

4.8.1 Pedestrian gates shall be a galvanized steel material 1.900-in. (48-mm) outside diameter tubular or 2 in. (51 mm) square. Typical gate size shall be 4 ft (1.2 m) wide by 7 ft (2.1 m) high complete with transom. Manual or electric security locks shall be installed in swing gate frames using a lock box and weatherproof enclosure.

4.8.2 *Vehicular Gates*—Vehicular gates such as those used for sally ports shall be single leaf or double leaf overhead slide

gates per Specification F 1184. Consult correctional specialists for motor type, controls, locking capabilities and related security issues, per Specifications F 1916. Electric operators shall comply with Underwriters Laboratories 325.

4.9 *Accessories*—If accessories such as electronic sensors, gate operators, etc., are to be employed, the designer is encouraged to contact various producers of these products for product information and performance criteria per Specification F 1916.

## 5. Fabric Attachments

5.1 *Line Post*—Fabric shall be attached with tie wires or other appropriate fasteners per Specification F 1916.

5.2 *Rails*—Fabric shall be attached with tie wires or other appropriate fasteners per Specification F 1916.

5.3 *Terminal Post*:

5.3.1 *Fabric*, shall be attached to the terminal post using tension bars with tension bands or vertical straps, per Specification F 1916.

## 6. Rails

6.1 Top, intermediate, and bottom rails may be specified at the discretion of the designer per Specification F 1916.

## 7. Barbed Wire

7.1 Barbed wire shall be installed, in accordance with Specification F 1916, with one or more strands, depending on the degree of security required, or in conjunction with the use of barbed tape obstacles.

7.2 Supporting arms for barbed wire, when supplied, shall meet the requirements of Specification F 626.

## 8. Tension Wire

8.1 Fabric shall be secured to tension wire as directed in Specification F 1916, using steel hog rings, per Specification F 626.

8.2 Tension wire shall be stretched independently from the fabric and not interwoven with the fabric, in accordance with Specification F 1916.

## 9. Keywords

9.1 barbed tape obstacles; barbed wire; chain-link fence fabric; chain-link fence framework; high security; wire coating; wire gage

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# Standard Guide for Fences for Residential Outdoor Swimming Pools, Hot Tubs, and Spas<sup>1</sup>

This standard is issued under the fixed designation F 1908; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon ( $\epsilon$ ) indicates an editorial change since the last revision or reapproval.

## 1. Scope

1.1 This guide provides recommended minimum requirements for various types of fences for residential outdoor swimming pools, hot tubs, and spas.

1.2 The values stated in inch-pound units are to be regarded as the standard. The values stated in parentheses are for information only.

## 2. Referenced Documents

### 2.1 ASTM Standards:

A 392 Specification for Zinc-Coated Steel Chain-Link Fence Fabric<sup>2</sup>

A 491 Specification for Aluminum-Coated Steel Chain-Link Fence Fabric<sup>2</sup>

F 552 Terminology Relating to Chain Link Fencing<sup>2</sup>

F 668 Specification for Poly(Vinyl Chloride) (PVC)-Coated Steel Chain-Link Fence Fabric<sup>2</sup>

F 1183 Specification for Aluminum Alloy Chain-Link Fence Fabric<sup>2</sup>

F 1345 Specification for Zinc-5 % Aluminum-Mischmetal Alloy-Coated Steel Chain-Link Fence Fabric<sup>2</sup>

### 2.2 CPSC Document:<sup>3</sup>

CPSC Staff Recommendations, Barriers for Residential Swimming Pools, Spas, and Hot Tubs (March 1992)

### 2.3 NSPI Document:<sup>4</sup>

ANSI/NSPI-8 1996 Model Barrier Code for Residential Swimming Pools, Spas and Hot Tubs

### 2.4 BOCA Document:<sup>5</sup>

The BOCA National Building Code/1996—13th Edition

### 2.5 SBCCI Document:<sup>6</sup>

1993 SBCCI Bluebook, Standard Swimming Pool Code

### 2.6 NFPA Document:<sup>7</sup>

National Electrical Code®, NFPA 70-1996

## 3. Terminology

3.1 See Terminology F 552 for definitions of terms relating to chain link fencing.

### 3.2 Definitions of Terms Specific to This Standard:

3.2.1 *fence, n*—a type of barrier that surrounds and obstructs access to the pool, tub, or spa.

3.2.2 *grade, n*—the finished elevation at any specified point of the ground or pavement outside the pool area.

3.2.3 *hot tub, n*—See *spa*.

3.2.4 *outdoor, adj*—located outside of a completely enclosed building or other structure.

3.2.5 *residential, adj*—situated on the premises of a detached one- or two-family dwelling or a one-family town house not more than three stories in height.

3.2.6 *spa (nonportable), n*—a permanent structure containing water over 24 in. (610 mm) deep, in which the water-heating and water-circulating equipment are not an integral part of the product, intended for recreational bathing.

3.2.7 *spa (portable), n*—a nonpermanent structure containing water over 24 in. (610 mm) deep, in which all controls, water-heating, and water-circulating equipment are an integral part of the product, intended for recreational bathing.

3.2.8 *swimming pool, n*—an in-ground, on-ground, or above-ground structure of a permanent, semi-permanent, or portable fabrication containing water over 24 in. (610 mm) deep and designed and constructed in accordance with local codes, used for bathing, swimming, diving, racing, or other activity.

## 4. Summary of Practice

4.1 This guide is based in part upon recommendations of the United States Consumer Product Safety Commission (CPSC). It also incorporates certain provisions of the National Spa and Pool Institute (NSPI) Model Barrier Code for Residential Swimming Pools, Spas and Hot Tubs.

## 5. Significance and Use

5.1 This guide sets forth minimum standard requirements

<sup>1</sup> This guide is under the jurisdiction of ASTM Committee F-14 on Fences and is the direct responsibility of Subcommittee F14.10 on Specific Applications.

Current edition approved July 10, 1998. Published November 1998.

<sup>2</sup> *Annual Book of ASTM Standards*, Vol 01.06.

<sup>3</sup> Available from United States Consumer Product Safety Commission, Washington, DC 20207.

<sup>4</sup> Available from National Spa and Pool Institute, 2111 Eisenhower Avenue, Alexandria, VA 22314.

<sup>5</sup> Available from Building Officials and Code Administrators International Inc., 4051 W. Flossmoor Rd., Country Club Hills, IL 60478-5795.

<sup>6</sup> Available from Southern Building Code Congress International, 900 Montclair Rd., Birmingham, AL 35213-1206.

<sup>7</sup> Available from the National Fire Protection Association, Quincy, MA 02269.

for use in local codes and ordinances relating to residential outdoor swimming pools, hot tubs, and spas.

5.2 This guide does not have the effect of law, nor is it intended to supersede local codes and ordinances of a more restrictive nature.

5.3 Studies, as listed in Annex A1, have been referenced as the bases for certain recommendations in this guide and will assist those who intend to provide protection against drownings and near-drownings by restricting access to children under the age of five years in residential swimming pools, spas, and hot tubs. This would include, but not be limited to, state and local governments, model code organizations, building code groups, and consumers. It is understood that the format will vary depending upon the specific use and local conditions.

**6. Requirements**

6.1 *Height*—The top of the fence shall be a minimum of 48 in. (1219 mm) above grade measured on the side of the fence that faces away from the swimming pool. If the fence is mounted on top of an above ground pool, the top of the fence shall be a minimum of 36 in. (914 mm) above the top of the pool structure, provided the top of the pool structure is a minimum of 48 in. (1219 mm) above grade (see 3.2.2 for definition of *grade* specific to this guide).

6.2 *Visibility*—The fence on top of an above ground pool shall be so designed and constructed that it has at least a 65 % open area to allow visibility from a designated supervising area outside the pool area to inside the pool area.

6.3 *Ground Clearance*—The maximum vertical clearance between grade and the bottom of the fence shall be 4 in. (102 mm) measured on the side of the fence that faces away from the swimming pool. Where the top of the pool structure is above grade, such as an above ground pool, the fence may be at ground level or mounted on top of the pool structure. Where the fence is mounted on top of the pool structure, the space between the top of the pool structure and the bottom of the fence shall be no greater than 4 in. (102 mm) in any direction.

6.4 *Solid Barriers* that do not have openings, such as masonry or stone walls, shall not contain indentations or protrusions except for normal construction tolerances and tooled masonry joints. Such indentations shall not be deeper than 0.375 in. (10 mm).

6.5 *Horizontal and Vertical Members*—Where the fence is composed of horizontal and vertical members and if the distance between the tops of the horizontal members is less than 45 in. (1143 mm), the horizontal members shall not extend more than 0.375 in. (10 mm) outside of the enclosure, and the spacing between the vertical members shall not exceed 1 3/4 in. (44 mm) (see Fig. 1). If the distance between the tops of the horizontal members is 45 in. (1143 mm) or more, the spacing between the vertical members shall not exceed 4 in. (102 mm) (see Fig. 2). Where there are decorative cutouts, the spacing within the cutouts shall not exceed 1 3/4 in. (44 mm).

6.6 *Chain Link Fences*—Mesh opening for chain link fences shall be a nominal 1 1/4 in. (32 mm) measured between the parallel sides of the mesh, and a maximum of 1 3/4 in. (44 mm) measured horizontally between the corners of the installed mesh, as illustrated in Fig. 3 (see Note 1), unless the fence is provided with privacy slats (see Note 2) fastened at the top or

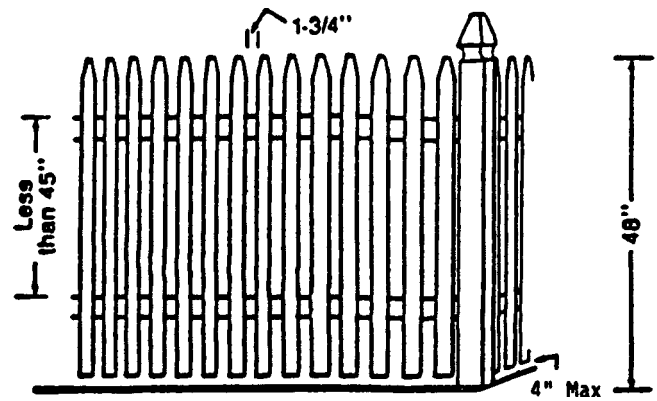


FIG. 1 If Horizontal Members are Less Than 45 in. Apart, Vertical Spacing Shall Not Exceed 1-3/4 in.

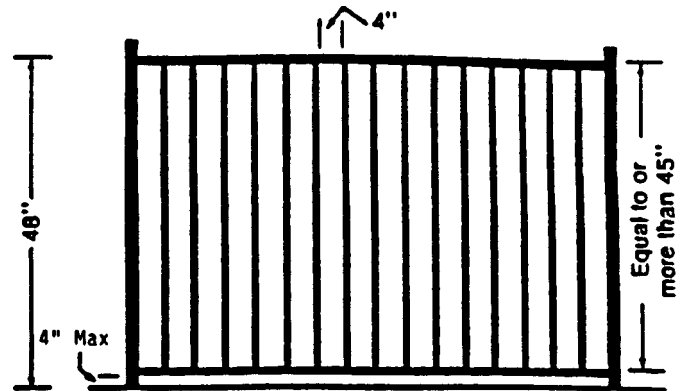


FIG. 2 If Horizontal Members are Equal to or More Than 45 in. Apart, Vertical Spacing Shall Not Exceed 4 in.

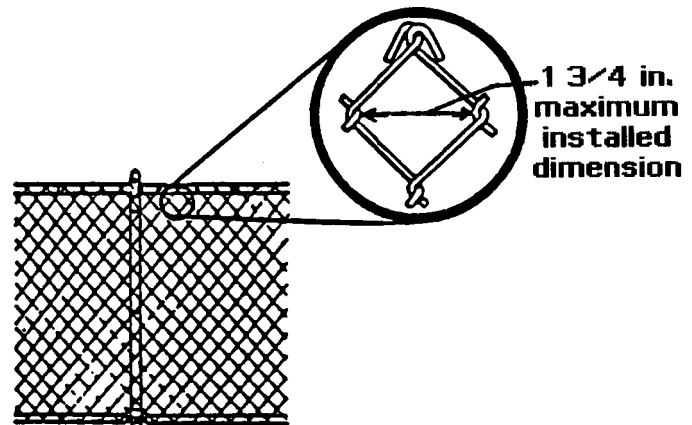


FIG. 3 Nominal 1-1/4 in. Square Chain Link Mesh

the bottom, in which case no opening in the mesh shall exceed 1 3/4 in. (44 mm).

NOTE 1—If the tolerance of ±1/8 in. (3.2 mm) indicated in Specifications A 392, A 491, F 668, F 1183, and F 1345 is rigidly applied to an ordered nominal mesh size of 1 1/4 in. (32 mm) measured between the parallel sides of the mesh, the result could be a dimension exceeding the specified maximum of 1 3/4 in. (44 mm) measured horizontally between the corners of the installed mesh. The degree of tension applied to the fabric during installation could also affect this horizontal dimension. In all cases, the horizontal opening between the corners of the fabric mesh after tensioning shall not exceed 1 3/4 in. (44 mm).

NOTE 2—*Caution Regarding Privacy Slats*—Privacy slats where used shall not violate the requirements of 6.2 regarding visibility.

6.7 *Diagonal Members:*

6.7.1 Where the fence is composed of diagonal members, such as in a lattice fence, any opening created by the diagonal members shall be a maximum of 1 3/4 in. (44 mm) measured in its largest direction.

6.7.2 Diagonal bracing members extending from one side to the opposite side creating a ladder effect on all styles of fences and gates are not permitted where spacing of vertical members in any area between posts exceeds 1 3/4 in. (44 mm).

6.8 *Access Gates:*

6.8.1 *Double Leaf* access gates shall comply with the requirements of 6.1-6.6 and shall be equipped with a padlock or other key-operated locking device that must be locked when the gate is not in use.

6.8.2 *Single Leaf* access gates shall open outward away from the pool, shall be self-closing, and shall have a self-latching device. Where the release mechanism of the self-latching device is located less than 54 in. (1372 mm) above grade, the release mechanism shall be located on the pool side of the gate a minimum of 3 in. (76 mm) below the top of the gate and fence shall have no opening greater than 1/2 in. (13 mm) within 18 in. (457 mm) of the release mechanism when the gate is in the fully closed position (see Fig. 4).

6.9 *Buildings*—The fence shall completely surround the pool structure except where a building or dwelling or portion thereof is utilized as part of the pool enclosure. If the exterior wall or walls of that portion of the building contains doors, windows, or other openings, it shall comply with the following provisions:

6.9.1 *Doors*—Doors in the wall of a building or dwelling that allow direct access through the wall to the pool shall be provided with one of the following:

6.9.1.1 An alarm capable of detecting unauthorized entry through the door into the pool area and which, when activated, emits a sound of sufficient volume to be heard in the building or dwelling. The audible warning shall commence not more

than 7 s after the door and/or its screen, if present, are opened and shall sound continuously for a minimum of 30 s. The alarm shall have a minimum sound pressure rating of 85 dB at 10 ft and the sound of the alarm shall be distinctive from other household sounds such as smoke alarms, telephones, and door bells. The alarm shall automatically reset under all conditions. The alarm shall be equipped with manual means such as touch pads or switches to temporarily deactivate the alarm for a single opening from either direction. Such deactivation shall last for no more than 15 s. The deactivation touch pads or switches shall be located at least 54 in. (1372 mm) above the threshold of the door; or

6.9.1.2 A self-latching device on a self-closing door that is either:

- (1) At least 54 in. (1372 mm) above floor level, or
- (2) At any convenient height if the device uses a key, electronic opener, or integral combination lock, so long as it does not negate the function of the door.

6.9.2 *Windows*—Windows in the wall of a building or dwelling that allow direct access through the wall to the pool and are located 48 in. (1219 mm) or higher above floor level, and where there is no foothold in the building or dwelling wall, shall be exempt and considered equivalent protection to the fence. Windows in the wall of a building or dwelling that allow direct access through the wall to the pool and where the lowest opening is at a height of less than 48 in. (102 mm) above floor level, shall comply with one of the following requirements:

6.9.2.1 Window guards, screens, or other means of equal protection shall limit access such that there are no openings exceeding 4 in. (102 mm); or

6.9.2.2 Windows shall be fixed in such a way that they will not open sufficiently far to create a gap exceeding 4 in. (102 mm); or

6.9.2.3 The lowest opening panel of a window shall be located not less than 48 in. (1219 mm) above the floor and there shall be no footholds wider than 0.4 in. (10 mm) on the internal wall down to 42 in. (1067 mm) below the lowest opening panel.

6.10 *Above-Ground Pools or On-Ground Pools:*

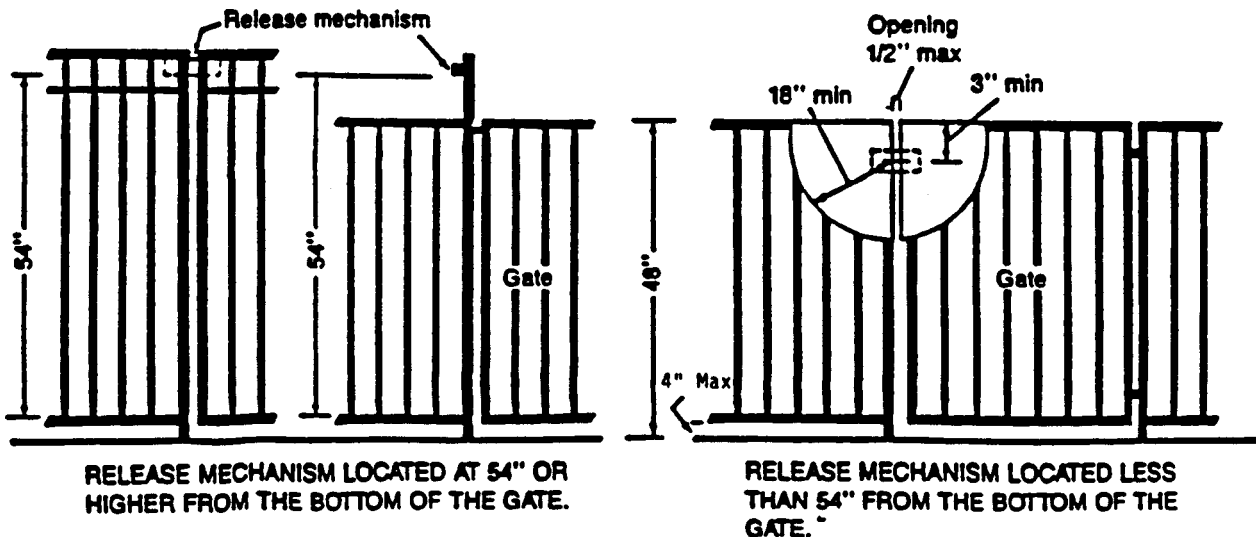


FIG. 4 Latch Release Mechanism

6.10.1 *Pool Wall*—An above-ground or on-ground pool wall itself may be the barrier if the pool structure is on grade and the wall is at least 48 in. (1219 mm) in height. Other types of barriers can be mounted on the pool structure or can surround the pool at ground level. Where the barrier is mounted on the pool structure, the opening between the top surface of the pool frame and the bottom of the fence shall be no greater than 4 in. (102 mm) in any direction. Where an above-ground or on-ground pool wall is less than 48 in. (1219 mm) above the ground, it is not considered a barrier and therefore a barrier fence in accordance with 6.1-6.8 shall be provided.

6.10.2 *Ladders or Steps*—Where an above-ground or on-ground pool wall is used as a barrier or where the barrier is mounted on the pool structure, and the means of access to the pool is a ladder or steps, then:

6.10.2.1 The ladder or steps shall be capable of being secured, locked, or removed to prevent access; or

6.10.2.2 The ladder or steps shall be surrounded by a barrier fence that meets the requirements of 6.1-6.8.

6.10.3 *Fence Mounted on Top of 48 in. (1219 mm) or Higher Above Ground or On Ground Pool Wall Structure:*

6.10.3.1 Where provided, the top rail of a fence mounted on top of the pool structure or deck of an above-ground or on-ground pool that is in conformance with 6.10.1 shall be a minimum of 36 in. (914 mm) above the deck surface.

6.10.3.2 Where a picket or ornamental type fence is provided, it shall comply with the 45 in. (1143 mm) height requirements of 6.5.

6.10.3.3 *Visibility*—Where fencing is required and/or provided with the pool or deck, it shall comply with the requirements of 6.2.

6.10.4 *Deck*—Where an above-ground or on-ground pool has a deck that abuts or is adjacent to a dwelling and direct access to the deck is through the exterior wall of the dwelling, such access shall be in compliance with 6.9.

6.11 *Bonding and Grounding*—Continuous runs of metal fencing, installed in the ground within 10 ft of the pool, shall be bonded and grounded at the distribution panel of the electric power source for the swimming pool, or otherwise in compliance with Section 680-22 of the National Electrical Code.

## 7. Prohibited Locations

7.1 Fences shall be located so as to prohibit the use of permanent structures, equipment, or similar objects to aid in climbing the fence.

7.2 *Clear Zone*—There shall be a clear zone of at least 48 in. (1219 mm) between the swimming pool barrier and any permanent structures or pool equipment such as pumps, filters, heaters, etc. that can be used as an aid to climb the barrier.

## 8. Maintenance and Inspection

8.1 It is the responsibility of the home owner, occupant, or tenant to maintain the integrity of the fence and to regularly inspect the gates, doors, etc. for proper closing and locking operation, and the alarms for correct operation.

8.2 Keep the area outside the fence free of toys, furniture, or other objects that could be moved by a child and used to climb the fence.

## 9. Keywords

9.1 fence; fences; hot tubs; pools; spas; swimming pools

## ANNEX

### (Mandatory Information)

#### A1. RATIONALE

A1.1 The presence of a fence around a residential swimming pool, spa, or hot tub is only one in many available layers of passive protection against drownings or near-drownings. Such passive protection should never be construed as taking the place of constant adult supervision.

A1.2 About 350 children under 5 years of age drown each year in residential swimming pools, spas, and hot tubs. No other age group is as vulnerable. For the age group 5 to 14, with twice as many children in the population, there are one-fifth as many drownings in pools.

A1.3 In a study of drowning and near-drowning incidents (1),<sup>8</sup> CPSC found that the majority of the victims lived in or were visiting the residence where the accident happened; less than two percent of the accidents occurred when a child

trespassed on the property. Most of the victims were either near or in the residence immediately prior to the accident and reached the pool unnoticed.

A1.4 For these reasons, the CPSC staff recommendations and those of NSPI are intended to limit or delay a child under five years of age from gaining unsupervised access to the pool from the house or yard. The recommendations consider anthropometric and developmental characteristics of children under five. A fence should not have footholds and handholds, and spaces should be limited in size and location to preclude a child from climbing over or passing through the fence. Latches on gates should be shielded or out of reach.

A1.5 The following are rationale for the various subsections in Section 6:

A1.5.1 6.1—The minimum 48 in. (1219 mm) fence height above grade is based on the ability of children under five years old to climb fences (2) and on appropriate anthropometric (3,

<sup>8</sup> The boldface numbers in parentheses refer to the list of references at the end of this guide.

4) and developmental characteristics (5, 6, 7) of children under age five.

A1.5.2 6.2—This requirement is essential to proper adult supervision of children within the pool area.

A1.5.3 6.3—This requirement is based on the head breadth and chest depth of a 13- to 18-month old (3) and is intended to preclude passing through an opening of a type not otherwise specified in the remaining subsections of Section 6.

A1.5.4 6.4—This requirement is intended to reduce the potential for gaining a foothold.

A1.5.5 6.5—If horizontal members are less than 45 in. (1143 mm) apart, a child may gain both a handhold and a foothold. The 1 3/4 in. (44 mm) space requirement is based on the foot width of a 13- to 18-month-old (6) and is intended to preclude his gaining a foothold. The 4 in. (102 mm) space requirement is intended to preclude young children from passing through the fence (see 6.3). The 45 in. (102 mm) horizontal member spacing is intended to prevent young children from using the horizontal members as a ladder.

A1.5.6 6.6—The 1 3/4 in. (44 mm) maximum horizontal opening in the chain link mesh is based on the foot width for young children and is intended to reduce the potential for gaining a foothold (see Fig. 3). During the research leading to the selections in this standard guide, based upon comparative mesh size climbability studies (8), several differences of opinion on the rationale for this size mesh were noted. At least two organizations, NSPI and SBCCI (see 2.3 and 2.5), have

written standards calling for a maximum of 2 1/4 in. (57 mm) measured between the parallel sides of the mesh, which is the generally accepted standard for residential chain link fence. At least two other organizations, CPSC and BOCA (see 2.2 and 2.4), consider the 1 3/4 in. (44 mm) maximum horizontal opening the only acceptable standard.

A1.5.7 6.7—This requirement is intended to reduce the potential for gaining a foothold (see 6.5).

A1.5.8 6.8—A single leaf access gate should open outward because, in the event the latch fails to operate, a child who pushes the gate will not gain immediate access to the pool and may even engage the latch. Double leaf access gates are not required to have a self-closing device since such devices are generally prohibitively expensive and often are not available for large gates. Any such gates should be securely locked with a suitable padlock or other device. The 54 in. (1372 mm) height of the release mechanism is intended to keep children under five years old from reaching it based on the reaching height of 3.5- to 4.5-year-old children (4). For release mechanisms on the pool side of the gate, the 3 in. (76 mm) minimum requirement is intended to prevent a child from reaching over to unlatch the gate. The 1/2 in. (13 mm) maximum requirement is intended to prevent reaching the latch release through the gate or fence.

A1.5.9 6.11—This section was included to ensure against electrical shock hazards from ungrounded or improperly grounded metal fences.

## REFERENCES

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- (2) Nixon, J.W., Pearn, J.H., and Petrie, G.M., "Childproof Safety Barriers," *Australian Pediatric Journal*, Vol 15, 1979, pp. 260–262.
- (3) *Physical Characteristics of Children as Related to Death and Injury for Consumer Product Design and Use*, May 31, 1975, Highway Safety Research Institute, The University of Michigan, Ann Arbor, Michigan.
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- (8) *Swimming Pool Safety: Fence Climbability By Children*, prepared for National Institute of Child Health and Human Development, National Institute of Health, Contract N43-HD-8-2912, by COMSIS Corporation, 8737 Colesville Road, Silver Spring, MD 20910.

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## Standard Specification for Long Barbed Tape Obstacles<sup>1</sup>

This standard is issued under the fixed designation F 1910; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon ( $\epsilon$ ) indicates an editorial change since the last revision or reapproval.

### 1. Scope

1.1 This specification covers barbed tape materials and configurations used for security barriers.

### 2. Referenced Documents

#### 2.1 ASTM Standards:

A 176 Specification for Stainless and Heat-Resisting Chromium Steel Plate, Sheet and Strip<sup>2</sup>

A 240 Specification for Chromium and Chromium-Nickel Stainless Steel Plate, Sheet and Strip for Pressure Vessels and for General Applications<sup>2</sup>

A 370 Test Methods and Definitions for Mechanical Testing of Steel Products<sup>2</sup>

A 666 Specification for Annealed or Cold-Worked Austenitic Stainless Steel Sheet, Strip, Plate and Flat Bar<sup>2</sup>

A 764 Specification for Metallic Coated Carbon Steel Wire, Coated at Size and Drawn to Size for Mechanical Springs<sup>2</sup>

F 1379 Terminology Relating to Barbed Tape<sup>3</sup>

### 3. Terminology

3.1 Refer to Terminology F 1379.

### 4. Classification

4.1 Refer to 5.1.8.

### 5. Ordering/Specifying Information

5.1 Ordering or specifying barbed tape shall include the following information as per sample specification, or by referencing item numbers in Tables 1 and 2 (indicate number of loops, if applicable). Material furnished under this specification shall conform to applicable requirements of current editions of ASTM Standards.

NOTE 1—The following sample specification is provided to assist when specifying or ordering barbed tape material. Actual size and style will vary by individual job requirements.

<sup>1</sup> This specification is under the jurisdiction of ASTM Committee F14 on Fences and is the direct responsibility of Subcommittee F14.40 on Chain Link Fence and Wire Accessories.

Current edition approved July 10, 2003. Published September 2003. Originally approved in 1998. Last previous edition approved in 1998 as F 1910 - 98.

<sup>2</sup> Annual Book of ASTM Standards, Vol 01.03.

<sup>3</sup> Annual Book of ASTM Standards, Vol 01.06.

*Sample Specification Only*—Barbed tape obstacle shall be 30 in. diameter ( $\pm 2$  in.). Each loop shall consist of 24 ( $\pm 1$ ) clusters of four needle-sharp barbs on 4 in. centers, each barb measuring a minimum of 1.2 in. in length. The barbed tape shall be fabricated from Series 430 stainless steel with optional hardness. The barbed tape shall be permanently cold-clenched over an austenitic mechanical spring core wire. The wire shall have a diameter of 0.098 in. with a minimum tensile strength of approximately 140 psi. The barbed tape shall have a minimum 230° wrap about the core wire. Adjacent alternate loops shall be clipped together in five (5) locations around the circumference to obtain the concertina effect. Clip spacing of the extended coil shall be  $12 \pm 2$  in. Clips shall be capable of withstanding a minimum pull load of 200 lb. Each coil shall contain 51 loops and cover  $25 \pm 1$  ft.

5.1.1 *Quantity*—The number of units of barbed tape required. For fixed length units, the length per unit should be specified.

5.1.2 *Description*—Barbed tape shall be described as single coil helical, single coil concertina, double coil concertina, or double coil helical.

5.1.3 *Diameter*—The purchaser shall specify the packaged diameter. When double coil products are specified, the inner and outer coil packaged diameters shall be given.

5.1.4 *Barb Length*—Refer to Terminology F 1379 and Tables 1 and 2.

5.1.5 *Coil Loops*—The number of coil loops shall be specified by the purchaser.

5.1.6 *Unit Length*—The purchaser shall specify the installed length and coil spacing, including the coil spacing tolerance.

5.1.7 Number of attachment points, in accordance with Terminology F 1379 and Tables 1 and 2.

5.1.8 *Cross Sections*—The purchaser shall specify the cross sections in accordance with Terminology F 1379.

### 6. Material

6.1 *Composition*—Barbed tape shall be manufactured from stainless and galvanized steel in accordance with the ASTM standards listed in Section 2. Manufacturers are not necessarily limited to those materials listed.

6.1.1 *Stainless Steel*—Stainless steel strip shall be either ferritic or austenitic. Stainless steel should be ordered to the AISA or UNS designations to ensure the correct chemistry.

6.1.1.1 Ferritic stainless steels shall be produced in accordance with Specification A 176 or Specification A 240.



6.1.1.2 Austenitic stainless steels shall be purchased in accordance with Specification A 666.

## 7. Dimensions and Permissible Variations

7.1 Permissible variations within coil diameters shall be as specified in Tables 1 and 2 for standard trade sizes.

## 8. Workmanship, Finish and Appearance

8.1 *Workmanship*—Coil loops shall not be kinked, unless it is part of the design.

8.1.1 Each coil shall be one continuous length properly coiled and firmly tied for shipping. Welds made in the strip prior to forming are permitted. A maximum of three splices per coil are permitted either by overlapping and welding or permanently clamping together with a suitable device designed for the purpose.

8.2 Surfaces shall be smooth and free of rust with no serious defects, such as pits, die marks, and other defects to impair the integrity of the product.

## 9. Certification

9.1 When specified in the purchase order or contract, a manufacturer's certification of compliance shall be furnished to the purchaser showing the quantity, size and type of barbed tape. The certification of compliance shall state that the representative barbed tape is in accordance with the specification.

## 10. Keywords

10.1 barbed tape

**TABLE 1 Stainless Steel Long Barbed Tape (Reinforced) (See Terminology F 1379, Figs. 2 and 3)**

NOTE 1—Maximum barb point radius = 0.005 in.

NOTE 2—Minimum barb length = 1.2 in.

NOTE 3—Maximum barb spacing = 4 in.

Item Number	Description	Barbed Tape Material	Core-Wire Material	Barb Clusters Per Loop	Coil Loops	Coil Loop Spacing $\pm 2.0$ in.	Coil Length, ft	Attachment Points
Helical								
1	18 in. Single Coil Helical	430 SS 0.025 in. Thick	0.098 SS 300 Series 140 KSI (965 MPa)	13	33	12 in. 18 in.	33 50	0 0
2	18 in. Single Coil Helical	430 SS 0.025 in. Thick	0.098 Galvanized Steel Class III	13	33	12 in. 18 in.	33 50	0 0
3	18 in. Single Coil Helical	430 SS 0.025 in. Thick	0	13	33	12 in. 18 in.	33 50	0 0
4	18 in. Type III Single Coil Helical	300 Series SS 0.025 in. Thick	0	13	33	12 in. 18 in.	33 50	0 0
5	24 in. Single Coil Helical	430 SS 0.025 in. Thick	0.098 SS 300 Series 140 KSI (965 MPa)	19 $\pm$ 1	33	12 in. 18 in.	33 50	0 0
6	24 in. Single Coil Helical	430 SS 0.025 in. Thick	0.098 Galvanized Steel Class III	19 $\pm$ 1	33	12 in. 18 in.	33 50	0 0
7	24 in. Single Coil Helical	430 SS 0.025 in. Thick	0	19 $\pm$ 1	33	12 in. 18 in.	33 50	0 0
Concertina								
8	18 in. Single Coil Concertina	430 SS 0.025 in. Thick	0.098 Galvanized Steel Class III	13	31 51	16 in. 12 in.	20 25	03 03
9	18 in. Single Coil Concertina	430 SS 0.025 in. Thick	0.098 SS 300 Series 140 KSI (965 MPa)	13	31 51	16 in. 12 in.	20 25	03 03
10	24 in. Single Coil Concertina	430 SS 0.025 in. Thick	0.098 Galvanized Steel Class III	19 $\pm$ 1	31 51	16 in. 12 in.	20 25	03 03
11	24 in. Single Coil Concertina	430 SS 0.025 in. Thick	0.098 SS 300 Series 140 KSI (965 MPa)	19 $\pm$ 1	31 51	16 in. 12 in.	20 25	03 03
12	30 in. Single Coil Concertina	430 SS 0.025 in. Thick	0.098 Galvanized Steel Class III	24 $\pm$ 1	31 51	16 in. 12 in.	20 25	03 03
13	30 in. Single Coil Concertina	430 SS 0.025 in. Thick	0.098 SS 300 Series 140 KSI (965 MPa)	24 $\pm$ 1	31 51	16 in. 12 in.	20 25	03 03
14	30 in. Single Coil Concertina	430 SS 0.025 in. Thick	0.098 Galvanized Steel Class III	24 $\pm$ 1	51 81 101	12 in. 12 in. 12 in.	25 40 50	05 05 05

**F 1910 – 98 (2003)****TABLE 1** *Continued*

Item Number	Description	Barbed Tape Material	Core-Wire Material	Barb Clusters Per Loop	Coil Loops	Coil Loop Spacing $\pm 2.0$ in.	Coil Length, ft	Attachment Points
15	30 in. Single Coil Concertina	430 SS 0.025 in. Thick	0.098 SS 300 Series 140 KSI (965 MPa)	24 $\pm$ 1	51	12 in.	25	05
					81	12 in.	40	05
					101	12 in.	50	05
16	40 in. Single Coil Concertina	430 SS 0.025 in. Thick	0.098 Galvanized Steel Class III	31 $\pm$ 1	51	12 in.	25	07
					81	12 in.	40	07 07
17	40 in. Single Coil Concertina	430 SS 0.025 in. Thick	0.098 SS 300 Series 140 KSI (965 MPa)	31 $\pm$ 1	51 81	12 in. 12 in.	25 40	05 05
18	40 in. Single Coil Concertina	430 SS 0.025 in. Thick	0.098 SS 300 Series 140 KSI (965 MPa)	31 $\pm$ 1	51 81	12 in. 12 in.	25 40	07 07
19	60 in. Single Coil Concertina	430 SS 0.025 in. Thick	0.098 Galvanized Steel Class III	45 $\pm$ 1	51 81	12 in. 12 in.	25 40	09 09
20	60 in. Single Coil Concertina	430 SS 0.025 in. Thick	0.098 SS 300 Series 140 KSI (965 MPa)	45 $\pm$ 1	51 81	12 in. 12 in.	25 40	09 09
21	24/30 in. Double Coil Concertina	430 SS 0.025 in. Thick	0.098 Galvanized Steel Class III	43 $\pm$ 2	31	16/16 in.	20	3
22	24/30 in. Double Coil Concertina	430 SS 0.025 in. Thick	0.098 SS 300 Series 140 KSI (965 MPa)	43 $\pm$ 2	31	16/16 in.	20	3

**TABLE 2 Non-Reinforced (See Terminology F 1379, Fig. 1)**

Item Number	Description	Barbed Tape Material	Core-Wire Material	Barb Clusters per Loop	Coil Loops	Coil Loop Spacing $\pm 2$ in.	Coil Length, ft	Attachment Points	Number of 7 $\times$ 7SS Cables
Double Helical									
23	24/30 GPBTO Type II	300 Series SS 0.025 in. Thick	none	19/24 $\pm 1$	33/33	24/24	66	0	4-3/64
Concertina									
24	24 in. Single Coil Concertina	300 Series SS 0.025 in. Thick	none	19 $\pm 1$	101	12 in.	50	3	1-3/64 $\times$ 5/64
25	30 in. Single Coil Concertina	300 Series SS 0.025 in. Thick	none	24 $\pm 1$	101	12 in.	50	5	1-3/64 $\times$ 5/64
26	40 in. Single Coil Concertina	300 Series SS 0.025 in. Thick	none	31 $\pm 1$	101	12 in.	50	7	1-3/64 $\times$ 5/64
27	60 in. Single Coil Concertina	300 Series SS 0.025 in. Thick	none	45 $\pm 1$	101	12 in.	50	13	1-3/64 $\times$ 5/64

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## Standard Practice for Installation of Barbed Tape<sup>1</sup>

This standard is issued under the fixed designation F 1911; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon ( $\epsilon$ ) indicates an editorial change since the last revision or reapproval.

### 1. Scope

1.1 This practice covers the installation procedure for barbed tape.

1.2 The primary purpose of this practice is to guide those responsible for or concerned with the installation of barbed tape on chain link fences, masonry walls, roofs or used as ground barriers. This standard is not intended to cover aspects of perimeter security for establishing levels of product performance or give analysis relating to various design comparisons.

1.3 This standard involves the use of material, that may cause injury, including exposure to hazardous materials, and operation of specialized equipment.

1.4 *This standard does not purport to address all of the safety concerns, if any associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

### 2. Referenced Documents

#### 2.1 ASTM Standards:

F 1379 Terminology Relating to Barbed Tape<sup>2</sup>

F 1910 Specification for Long Barbed Tape Obstacles<sup>2</sup>

F 1916 Specification for Selecting Chain Link Barrier Systems With Coated Chain Link Fence Fabric and Round Posts for Detention Applications<sup>3</sup>

### 3. Terminology

3.1 Refers to Terminology F 1379.

### 4. Significance and Use

4.1 This practice is intended to provide standard requirements utilizing specialized equipment and hand tools.

4.2 Ensure that the barbed tape is fabricated from acceptable material and well constructed. Field verification of the barbed tape's acceptability shall be in accordance with the project's specifications and this specification.

<sup>1</sup> This practice is under the jurisdiction of ASTM Committee F14 on Fences and is the direct responsibility of Subcommittee F14.40 on Chain Link Fence and Wire Accessories.

Current edition approved July 10, 1998. Published December 1998.

<sup>2</sup> *Annual Book of ASTM Standards*, Vol 01.06.

<sup>3</sup> *Annual Book of ASTM Standards*, Vol 15.07.

### 5. Site Preparation

5.1 The owner shall specify the location in which the barbed tape shall be installed by furnishing drawings or personal instruction.

5.2 Barbed tape obstacles shall be in accordance with Specification F 1910 barbed tape specifications.

NOTE 1—Refer to Terminology F 1379 for barb configuration and cross sections.

### 6. Installation

6.1 When the specifications are unclear, refer to these instructions or contact the owner for information pertaining to placement, coil attachment, splicing, etc.

#### 6.2 Non-Reinforced (Concertina):

6.2.1 *Description*—Barbed obstacle capable of being permanently or temporarily installed. Barbed tape used for some temporary installations shall have the ability of being recovered and used repeatedly.

6.2.2 *Top of the Fence Installation*—Barb Arms are recommended for top of the fence installations. Single 45° barb arms with a single strand of barbed wire or tension wire located in the outer position of the arm will support coils deployed at the top of the fence. Barb arms are positioned so that arms are out of reach from the approach side. “V” arms are not recommended for security applications where climbing is a threat or where only one row of barbed tape is specified. Two rows of barbed tape are recommended where “V” arms are specified. See Fig. 1.

6.2.2.1 *Deployment*—Stretch the coils out and allow them to rotate (spiral) naturally around their central axis. Allowing the coil to rotate will ensure that there is no mechanical stress within the obstacle before tying. Locate the coil loops uniformly at the specified coil spacing. The coil spacing is predetermined by one or more permanently attached cables running the entire length of the roll. The number of cables depends largely on the diameter and application. Coil loop spacing for non-reinforced products are generally 12.0 in. See Fig. 2.

6.2.2.2 *Tie Points*—Before making the final attachment to the fence, inspect the coils for tangles and proper coil spacing. Attach the first ties to the single strand of barbed wire, cable or tension wire located in the barb arm. Tie parallel coil loops at the desired spacing, determined by the spacer cable. Attach the

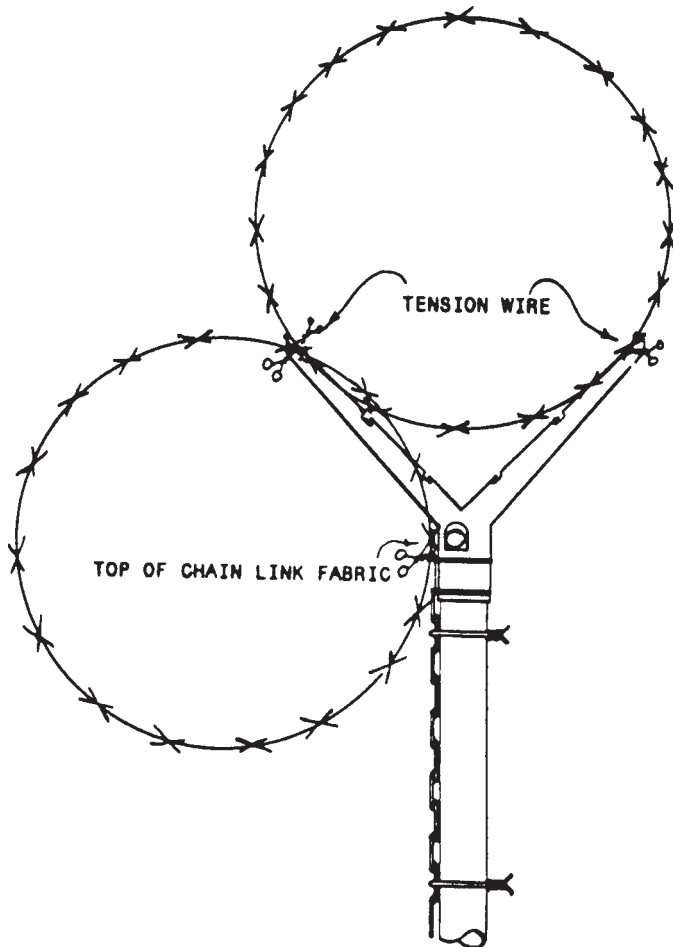


FIG. 1 "V" Arm Installation Wire-Reinforced and Non-Reinforced Barbed Tape Concertina.

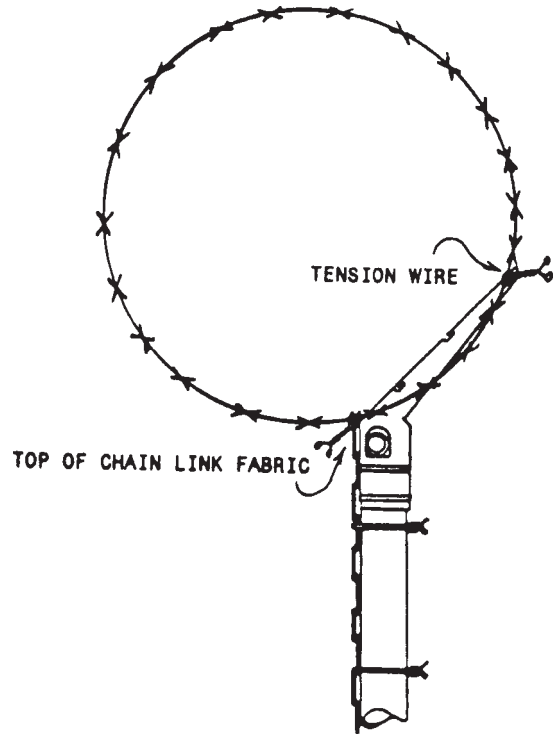


FIG. 2 45° Arm Installation Wire Reinforced and Non-Wire Reinforced Barbed Tape Concertina

second tie points to the top of the chain link at the desired spacing. Tie wires for detention applications are stainless steel 16 gage minimum, for commercial and industrial applications stainless steel 18 gage minimum is adequate. Large stainless steel hog rings with a minimum cross section of 12½ gage, may be used. Hog rings are not recommended where electronic detection is an integral part of the barrier system. For high security application, the hog ring cross section must be strong enough to prevent opening the ring by pulling on the barbed tape.

6.2.3 *Side of The Fence Installation*—Coils shall be installed horizontally on the approach side of the fence. Design criteria will obviously change depending on the threat.

6.2.3.1 *Deployment*—Follow deployment instructions described for top of the fence (6.2.2.1).

6.2.3.2 *Tie Points*—Before making the final attachment to the fence, inspect the coil for tangles and proper coil loop spacing. Improper coil loop spacing and tangles will reduce the coil's specified yield length. Attach the parallel coil loops to the fence fabric at the desired spacing determined by the spacer cables. Every coil intersecting the fence need not be tied. Ties for detention applications are stainless steel 16 gage minimum; for commercial and industrial applications stainless steel 18 gage minimum is adequate. Large stainless steel hog rings

capable of providing an overlapping wrap around both the chain link and barbed tape may be used. Hog rings are not recommended where electronic detection is an integral part of the barrier system.

6.2.4 *Bottom of the Fence Installation*—Ground barriers are coils placed horizontal, in vertical stacks at the base of the fence and tied consecutively together. Stacked coils are tied approximately 36 in. to 48 in. on center (o.c.) to adjacent rows. See Fig. 3.

6.2.4.1 *Deployment*—Follow deployment instructions described in (6.2.2.1).

6.2.4.2 *Tie Points*—Follow tying instructions from 6.2.3.2.

6.2.5 *Splicing*—Connect the trailing end of an installed roll and the leading end of an un-installed roll. Connect the two rolls at the point where the cable (or cables) from each roll come together. Tie the cable loops and closest barb cluster together with the minimum 18 gage stainless steel tie wire. This tie secures the ends of the cables and matching barb clusters together. Maintain a uniform diameter by aligning the remaining barb clusters around the perimeter of the coil. Complete the splice by tying the end turns of the leading and trailing rolls together. Place additional ties where the coils would have been spot welded if manufactured into one continuous roll. Additional ties may be required to strengthen or improve on the appearance of the splice.

NOTE 2—It is important that larger diameter coils with two or more cables have at least one cable continue uninterrupted through the entire run. This prevents diameter distortion at the splice.

6.2.6 *Ground Anchors*—Coils deployed on the ground shall be anchored as required, depending on the application and security threat. For security applications, place ground stakes 5

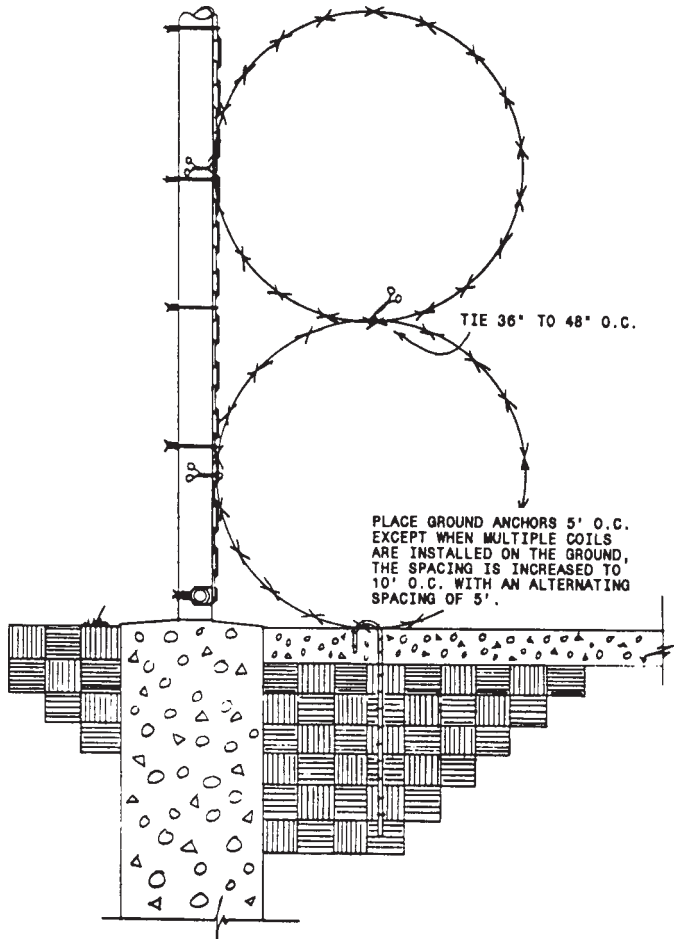


FIG. 3 Side and Bottom of Fence Installation Wire Reinforced and Non-Reinforced Barbed Tape Concertina.

ft. o.c.. Multiple coils on the ground for high security applications; stakes are generally 10 ft. o.c. with an alternating offset pitch of 5 ft. between rows. Length and type of anchors are determined in accordance with inherent weather and soil conditions.

6.3 Non-Reinforced 24/30 in. Double Coil (Helical Type II):

6.3.1 Description— Double coil Type II is constructed of one 24 in. diameter helical coil inside a 30 in. diameter helical coil. Inner and outer coils are alternately joined together with four cables at a predetermined spacing. Type II barbed tape is the only barbed obstacle having a top and bottom. The bottom is located mid distance between the shorter pair of spacer cables. See Fig. 4.

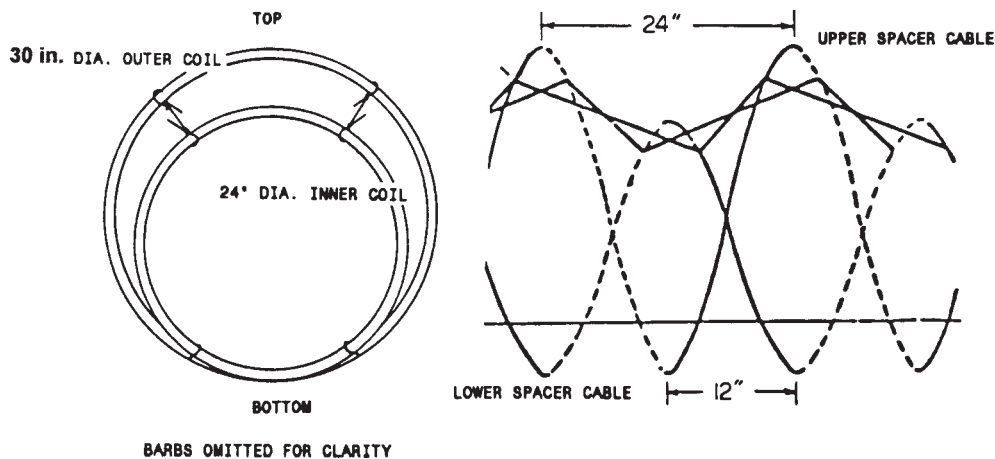
6.3.2 Top of the Fence Installation—Barb arms are recommended for top of the fence installations. Single 45° barb arms with a single strand of barbed wire, tension wire or 3/16 in. diameter cable, located in the outer position of the arm will support coils deployed at the top of the fence. Barb arms are positioned so that the arms are out of reach from the approach side of the obstacle.

6.3.2.1 Deployment—Stretch the coil out and locate the coil loops uniformly as predetermined by the four spacer cables. Rotate the entire coil assembly approximately 45°; positioning the bottom, mid way between the tension wire and top of the fence fabric. Inner and outer coil spacings are fixed at 24 in. The alternating offset spacing between the inner and outer coils is 12 in. o.c. at the bottom of the obstacle.

6.3.2.2 Tie Points—Before making the final attachment to the fence, inspect the coils for tangles and proper coil spacing. The inner and outer coils shall be securely attached in two locations: one to the barbed wire, tension wire or cable located in the barb arm and the other to the top of the fence fabric. See Fig. 5. For installations using “V” arms; a second row of barbed tape shall be installed to prevent using the arm as a breaching aid. To reduce distortion as a result of adverse weather conditions, spacer cables shall remain tight throughout the installation. 16 gage, minimum, stainless steel ties are used to secure barbed obstacles to the fence. See Fig. 6.

6.3.3 Side of the Fence Installations—Coils shall be installed horizontally on the approach side of the fence. Design criteria will obviously change depending on the threat.

6.3.3.1 Deployment—Follow the same procedure for deployment as described in 6.2.3.1, except, that after dispensing the coil, rotate the coil assembly 90° and place the bottom of the obstacle against the fence.



BARBS OMITTED FOR CLARITY

FIG. 4 Double Coil Non-Reinforced

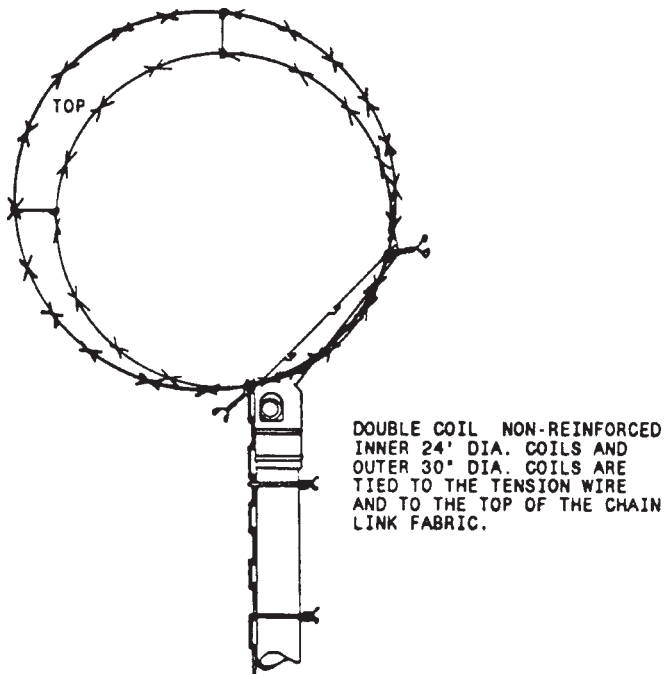


FIG. 5 Top of the Fence 45° Barb Arm Installation

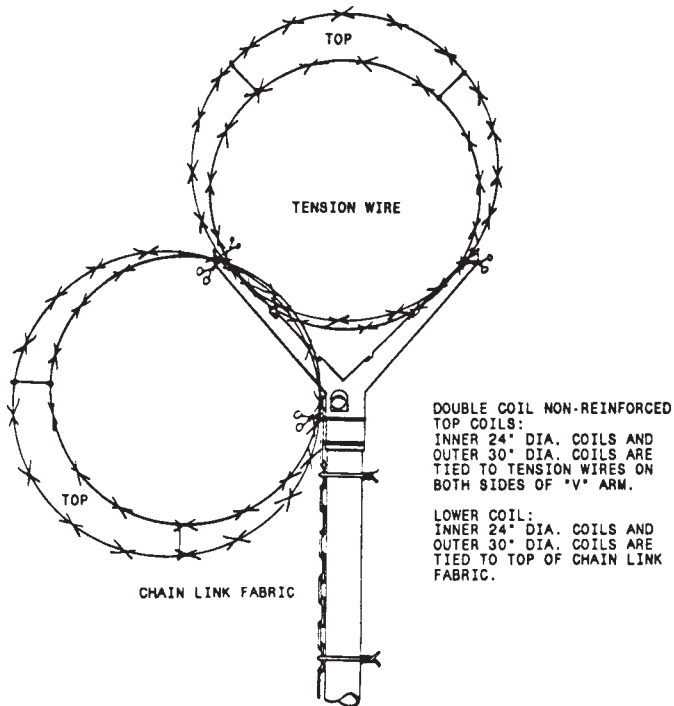


FIG. 6 Top of the Fence "V" Arm Installation

6.3.3.2 *Tie Points*—Attach the inner and outer coil loops to the fence fabric 12 in. o.c.. 16 gage minimum stainless tie wires are used for this purpose.

6.3.4 *Bottom of the Fence Installations*—Coils at the base of the fence shall be installed with the bottom of the coil resting on the ground or prepared surfaces. Consult with the manufacturer for information pertaining to coil stacking or unusual finished grade conditions that may cause installer to deviate from the standard installation.

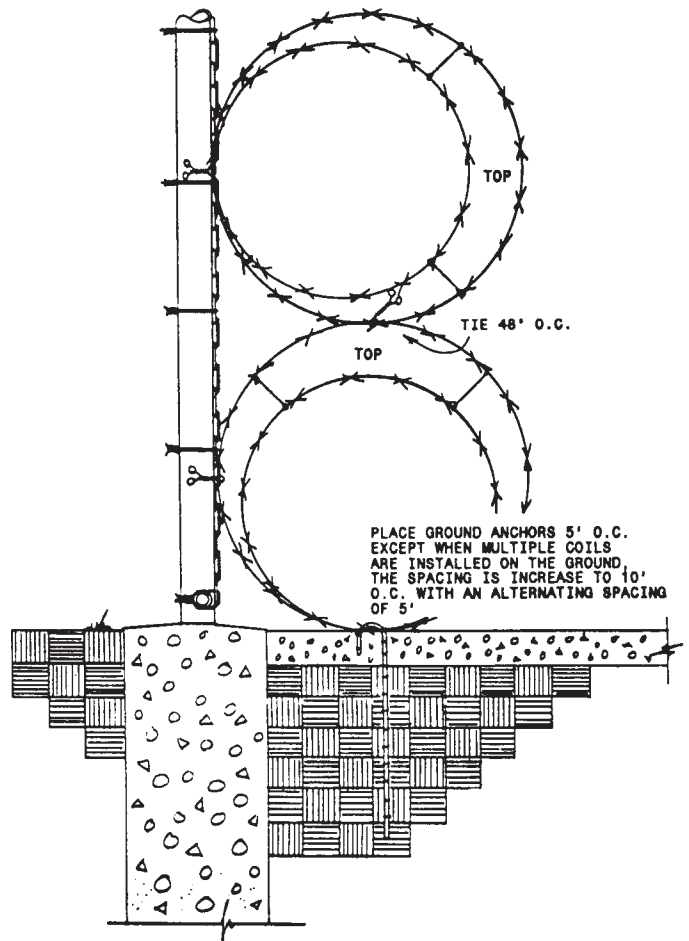


FIG. 7 Side and Bottom of the Fence Installation Non-Reinforced Barbed Tape

6.3.4.1 *Deployment*—Follow the same procedure for deployment as described in 6.3.2.1, except, that after dispensing the coil, the bottom of the obstacle shall rest on the ground.

6.3.4.2 *Tie Points*—Attach the outer coil loops to the fence fabric 24 in. o.c. 16 gage minimum stainless tie wires are used for this purpose. Adjacent coils stacked vertically and running horizontally are tied together approximately 48 in. o.c. throughout the stack.

6.3.5 *Splicing*—Connect the trailing end of the installed roll and the leading end of the un-installed roll. Connect the two rolls at the point where the four spacer cables terminated at the end turns. Adjust the rolls so that the top of each roll is relative to one another. Align the four spacer cables and matching barb clusters. At each attachment point, tie the two cables and matching barb clusters together. Complete the splice with 16 gage stainless steel tie wires diagonally across the barb. Hog rings may be used if they are designed for the purpose. Repeat this procedure for the remaining cables, as if they were manufactured into one continuous roll. Additional ties may be required to strengthen or improve on the appearance of the splice.

6.3.6 *Ground Anchors*—Coils deployed on the ground shall be anchored as required, depending on the application and security threat. For security applications, place ground stakes 5

ft. o.c.. Multiple coils on the ground for high security applications: stakes are generally 10 ft. o.c. with an alternating offset pitch of 5 ft. between rows. Length and type of anchors are determined in accordance with inherent weather and soil conditions.

#### 6.4 *Wire Reinforced, (Single Coil Concertinas),*

6.4.1 *Description*—Diameters ranging from 18 in. to 61 in. are fabricated by cold clinching the flat barbed portion of the tape around a core wire. Adjacent alternate loops are clipped together around the circumference, creating the concertina effect.

6.4.2 *Top of the Fence Installation*—Barb arms are recommended for top of the fence installations. Single 45° barb arms with a single strand of barbed wire or tension wire located in the outer position of the arm will support coils deployed at the top of the fence. Barb arms are positioned so that arms are out of reach from the approach side. “V” arms are not recommended for security applications where climbing is a threat or where only one row of barbed tape is specified. Two rows of barbed tape are recommended where “V” arms are specified. See Fig. 1.

6.4.2.1 *Deployment*—Stretch the coil out and allow it to rotate naturally around its central axis. Allowing it to rotate will ensure that there is no mechanical stress within the obstacle before tying. Locate the coil loops uniformly at the specified coil spacing. Coil loop spacings for concertina products will vary depending on the coil configuration and number of clips.

6.4.2.2 *Tie Points*—Before making the attachment to the fence, inspect the coils for tangles and proper coil spacing. Attach the first group of ties to the single strand of barbed wire, cable or tension wire located in the barb arm. Tie parallel coil loops at the desired spacing. Attach the second group of ties to the top of the chain link at the desired spacing. Tie wires for detention applications are stainless steel 16 gage minimum, for commercial and industrial applications stainless steel 18 gage minimum is adequate. Large stainless steel hog rings with a minimum cross section of 12½ gage, may be used. Hog rings are not recommended where electronic detection in an integral part of the barrier system. For high security application, the hog ring cross section must be strong enough to prevent opening the ring by pulling on the barbed tape.

6.4.3 *Side of the Fence Installation*—Coils shall be installed horizontally on the approach side of the fence. Design criteria will obviously change depending on the threat.

6.4.3.1 *Deployment*—Stretch the coils out and allow them to rotate (spiral) naturally around their central axis. Allowing the coil to rotate will ensure that there is no mechanical stress within the obstacle before tying. Locate the coil loops uniformly at the specified coil spacing. Coil loop spacing for concertina products will vary depending on the coil configuration and number of clips. Coil loop spacings for wire reinforced products are generally 12.0 in. See Fig. 2.

6.4.3.2 *Tie Points*—Before making the attachment to the fence, inspect the coils for tangles and proper coil spacing. Attach the parallel coil loops to the side of the fence using twistable tie wires. Ties for detention applications are stainless steel 16 gage minimum. For commercial and industrial appli-

cations stainless steel 18 gage minimum ties are adequate. Large stainless steel hog rings used for this purpose should be of sufficient size to wrap completely around the tape and fabric with an overlap.

6.4.4 *Bottom of the Fence Installation*—Coils installed at the base of the fence are placed horizontal in vertical stacks and tied consecutively together. Stacked coils are tied approximately 36 in. to 48 in. o.c. to adjacent rows. See Fig. 3.

6.4.4.1 *Deployment*—Stretch the coils out and allow them to rotate (spiral) naturally around their central axis. Allowing the coil to rotate will ensure that there is no mechanical stress within the obstacle before tying. Locate the coil loops uniformly at the specified coil spacing. Coil loop spacings for concertina products will vary depending on the coil configuration, number of clips and barrier density. See Fig. 2.

6.4.4.2 *Tie Points*—Follow instructions for tying described in 6.4.3.2. See Fig. 3.

6.4.5 *Splicing*—Connect the trailing end of the installed roll and the leading end of the un-installed roll. Aligning the clips from the leading and trailing rolls will allow the splicing tails to overlap a minimum of one barb cluster. Tie the overlapping barbs together (diagonally across the barbs) so as not to allow one barb from slipping past the other. Complete the splice by placing additional ties around the perimeter of splice where clips would have been installed if manufactured into one continuous roll.

NOTE 3—Short barb military concertinas are not equipped with splicing tails: complete the splice by tying the end coils together approximately where clips would have been if manufactured in one continuous roll.

6.4.6 *Ground Anchors*—Coils deployed on the ground shall be anchored as required, depending on the application and security threat. For security applications, place ground stakes 5 ft. o.c.. Multiple coils on the ground for high security applications: stakes are generally 10 ft. o.c. with an alternating offset pitch of 5 ft. between rows. Length and type of anchors are determined in accordance with inherent weather and soil conditions.

#### 6.5 *Wire Reinforced (Double Coil Concertina):*

6.5.1 *Description*—Double coil concertina units are constructed of a smaller diameter coil placed inside a larger diameter coil with the ends fastened together to aid in deployment. Each concertina coil is fabricated by cold clinching the flat barbed portion of the tape around a core wire. Adjacent alternating loops are clipped together around the circumference creating the concertina effect.

6.5.2 *Top of The Fence Installation*—Barb Arms are recommended for top of the fence installations. Single 45° barb arms with a single strand of barbed wire or tension wire located in the outer position of the arm will support the double coil unit deployed at the top of the fence. Barb arms are positioned so that arms are out of reach from the approach side. “V” arms are not recommended for security applications where climbing is a threat or where only one double coil unit is specified. Two rows of barbed tape are recommended where “V” arms are specified. See Fig. 1.

6.5.2.1 *Deployment*—Stretch the unit out and allow the coils to rotate (spiral) naturally around it central axis. Allowing the coil to rotate will ensure that there is no mechanical stress



within the obstacle before tying. Locate the inner and outer coil loops uniformly at the specified coil spacing. Coil loop spacings for double coil concertina products may vary depending on the coil configuration and clipping arrangement.

**6.5.2.2 Tie Points**—Before making the final attachment to the fence inspect the coils for tangles and proper coil spacing. When fully deployed, the inner coil loops are approximately located between the outer coil loops. Attach the outer coil loops to the single strand of barbed wire, cable or tension wire located in the barb arm. Tie parallel coil loops at the desired spacing. The second group of ties, secure the outer coil loops to the top of the chain link at the desired spacing. Where electronic detection is an integral part of the barrier system, the inner coil is also tied to the top of the chain link fabric. Tie wires for detention applications are stainless steel 16 gage minimum, for commercial and industrial applications stainless steel 18 gage minimum is adequate. Stainless steel hog rings with a minimum cross section of 12 ½ gage, may be used. Hog rings used for this purpose shall be of sufficient size to wrap completely around the tape and fabric with an overlap. See Fig. 8.

**6.5.3 Side of the Fence Installations**—Coils shall be installed horizontally on the approach side of the fence. Design criteria will obviously change depending on the threat. Consult with the manufacturer for alternative methods of installations.

**6.5.3.1 Deployment**—Stretch the coil out and allow it to rotate (spiral) naturally around its central axis. Allowing the coils to rotate will ensure that there is no mechanical stress within the obstacle before tying. Locate the inner and outer coil loops uniformly at the specified coil loop spacing. Coil loop spacings for double coil concertina products may vary depending on the coil configuration and clipping arrangement.

**6.5.3.2 Tie Points**—Before making the final attachment to the fence fabric, inspect the coils for tangles and proper coil spacing. When fully deployed the inner coil loops are approximately located between the outer coil loops. Attach the outer coil loops to the side of the fence; by tying parallel coil loops at the desired spacing. Where electronic detection is an integral part of the barrier system, the inner coil is also tied to the side of the fence. Tie wires for detention applications are stainless steel 16 gage minimum, for commercial and industrial applications stainless steel 18 gage minimum is adequate. Stainless steel hog rings with a minimum cross section of 12 ½ gage, may be used. Hog rings used for this purpose shall be of sufficient size to wrap completely around the tape and fabric with an overlap. See Fig. 9.

**6.5.4 Bottom of the Fence Installation**—Coils at the base of the fence are placed horizontal in vertical stacks and tied consecutively together. Stacked coils are tied approximately 36 in. to 48 in. o.c. to adjacent rows. See Fig. 3.

**6.5.4.1 Deployment**—Stretch the coil out and allow it to rotate (spiral) naturally around its central axis. Allowing it to rotate will ensure that there is no mechanical stress within the obstacle before tying. Locate the inner and outer coil loops uniformly at the specified coil loop spacing, both the inner and outer coils will rest on the ground. Coil loop spacings for double coil concertina products may vary depending on the coil configuration and clipping arrangement.

**6.5.4.2 Tie Points**—The outer coil is secured in the same manner as described in 6.5.3.2, except the inner coil will rest on the ground or prepared surface.

**6.5.5 Splicing**—Connect the trailing ends of the double coil unit to the leading ends of the un-installed unit. Aligning the clips from the leading and trailing end of the inner coil will allow the splicing tails to overlap a minimum of one barb cluster. Tie the overlapping barbs together (diagonally across the barbs) to prevent one barb from slipping past the other. Complete the splice by placing an additional tie approximately 180° across from the overlapping splice, where attaching clips would have been if manufactured in one continuous roll. Larger diameter double coil units may require more than one splicing tie on the opposite side away from the overlap. Repeat the above procedure for the outer coil.

**NOTE 4**—If coils are allowed to rotate around their central axis, during installation, you may choose to remove the ring or cable attachment joining the end coil loops together. Removing the end attachments during the splicing operations, permits the inner coil to assume its natural position when secured to the fence or resting in the bottom of the outer coil.

**6.5.6 Ground Anchors**—Coils deployed on the ground shall be anchored as required, depending on the application and security threat. For security applications; place ground stakes 5 ft. o.c. Multiple coils on the ground for high security applications: stakes are generally 10 ft o.c. with an alternating offset pitch of 5 ft between rows. Length and type of anchors are determined in accordance with inherent weather and soil conditions.

**NOTE 5**—Tying the inner diameter coil to the top and side of the fence is not necessarily limited to those installations specifying electronic detection. Tying the inner coil provides greater strength and stability to the barrier system.

## 6.6 Wire Reinforced (Single Helical Coils):

**6.6.1 Description**—Coil Diameters up to 25 in. are fabricated by cold clinching the flat barbed portion of the tape around a core wire. There are no attaching clips around the circumference, except for manufactured, in line, splice connections.

**NOTE 6**—Before untying the roll, while the barb clusters are still aligned in the packaged condition, paint one row of barb clusters with a bright color. The brightly painted barb clusters will serve as a point of reference for tying the tape in place at the top or side of the fence; including roof and wall mounted tension wires.

**6.6.2 Top of the Fence Installation**—The following fence toppings are primarily used for industrial/commercial applications. The following methods of attachment are commonly used: extended line and terminal post with barbed wire or tension wire, 45° barb arms or “V” barb arms with barbed wire, no arms with top rail and no arms with top tension wire.

**6.6.2.1 Deployment**—After removing the bundling ties, uncoil the helical coils one by one and place them at the specified spacing.

**6.6.2.2 Tie Points**—Attach the dispensed coils from the opposite side of the fence. 12 ½ in. gage minimum hog ring or 18 in. gage minimum tie wires are used for this purpose. Tie wires and hog ring materials shall be compatible to that of the barbed tape.

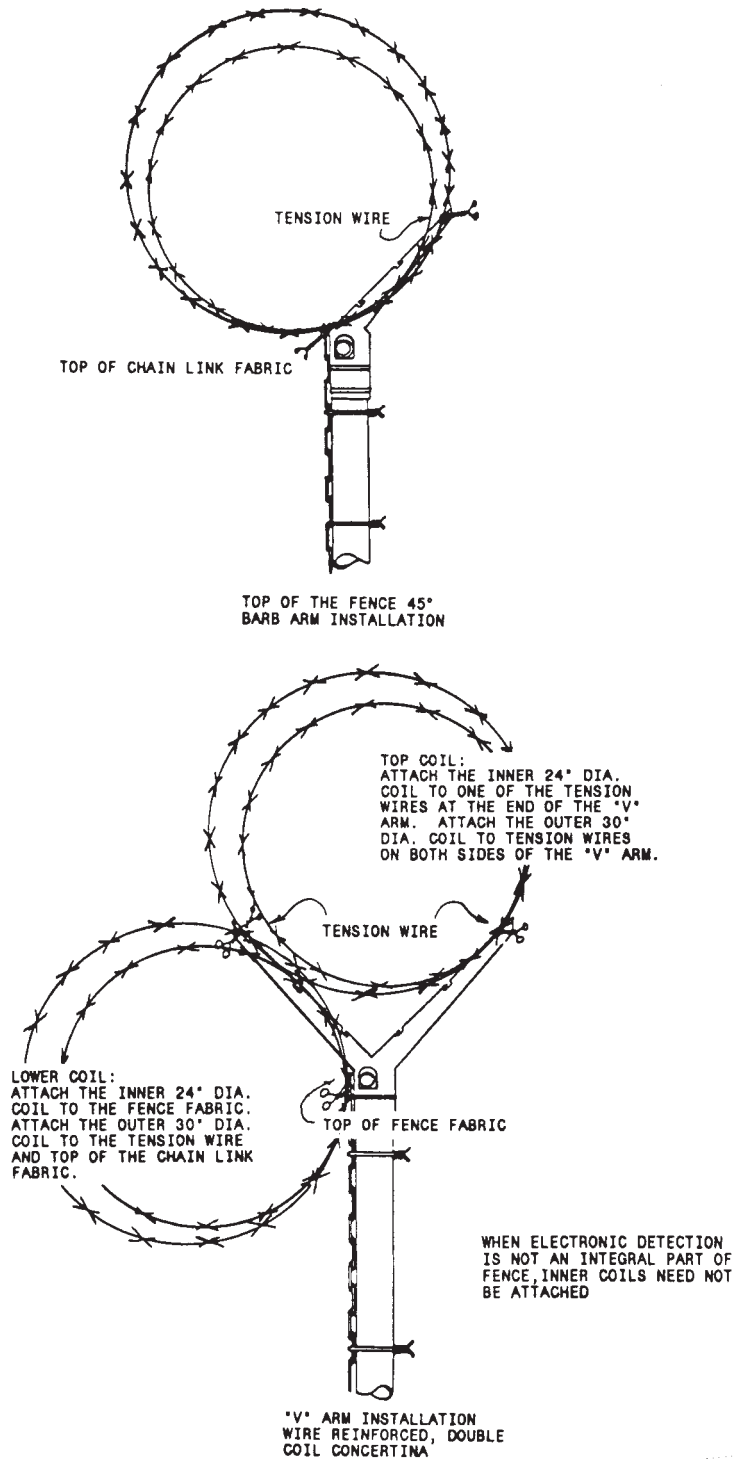


FIG. 8 Wire Reinforced Double Coil Concertina

6.6.3 *Side of the Fence Installation*—Coils shall be installed horizontally on the approach side of the fence. Design criteria will obviously change depending on the threat. Consult with the manufacturer for alternative methods of installations.

6.6.3.1 *Deployment*—Follow deployment procedures described in 6.5.3. The coil shall *not* rotate around its central axis, and every coil *will* be tied to the fence.

6.6.3.2 *Tie Points*—Helical coils are secured in the same manner described in 6.5.2.2.

6.6.4 *Splicing*—Overlap the leading and trailing ends of the barbed tape a minimum of one barb cluster. Tie the barb clusters (diagonally across the barb) together using 18 gage stainless steel or 16 gage zinc coated tie wires. Hog rings may also be used for this purpose.

NOTE 7—Placement and tying of coils to the fence will appear similar to those in Fig. 1, Fig. 2, Fig. 3, and Fig. 10.

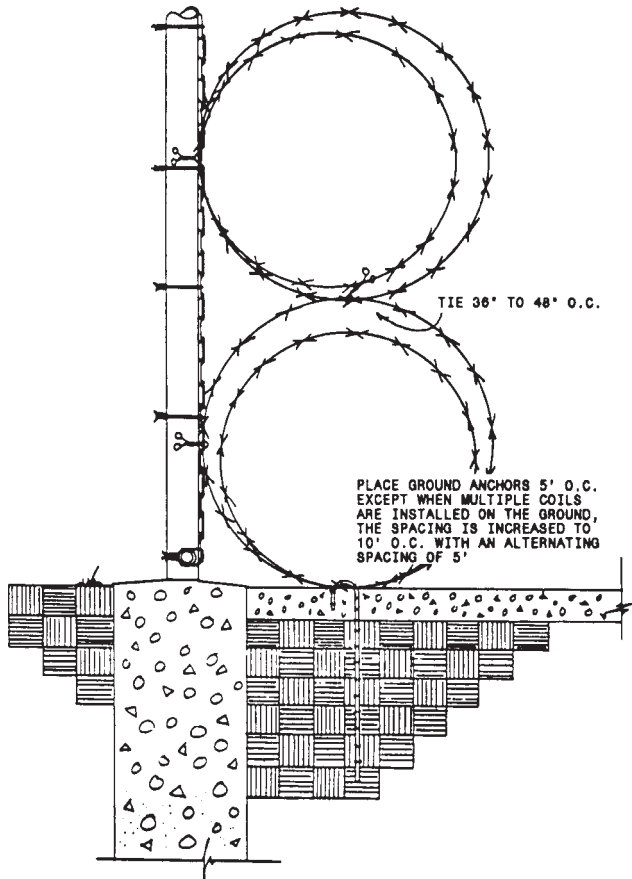


FIG. 9 Side and Bottom of Fence Installation Wire Reinforced Double Coil Concertina

NOTE 8—Helical barbed tape for industrial/commercial applications is easily adapted to numerous structures not shown. For additional information contact the manufacturer.

6.7 Roll Formed Helical Coil with No Reinforcing Wire,

6.7.1 Description— 12, 18 and 24 ft diameter barbed tape with a geometrical stiffening groove running longitudinally through the center of the tape. All installation instructions are similar to those described in 6.5 for helical coils, wire reinforced barbed tape.

7. Installation Tolerances

7.1 Concertina Security Coils—Security coil’s yield length is proportional to coil loop spacings. See Table 1.

7.1.1 Concertina Coil Diameters—Concertina security coils will reduce in diameter, proportional to the coil loop spacing: for each inch of coil loop spacing, the diameter will reduce approximately  $\frac{5}{32}$  inch.

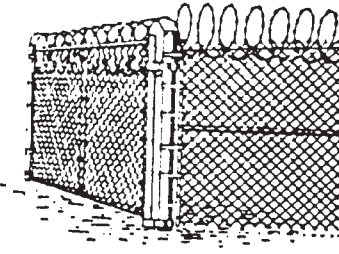
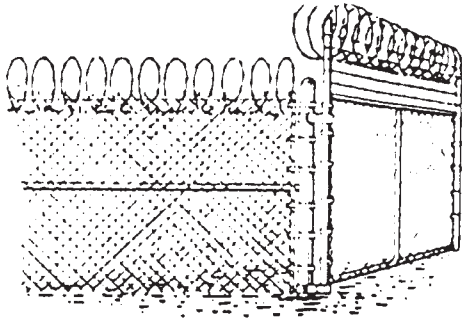
7.2 Helical Security Coils—Helical coil’s yield length is proportional to coil loop spacings. See Table 2.

7.2.1 Helical Coil Diameters—All helical security coils will reduce in diameter, proportional to the coil loop spacing: for each inch of coil loop spacing, the diameter will reduce approximately  $\frac{1}{32}$  in.

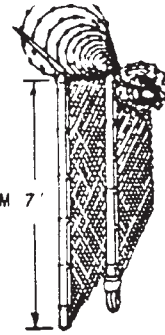
7.3 Minimum Height (warning)—Barbed tape installed on fences and walls shall have a minimum height of 7 ft to the bottom of the coil. If lower heights or ground installations are required, additional intermediate fencing is mandatory to restrict access and prevent accidental encounters with the barriers.

8. Keywords

8.1 barbed tape; barbed tape, installation

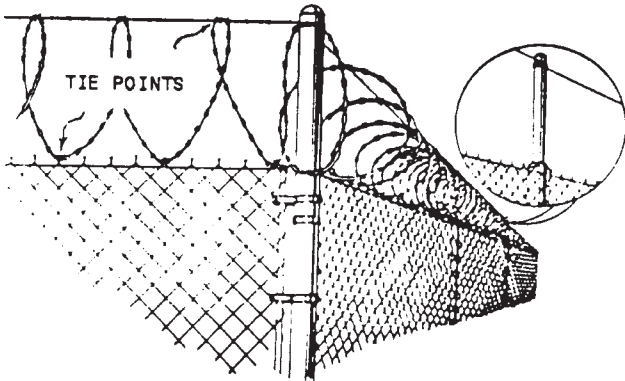


GATE VARIATIONS



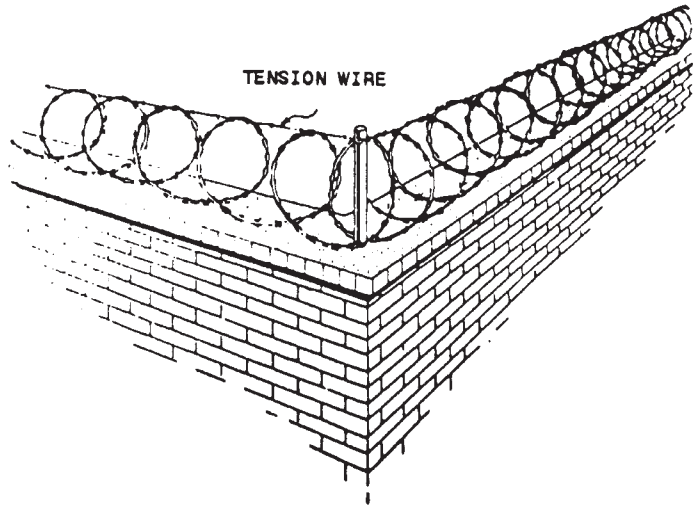
MINIMUM 7'

FENCE & SLIDING GATE



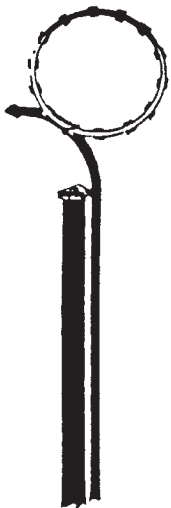
TIE POINTS

EXTENDED LINE POST

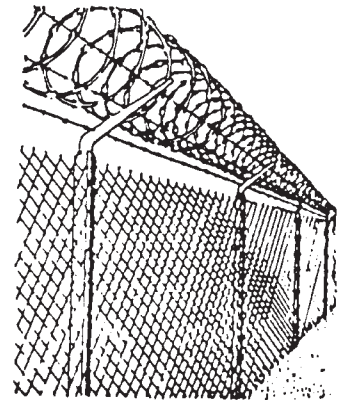


TENSION WIRE

TOP OF WALL



DECORATIVE FENCE



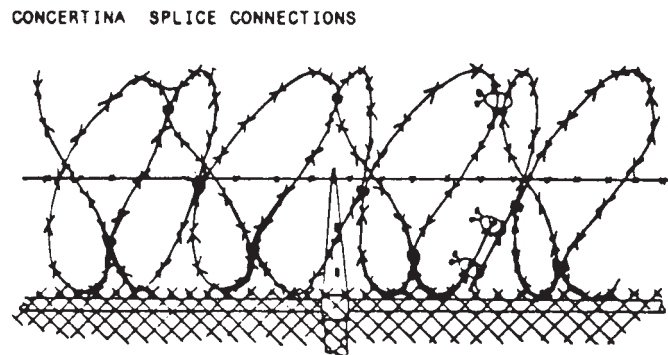
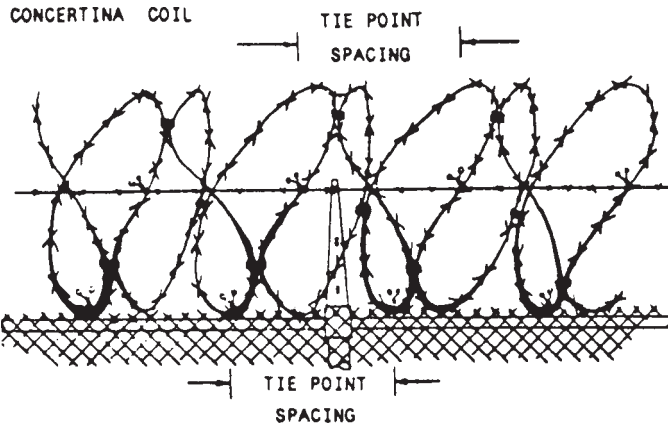
TOP OF FENCE, FOR FENCE FABRIC SHY OF 7 FEET

FIG. 10 Industrial/Commercial Installations

TABLE 1 Maximum Allowable Tolerance (Concertina)

NOTE 1—Allow up to 2 ft material loss when covering inside or outside corners.

Coil Loops Per Roll	Spacing, in. $\pm$ 2 in.	Yield, Ln. ft	Yield, Not to Exceed $\pm$ Ln. ft
31 (18 in. Dia)	12	15	1
31	16	20	1
31/31	16/16	20	1
51	12	25	1
56 (Type II)	21	50	1
81	12	40	1
101	12	50	1



The number of connections opposite to the overlapping splice will vary depending on the number of clips.

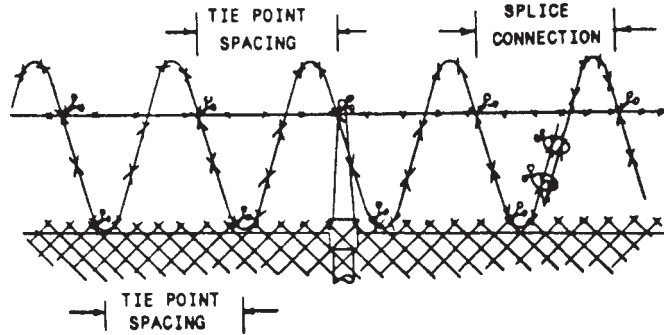
Hog-rings or twistable tie wires are used to complete the splice.

TABLE 2 Maximum Allowable Tolerance (Helical)

NOTE 1—Allow up to 2 ft material loss when covering inside or outside corners.

Coil Loops Per Roll	Spacing, in. $\pm$ 2 in.	Yield, Ln. ft	Yield, Not to Exceed $\pm$ Ln. ft
33	18	50	1
33/33 (Type II)	24/24	66	+1, -3

HELICAL COIL



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# Standard Practice for Installation of Rigid Poly(Vinyl Chloride) (PVC) Fence Systems<sup>1</sup>

This standard is issued under the fixed designation F 1999; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon ( $\epsilon$ ) indicates an editorial change since the last revision or reapproval.

## 1. Scope

1.1 This practice covers the minimum requirement for and methods of installation for rigid poly(vinyl chloride) (PVC) fencing systems and fence accessories in areas where the maximum frost penetration does not exceed 30 in. (76 cm). In all cases, refer also to the specific manufacturer's instructions for installation.

1.2 This practice is intended to guide those responsible for or concerned with installation of rigid (PVC) fence systems.

1.3 This practice does not preclude any test method that is proven to give equal or better performance under any weather, soil, or frost conditions.

1.4 End-use and applicable code requirements shall be considered in the choice of fence style, spacing, height, and installation method.

1.4.1 Paddock fencing for livestock may need to be more durable than perimeter fence.

1.4.2 Residential fence styles may not be designed for balcony or guardrail use.

1.5 The values stated in inch-pound units are to be regarded as standard. The values given in parentheses are for information only.

1.6 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

## 2. Referenced Documents

### 2.1 ASTM Standards:

A 706/A 706M Specification for Low-Alloy Steel Deformed and Plain Bars for Concrete Reinforcement<sup>2</sup>

D 2564 Specification for Solvent Cements for Poly(Vinyl Chloride) (PVC) Plastic Piping Systems<sup>3</sup>

F 964 Specification for Rigid Poly(Vinyl Chloride) (PVC) Exterior Profiles Used for Fencing<sup>4</sup>

## 3. Terminology

### 3.1 Definitions of Terms Specific to This Standard:

3.1.1 *clip*—a component used to lock rails into routed posts.

3.1.2 *end cap*—a component to cover the open end of a rail or other extrusion.

3.1.3 *exterior profile*—a rigid poly(vinyl chloride) (PVC) extrusion that conforms to Specification F 964.

3.1.4 *gate*—a hinged panel for passage into or out of a fenced area.

3.1.5 *hinge post*—the post to which a gate is attached.

3.1.6 *notch*—a method of creating a tab used to lock rails into routed posts.

3.1.7 *outside brackets*—components used to fasten rails to the outside of posts, when routed posts are not used.

3.1.8 *picket*—a vertical member in a fence panel, between or attached to the horizontal members.

3.1.9 *picket cap*—a component used to cover or decorate the open end(s) of picket.

3.1.10 *post cap*—a component used to cover the top of a post.

3.1.11 *posts*—the vertical structural support members of the fence.

3.1.12 *rails*—the horizontal members which insert into or attach to the posts. They serve as the sole sections between posts or as back rails to which picket verticals are attached.

3.1.13 *routed posts*—posts with holes cut into them to allow rails to be inserted.

3.1.14 *terminal post*—the end or last vertical structural support member of the fence.

## 4. Materials

4.1 *Exterior Profiles*, in accordance with Specification F 964.

4.2 *Solvent Cement*—Poly(Vinyl Chloride) (PVC) solvent cement in accordance with Specification D 2564.

4.3 *Reinforcing Steel Rods*, in accordance with Specification A 706/A 706M low-alloy steel deformed bars for concrete reinforcement.

## 5. Protection of Material in Transportation and Storage

5.1 Exterior profiles shall be supported in a manner that will prevent sagging, twisting, or bending. Fence products shall be stored in a manner that prevents accumulation of dust and dirt.

<sup>1</sup> This practice is under the jurisdiction of ASTM Committee F-14 on Fences and is the direct responsibility of Subcommittee F14.30 on Color.

Current edition approved Jan. 10, 2000. Published April 2000.

<sup>2</sup> *Annual Book of ASTM Standards*, Vol 01.04.

<sup>3</sup> *Annual Book of ASTM Standards*, Vol 08.04.

<sup>4</sup> *Annual Book of ASTM Standards*, Vol 01.06.

Exposure to sunlight is not harmful.

**6. Site Preparation**

6.1 Unless otherwise specified in the contract or purchase order, the purchaser shall indicate the location of fence lines, gates, and terminal posts with suitable stakes. Stake intervals shall not exceed 500 ft (152.5 m) or line of sight.

6.2 Unless otherwise specified in the contract or purchase order, the purchaser shall indicate the location of all underground utilities, USC&G benchmarks, property monuments, and other underground structures.

6.3 Unless otherwise specified in the contract or purchase order, the purchaser shall perform all necessary site clearing and grading. Clearance on both sides of the fence line is required.

**7. Installation of Posts**

*7.1 Preparation of Post Holes:*

7.1.1 Set posts in concrete in holes of diameter and depth as follows. Intended use and local conditions shall determine post footing dimensions, that is, under normal conditions the diameter shall be 4 in. (101 mm) greater than the largest cross section of the post. The depth shall be a minimum of 24 in. (609 mm) plus an additional 3 in. (76 mm) for each 1-ft (305-mm) increased fence height over 4 ft (1.22 m).

7.1.2 In areas where frost is common, the footing shall extend a minimum of 6 in. (152.4 mm) below the maximum frost level.

7.2 *Preparation of Post*—To secure post vertically, provide a means such as, but not limited to, notching, drilling, roughing, pinning, etc.

7.3 *Installation of Posts*—This practice includes three post setting methods. Method 1 should be used where there are mucky or loose soil conditions.

7.3.1 *Method 1*—Partially fill holes with concrete, then set the post into the concrete leaving approximately 2 to 4 in. (51 to 101 mm) of concrete below the bottom of the post (see Fig. 1). Continue filling the hole with concrete to within 6 to 9 in. (152.4 to 228.6 mm) of the top. Fill the remainder of the hole with soil or fine rocks. Where frost is not likely, the hole may be filled to ground level with concrete (see Note 1). The post shall extend a minimum of 18 in. (457.2 mm) into the concrete (see Fig. 2). Check to see that the post remains plumb until the concrete has set.

NOTE 1—Filling hole to top with concrete in frost areas will enhance upheaval of post and footers as concrete freezes faster than fill.

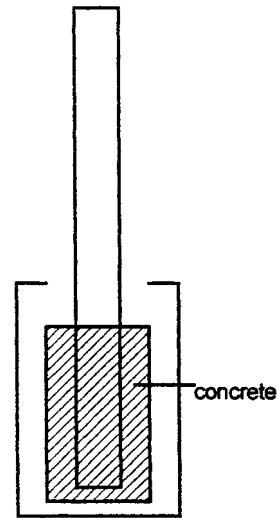


FIG. 1

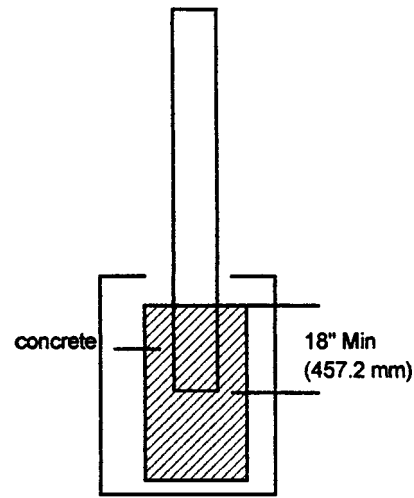


FIG. 2

7.3.2 *Method 2*—Tap the post into the bottom of the hole until the desired height of the post above ground level is reached (see Note 2 and Fig. 3). Add concrete around the post to the level specified in 7.3.1. Check to see that the post remains plumb until the concrete has set.

NOTE 2—This method should not be used where there are mucky or loose soil conditions as without concrete under the post, it may sink if downward pressure is applied.

7.3.3 *Method 3*—Tap the post into the bottom of the hole until the desired height of the post above ground level is reached (see Fig. 4). Fill the hole one fourth of the depth with concrete, then add fine rocks or gravel to one half of the depth of the hole, then add concrete to three fourths of the depth of the hole. Fill the remainder of the hole with soil, gravel, or fine rocks (see Note 1). Check to see that the post remains plumb until the concrete has set.

**8. Installation of Rails and Sections**

8.1 Explanation or contraction values for fence profiles are given in Table 1. Rails shall extend into routed posts with

**TABLE 1 Thermal Expansion in Inches (Millimetres ) for PVC Fence Profiles<sup>A</sup>**

Rail Length, ft (m)	80°F Temperature Change	100°F Temperature Change	120°F Temperature Change
6 (1.8)	3/32 (2.38)	1/8 (3.2)	5/32 (3.97)
8 (2.44)	1/8 (3.2)	5/32 (3.97)	3/16 (4.76)
10 (3.05)	5/32 (3.97)	3/16 (4.76)	1/4 (6.4)
12 (3.6)	3/16 (4.76)	7/32 (5.55)	9/32 (7.14)
14 (4.27)	7/32 (5.55)	9/32 (7.14)	11/32 (8.73)
16 (4.88)	1/4 (6.4)	5/16 (7.94)	3/8 (9.53)

<sup>A</sup>These values are calculated using a coefficient of linear thermal expansion of  $4.4 \times 10^{-5}$  in./in./°F.



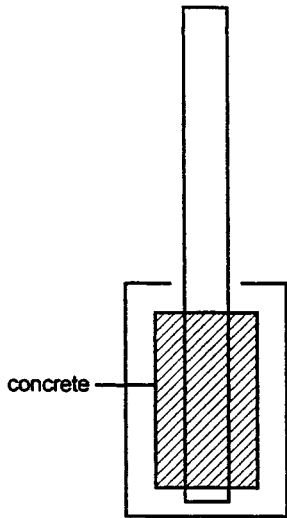


FIG. 3

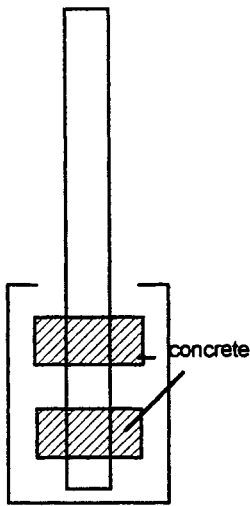


FIG. 4

sufficient distance between notches or clips, etc. and the inside wall of the post to accommodate the given contraction. When two rails are inserted into a post, end to end, a gap shall be provided between them for expansion. In all cases, rails shall extend a minimum of 1 in. (25.4 mm) into routed posts. The fractional dimensions shown in Table 1 are applied to both ends of the rail.

8.2 If outside brackets are used, they shall be fastened securely with noncorrosive fasteners in accordance with the manufacturer's instructions.

**9. Installation of Post Caps and Picket Tops, etc.**

9.1 Post caps, end caps, and picket caps, if not pre-fastened

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2" (50.8mm) Min

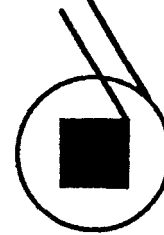


FIG. 5

by the manufacturer, shall be attached in accordance with the manufacturer's recommendation, or by noncorrosive fasteners, or by solvent cement bonding.

**10. Installation of Gates on Posts**

10.1 Gate hinge posts require more support than line posts. Follow the manufacturer's instructions regarding the use of inserts to minimize deflection.

10.2 Install gates true to opening and plumb in a closed position.

10.3 Gates shall operate freely, and closures shall be properly installed in accordance with all applicable codes and the manufacturer's recommendations.


10.4 Unless specified by an applicable code, the purchaser shall indicate the operational direction of the gates.

**11. Appearance**

11.1 The areas of installation shall be left neat and free of any debris caused by the installation of fence.

**12. Keywords**

12.1 fence; installation; rigid poly(vinyl chloride) (PVC)

 **F 1999**

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# Standard Guide for Fences/Barriers for Public, Commercial, and Multi-Family Residential Use Outdoor Play Areas<sup>1</sup>

This standard is issued under the fixed designation F 2049; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon ( $\epsilon$ ) indicates an editorial change since the last revision or reapproval.

## 1. Scope

1.1 This guide provides the recommended minimum requirements for denoting various types of fences/barriers for the protection of children's outdoor play spaces in public, commercial, and multi-family residential use locations. This guide excludes individual single family residential use play equipment locations.

1.2 This guide provides for the safety of occupants in play areas or zones as it pertains to vehicular intrusion as well as other participant intrusion, and for children containment or entry/exit.

1.3 *This guide does not purport to address the aspect of safety within a play area or zone. It is the responsibility of the user of this guide to establish appropriate safety practices as related to the play area and determine the applicability of regulatory requirements prior to use.*

1.4 This guide does not choose the product components for the fence system, the choice of which should be made by the operators of the play space and their specification writers or drafters based upon their determination of the merits of the products that could be used.

1.5 The values stated in inch-pound units are to be regarded as standard. The SI values given in parentheses are for information only.

## 2. Referenced Documents

### 2.1 ASTM Standards:

- A 123/A 123M Specification for Zinc Hot-Dip Galvanized Coatings on Iron and Steel Products<sup>2</sup>
- A 392 Specification for Zinc-Coated Steel Chain-Link Fence Fabric<sup>2</sup>
- A 491 Specification for Aluminum-Coated Steel Chain-Link Fence Fabric<sup>2</sup>
- F 552 Terminology Relating to Chain-Link Fencing<sup>2</sup>
- F 567 Practice for Installation of Chain-Link Fence<sup>2</sup>

F 626 Specification for Fence Fittings<sup>2</sup>

F 668 Specification for Poly(Vinyl Chloride) (PVC) and Other Organic Polymer-Coated Steel Chain-Link Fence Fabric<sup>2</sup>

F 1043 Specification for Strength and Protective Coatings on Metal Industrial Chain-Link Fence Framework<sup>2</sup>

F 1083 Specification for Pipe, Steel, Hot Dipped Zinc-Coated (Galvanized) Welded, for Fence Structures<sup>2</sup>

F 1183 Specification for Aluminum Alloy Chain-Link Fence Fabric<sup>2</sup>

F 1345 Specification for Zinc-5 % Aluminum-Mischmetal Alloy-Coated Steel Chain-Link Fence Fabric<sup>2</sup>

F 1664 Specification for Poly(Vinyl Chloride) (PVC)-Coated Steel Tension Wire Used with Chain-Link Fence<sup>2</sup>

### 2.2 CPSC Document:

Model Pool Barriers Publication

### 2.3 BOCA Document:

BOCA National Building Code/1993 – 12th Edition

### 2.4 Research Reports:

Colcote, L. R. and Mitchie, J. D., *National Cooperative Highway Research Program Report #54*, "Location, Selection, and Maintenance of Highway Guardrails and Median Barriers," S. W. Research Institute, San Antonio, TX

### 2.5 Building Codes:

Standard Building Code, 1994 Edition, 2nd printing

Uniform Building Code, Vol. II, Section 311.2.3.5: Vehicle Barrier

### 2.6 Other Documents:

Other association standard weld wire draft specifications.

## 3. Terminology

3.1 See Terminology F 552 for definitions of terms relating to chain-link fencing.

### 3.2 Definitions of Terms Specific to This Standard:

3.2.1 *fence, n*—type of containment that surrounds and obstructs primarily people passage to or from the play area.

3.2.2 *barrier, n*—type of containment or deflector system that surrounds and obstructs primarily vehicle passage into a play area, such as bollards and posts.

<sup>1</sup> This guide is under the jurisdiction of ASTM Committee F14 on Fences and is the direct responsibility of Subcommittee F14.10 on Specific Applications.

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<sup>2</sup> *Annual Book of ASTM Standards*, Vol 01.06.

3.2.3 *continuous barrier, n*—type of traffic barrier designed to prevent vehicular intrusion into a play area and that also impedes pedestrian passage to and from the play space.

3.2.4 *curb, n*—permanent, continuous structure made of concrete, asphalt, or other structural material presenting a 6 to 8 in. [15.24 to 20-32 cm] elevation change at the curbline.

3.2.5 *curbline, n*—pavement elevation change defining the edge of a fire lane, vehicular travel lane, or contiguous or individual parking spaces with depressions meeting ADA requirements.

3.2.6 *debris fence, n*—shield used to prevent flying post-crash or other debris from entering a play zone.

3.2.7 *discrete barrier, n*—barrier designed to prevent vehicular intrusion that allows for pedestrian passage to and from the play space.

3.2.8 *guardrail, n*—an example of a continuous barrier.

3.2.9 *low-speed, n*—less than 35 mph [56.33 km/h].

3.2.10 *play zone or area, n*—fenced-in or enclosed space or environment for public, multi-family residential, or commercial play use containing recreation equipment intended for activities by children where entry or egress access is limited.

3.2.10.1 *Discussion*—This may be through its adjacent apartment or home decorative lattice work, public or commercial building door, or via a controlled gate. Examples include, but are not limited to, the following: fast food establishments, day-care centers, shopping malls, and apartments.

3.2.11 *proximity, n*—within 5 ft [1 or 1.524 m] as measured by the least distance between the edge of the driving lane to perimeter of the play zone and its fence/barrier.

3.2.12 *structural bollards, n*—steel pipe structure filled with concrete installed in the ground with a concrete footing.

3.2.12.1 *Discussion*—A structural bollard is an example of a barrier and discrete barrier.

3.2.13 *vulnerable play zone, n*—play zone in the proximity of vehicular traffic.

3.2.14 *traffic, n*—movement of vehicles for purpose of driving-through or parking motions.

## 4. Site Covered

4.1 A play zone shall be protected in accordance with this guide in locations that are vulnerable to low-speed vehicular traffic, from activity and game conflicting uses, and for the control of entering or exiting the play zone or area. Protection shall be placed, as specified in Section 7, on all sides of the play zone.

## 5. Significance and Use

5.1 This guide sets forth minimum standard requirements for use in local codes and ordinances relating to public, multi-family, residential, and commercial outdoor play areas or zones and their environments.

5.2 This guide does not have the effect of law, nor is it intended to supersede local codes and ordinances of a more restrictive nature.

5.3 This guide provides certain recommendations to assist those who intend to provide protection against injuries or fatalities associated with any possible vehicle passage into, or pedestrian passage to or from, a play environment by children. This would include, but not be limited to, state and local

governments, model code organizations, building code groups, and consumers. It is understood that the format will vary depending upon the specific use and local conditions.

## 6. Methods of Protection

6.1 *Discrete and Continuous Barriers*—These methods of protection shall be determined by the vulnerable play area or play zone requirement for protection for vehicle intrusion and adjacent traffic circumstances.

6.1.1 *Continuous Barrier*—If a vulnerable play area has no exterior exit gate on the traffic side of the play zone, then the play area shall be protected with a continuous barrier on the traffic side as specified in the following sections. If pedestrian access through this continuous barrier is necessary, it shall meet applicable sections. Continuous barrier methods include, but are not limited to, guardrails, concrete or brick reinforced walls, and concrete jersey barriers.

6.1.2 *Discrete Barrier*—If a vulnerable play area has an exit gate on the traffic side of the play zone, then pedestrian access through a barrier is necessary and a discrete barrier should be provided on the traffic side as specified in the following sections. Discrete barrier methods include, but are not limited to, the following: structural bollards, trees, posts, and other vertical structures spaced no wider than 4 in.

6.1.3 *Fences*—All vulnerable play areas shall have fences with gates as described in the following section. This method of protection may include chain link and other materials of a minimum height of 4 ft [1.22 m] above grade.

6.1.4 *Building*—Where a building may abut or is adjacent to a play area or play zone, it may be used as part of the containment. If the building wall contains a door for ingress and egress into the play area, it shall comply with subsequent sections. If the building wall contains windows for viewing, it shall contain glazing that is unbreakable and shatter-proof.

6.2 *Buildings*—The fence shall completely surround the play zone or area environment except where a building or dwelling or portion thereof is utilized as part of the play environment enclosure. If the exterior wall or walls of that portion of the building contains doors, or other openings, it shall comply with the following provisions.

6.2.1 *Doors*—Doors in the wall of a building or dwelling that allow direct access through the wall to the play environment shall be provided with the following:

6.2.1.1 An alarm capable of detecting unauthorized entry or exit through the gate or opening into or from the play environment area when not in use and which, when activated, emits a sound of sufficient volume to be heard in the building or dwelling as a means of outdoor area security when deemed necessary. The audible warning shall commence not more than 7 s after the door, or its screen, if present, or both are opened and shall sound continuously for a minimum of 30 s. The alarm shall have a minimum sound pressure rating of 85 dB at 10 ft [3.4 m] and the sounds of the alarm shall be distinctive from other sounds such as auto alarms, smoke alarms, telephones, and door bells. The alarm shall automatically reset after 2 min under all conditions.

## 7. Requirements

7.1 *Continuous Barrier:*

7.1.1 *Strength and Deflection Limits*—The barrier used shall be able to withstand a one-time 10 000 lb [4535.9 kg] concentrated, point-load located 2 ft [0.61 m] above ground with permanent deformation less than 0.1 in. [2.54 mm] after a single load when tested in accordance with US DOT specifications.

7.1.2 *Maintenance*—If any permanent deformation or damage is done to a continuous barrier, the play area facility shall be closed until a new barrier has been installed.

7.1.3 *Inspection*—A visual check shall be done by the owner or operator on a regular basis to note damage. A sign should be posted with the name and owner to be notified if damage occurs.

7.1.4 *Distance*—Minimum unobstructed distance between the continuous barrier and the play area perimeter fence protection shall be no less than 2 ft [0.61 m].

7.1.5 The continuous barrier shall be placed edge to edge unless passage through is required, which shall be no more than 48 in.

#### 7.2 *Discrete Barriers:*

7.2.1 *Strength and Deflection Limits*—The barrier system used shall meet the requirements of 7.1.1.

7.2.2 Discrete barriers shall be placed a maximum of 42 in. [1.07 m] apart from each other (edge to edge).

7.2.3 *Maintenance*—Maintenance shall comply with 7.1.2.

7.2.4 *Distance*—The distance from discrete barrier to fence shall be in accordance with 7.1.4.

7.2.5 *Inspection*—Shall comply with 7.1.3.

#### 7.3 *Curbs:*

7.3.1 Curbs, in order to minimize casual contact with cars, shall be placed at a minimum distance between the travel lane and the play area zone as follows:

7.3.1.1 2 ft, 6 in. where there is no parking.

7.3.1.2 4 ft for angled parking.

7.3.1.3 5 ft where there is perpendicular parking.

#### 7.4 *Fences:*

7.4.1 *Fence Height*—The top of the fence shall be a minimum of 4 ft [1.22 m] above grade measured on the side of the fence that faces away from the play environment.

7.4.2 *Visibility*—The fence shall be designed and constructed so that it allows for a visibility to conform to the level of surveillance necessary from a designated supervising area outside or inside the play environment area to inside the play environment.

7.4.3 *Ground Clearance*—The maximum vertical clearance between grade and the bottom of the fence shall be no more than 4 in. measured on the side of the fence on both sides of the fence around the play environment and of a minimal distance to prevent toys from rolling under.

7.4.4 Solid barriers that do not have openings, such as masonry or stone walls, shall not contain indentations or protrusions except for normal construction tolerances and tooled masonry joints when used as both barriers and fences. Such indentations shall not be deeper than 0.375 in. [9.5 mm].

#### 7.5 *Fence Types:*

7.5.1 *Horizontal and Vertical Design*—Where the fence is composed of horizontal and vertical members, and if the distance between the tops of the horizontal members is less

than 45 in. [1.143 mm], the horizontal members shall be located on the side opposite the play environment to prevent egress over it. The spacing between the vertical members shall not exceed 1¾ in. [44.4 mm]. If the distance between the tops of the horizontal members is 45 in. [1.143 mm] or more, the spacing between the vertical members shall not exceed 4 in. [102 mm]. Where there are decorative cutouts, the spacing within the cutouts shall not exceed 1¾ in. [44.4 mm].

7.5.2 *Chain Link Mesh*—Mesh opening for fences shall be a nominal 1¼ in. [3.2 mm] measured between the parallel sides of the mesh, and a maximum of 1¾ in. [44.4 mm] measured horizontally between the corners of the installed mesh, unless the fence is provided with privacy slats fastened at the top or the bottom, in which case no opening in the mesh shall exceed 1¾ in. [44.4 mm].

7.5.2.1 If the tolerance of +⅛ in. [3.175 mm] indicated in Specifications A 392, A 491, F 668, F 1183, and F 1345 is rigidly applied to an ordered nominal mesh size of 1¼ in. [3.2 mm] measured between the parallel sides of the mesh, the result could be a dimension exceeding the specified maximum of 1¾ in. [44.4 mm] measured horizontally between the corners of the installed mesh. The degree of tension applied to the fabric during installation could also affect this horizontal dimension. In all cases, the horizontal opening between the corners of the fabric mesh after tensioning shall not exceed 1¾ in. [44.4 mm]. Privacy slats shall not violate the requirements of 7.4.2 regarding visibility.

#### 7.5.3 *Lattice:*

7.5.3.1 Where the fence is composed of diagonal members, such as in a lattice fence, any opening created by the diagonal members shall be a maximum of 1¾ in. [44.4 mm] measured in its largest direction.

7.5.3.2 Diagonal bracing members extending from one corner to the opposite corner creating a ladder effect on all styles of fences and gates are not permitted where spacing of vertical members in any area between posts exceeds 1¾ in. [44.4 mm].

#### 7.6 *Access Gates:*

7.6.1 Double leaf access gates for maintenance service or emergency shall comply with the requirements of 7.1.2 and shall be equipped with a locking key-operated locking device that is always locked but where the key location is noted.

7.6.2 Single leaf pedestrian access gates shall open outward away from the play environment, shall be self-closing, and shall have a self-latching device. The release mechanism of the self-latching device shall not be less than 48 in. [1.22 m] above grade. The gate and fence shall have no opening greater than ½ in. [13 mm] within 18 in. [457 mm] of the release mechanism when the gate is in the fully closed position.

#### 7.7 *Buildings:*

7.7.1 *Buildings Structures*—The fence shall completely surround the play environment except where a building or multi-family dwelling or portion thereof is utilized as part of the play environment enclosure. If the exterior wall or walls of that portion of the building contains doors, or other openings, it shall comply with the following provisions.

7.7.2 *Doors*—Doors in the wall of a building or dwelling that allow direct access through the wall to the play environment shall be provided with the following:

7.7.2.1 A self-latching device on a self-closing door at a minimum height of 4 ft [1.22 m], and

7.7.2.2 A latch at any convenient height that uses a key, electronic opener, or integral combination lock, so long as it does not negate the function of the door.

7.8 *Wall*—A wall may be the continuous barrier and the fence if the play environment structure is on grade and the wall is at least 4 ft [1.22 m] in height. Other types of barriers and fences can surround the play environment at ground level. Where the barrier is mounted on another structure, the opening between the top surface of the frame and the bottom of the fence shall be no greater than 2 in. [51 mm]. Where a wall is less than 48 in. [1.29 m] above the ground, it is not considered a continuous barrier and therefore a fence.

7.8.1 The wall, when provided, and the top rail of a fence when mounted on the top of the barrier, which is in conformance with other sections, shall be a minimum of 4 ft [1.22 m] above the play area surface.

7.9 *Picket or Ornamental Fence*:

7.9.1 A picket or ornamental type fence, when provided, shall comply with the requirements of prior appropriate sections.

## 8. Prohibited Locations

8.1 Fences shall be located so as to prohibit the use of permanent structures, equipment, or similar objects to aid in climbing the fence or climbing the adjacent structure.

8.2 *Clear Zone*—There shall be a clear zone of at least 72 in. [1.829 m] between the fence and any structures to prohibit climbing the fence or the adjacent building.

## 9. Maintenance and Inspection

9.1 It is the responsibility of the property owner, occupant, or tenant to maintain the integrity of the barrier, or fence, or both and to regularly inspect the gates, doors, and so forth, for proper closing and locking operation.

9.2 The area outside and inside the fence should be free of furniture or other objects that could be moved by a child and used to climb the fence into or out of the play zone.

## 10. Keywords

10.1 barriers; fence; fences

# ANNEX

## (Mandatory Information)

### A1. RATIONALE

A1.1 The presence of a fence, or barrier, or both around a play zone, play space, or play apparatus environment is in addition to adult or parent supervision.

A1.2 For these reasons, this guide is intended to limit or delay a child from gaining unsupervised access to or from the play environment. The recommendations consider anthropometric and developmental characteristics of children under twelve. A fence should not have footholds and handholds, and spaces should be limited in size and location to preclude a child from climbing over or passing through the fence. Latches on gates should be shielded or out of reach at least 4 ft height.

A1.3 This guide's provisions for a minimum 72 in. [1.829 m] fence height above grade is based on the ability of children to climb fences and on appropriate anthropometric and developmental characteristics of children.

A1.4 This guide is based on the head breadth and chest depth of a 13 to 18 month old and is intended to preclude

passing through an opening of a type not otherwise specified in the remaining subsections of Section 6.

A1.5 This guide is intended to reduce the potential for gaining a foothold. If horizontal members are less than 45 in. [1.143 m] apart, a child may gain both a handhold and a foothold. The 1¾ in. [44.4 mm] space requirement is based on the foot width of a 13 to 18 month old and is intended to preclude his gaining a foothold. The 45 in. [1.143 mm] horizontal member spacing is intended to prevent young children from using the horizontal members as a ladder. The 1¾ in. [44.4 mm] maximum horizontal opening in the chain link mesh is based on the foot width for young children and is intended to reduce the potential for gaining a foothold.

A1.6 This guide is intended to reduce entry or exits. The 4 in. [102 mm] space requirement is intended to preclude young children from passing through the fence.

A1.7 This guide is intended to reduce the potential for a vehicle entering the fenced play zone.

A1.8 This guide provides an emergency access gate that should open outward and be supervised. If a child pushes the gate unsupervised, they should not gain immediate access to or from the play zone and may further engage the device. Emergency access gates are required to have a self-closing and latching device. Any such emergency gate should be secured with a suitable device. The 48 in. [1.22 m] height of the release mechanism is intended to keep children under five years old from reaching it based on the reaching height of a 3.5 to 4.5

year old child. For release mechanisms on the outside of the gate, the 3 in. [76 mm] minimum requirement is intended to prevent a child from reaching over to unsecure the gate. The ½ in. [13 mm] maximum requirement is intended to prevent reaching the release mechanism through the gate or fence.

A1.9 This guide is to have fences, or barriers, or both that are manufactured to protect against electrical shock hazards from ungrounded or improperly grounded systems.

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# Standard Specification for Automated Vehicular Gate Construction<sup>1</sup>

This standard is issued under the fixed designation F 2200; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon ( $\epsilon$ ) indicates an editorial change since the last revision or reapproval.

## 1. Scope

1.1 This specification defines performance-based and prescriptive-based methods of evaluating various classes of gates that are used for vehicular traffic and are to be automated.

1.2 Gate types addressed in this specification include horizontal slide gates, horizontal swing gates, vertical lift gates, vertical pivot gates and overhead pivot gates.

1.3 Gate types not listed in this specification will be subject to any applicable provisions contained in this specification.

1.4 Automated vehicular gates that do not comply with this specification shall be subject to independent evaluation for compliance with UL 325.

## 2. Referenced Documents

### 2.1 ASTM Standards:

F 900 Specification for Industrial and Commercial Swing Gates<sup>2</sup>

F 1184 Specification for Industrial and Commercial Horizontal Slide Gates<sup>2</sup>

F 1911 Practice for Installation of Barbed Tape<sup>2</sup>

### 2.2 UL Standard:

UL 325 Standard for Door, Drapery, Gate, Louver, and Window Operators and Systems<sup>3</sup>

## 3. Terminology

3.1 *bottom retainer*—an angle or lip attached to the bottom horizontal member of a slide gate, usually used on a gate installed in a high security-related application, intended to protect a gate from crash-through related damage from vehicular impact.

3.2 *catcher*—see *receiver guide*.

3.3 *Class I Gate*—a gate intended for use in a home of one-to-four single family dwelling, or a garage or parking area associated therewith.

3.4 *Class II Gate*—a gate intended for use in a commercial location or building such as a multi-family housing unit (five or more single family units), hotel, garages, retail store, or other

building servicing the general public.

3.5 *Class III Gate*—a gate intended for use in an industrial location or building such as a factory or loading dock area or other locations not intended to service the general public.

3.6 *Class IV Gate*—a gate intended for use in a guarded industrial location or building such as an airport security area or other restricted access locations not servicing the general public, in which unauthorized access is prevented by means of supervision by security personnel.

3.7 *entrapment*—the condition of being caught or held in a position that increases the risk of injury.

3.8 *gate latch*—a manual mechanism that secures the gate in either the fully closed or fully open position.

3.9 *gate lock*—an electro-mechanical mechanism that locks the gate in either the fully closed or fully open position.

3.10 *positive stop*—a physical device that limits gate travel.

3.11 *protrusion*—an object less than 9 in.<sup>2</sup>(5806 mm) of cross sectional area and permanently attached to the gate with a surface that extends beyond the extreme horizontal or vertical planes created by the gate structure members.

3.12 *receiver post*—a post to which a receiver guide is attached.

3.13 *receiver guide*—a device mounted to a post or other fixed object which provides lateral stability to a closed gate.

3.14 *vehicular horizontal slide gate*—a gate that slides in a horizontal direction and is intended for use at a vehicular entrance or exit to a drive, parking lot, or the like.

3.15 *vehicular horizontal swing gate*—a gate that swings in a horizontal arc in a horizontal plane and is intended for use at a vehicular entrance or exit to a drive, parking lot, or the like.

3.16 *vehicular overhead pivot gate*—a gate made in one rigid piece designed to close an entire opening at a vehicular entrance or exit to a drive, parking lot, or the like, where opening and closing is accomplished by pivoting the gate about an axis, with or without a horizontal track to guide the top of the gate.

3.17 *vehicular vertical lift gate*—a gate that moves in the vertical direction and is intended for use at a vehicular entrance or exit to a drive, parking lot or the like.

3.18 *vehicular vertical pivot gate*—a gate that moves in an arc in a vertical plane and is intended for use at a vehicular entrance or exit to a drive, parking lot, or the like.

3.19 *weight bearing exposed roller*—an exposed roller that

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<sup>3</sup> Available from Underwriters' Laboratories, Corporate Progress, 333 Pfingsten Rd., Northbrook, IL 60062-2096.



supports weight from the gate.

**4. General Requirements**

4.1 Gates shall be constructed in accordance with the provisions given for the appropriate gate type listed in Sections 5-10.

4.2 Gates shall be designed, constructed and installed to not fall over more than 45 degrees from the vertical plane, when a gate is detached from the supporting hardware.

4.3 Gates shall have smooth bottom edges, with vertical bottom edged protrusions not exceeding 0.50 in. (12.7 mm) when other than the *Exceptions* listed in 4.8.

4.4 The minimum height for barbed tape shall not be less than 8 ft (2.44 m) above grade.

4.5 The minimum height for barbed wire shall not be less than 6 ft (1.83 m) above grade.

4.6 An existing gate latch shall be disabled when a manually operated gate is retrofitted with a powered gate operator.

4.7 A gate latch shall not be installed on an automatically operated gate.

4.8 Protrusions shall not be permitted on any gate.

*Exceptions:*

4.8.1 For all gates, vertical bottom edge protrusions not exceed 0.50 in. (12.7 mm) which shall be smooth on all surfaces with no sharp edges.

4.8.2 For all gates, gate locks and edge sensors shall not be considered protrusions.

4.8.3 Protrusions at the leading and trailing vertical gate edges shall not exceed .50 in. (12.7 mm), and shall be smooth on all surfaces with no sharp edges.

4.8.4 For horizontal slide gates and horizontal swing gates, top pickets and top decorative designs shall not be considered protrusions, provided they are in a vertical plane with respect to the gate. Protrusions extending outside the vertical plane shall be permitted provided such protrusions are located 7 ft (2.13 m) or more above grade.

4.8.5 For horizontal slide gates, gate locks, wheels and positive stops shall not be considered protrusions.

4.8.6 For horizontal slide gates, bottom retainers shall not be considered protrusions only when used in Class IV applications.

4.8.7 For vertical lift gates, gate locks, top pickets and top decorative designs shall not be considered protrusions.

4.8.8 For vertical lift gates, positive stops shall not be considered protrusions only when used at the top of gates.

4.8.9 For vertical pivot gates, gate locks shall not be considered protrusions.

4.9 Gates shall be designed, constructed and installed such that their movement shall not be initiated by gravity when an automatic operator is disconnected.

**5. Specific Applications**

5.1 Any non-automated gate that is to be automated shall be upgraded to conform to the provisions of this specification.

5.2 This specification shall not apply to gates generally used for pedestrian access and to vehicular gates not to be automated.

5.3 Any existing automated gate, when the operator requires replacement, shall be upgraded to conform to the provisions of

this specification in effect at that time.

**6. Vehicular Horizontal Slide Gates**

6.1 The following provisions shall apply to Class I, Class II and Class III vehicular horizontal slide gates:

6.1.1 All weight bearing exposed rollers 8 ft (2.44 m), or less, above grade shall be guarded or covered.

6.1.2 All openings shall be designed, guarded or screened from the bottom of the gate to a minimum of 48 in. (1.22 m) above grade to prevent a 2 1/4 in. (57 mm) diameter sphere from passing through the openings anywhere in the gate, and in that portion of the adjacent fence that the gate covers in the open position.

6.1.3 All openings located between 48 in. (1.22 m) and 72 in. (1.83 m) above grade shall be designed, guarded or screened to prevent a 4 in. (102 mm) diameter sphere from passing through the openings anywhere in the gate, and in that portion of the adjacent fence that the gate covers in the open position.

6.1.4 A gap, measured in the horizontal plane parallel to the roadway, between a fixed stationary object nearest the roadway (such as a gate support post) and the gate frame when the gate is in either the fully open position or the fully closed position, shall not exceed 2 1/4 in. (57 mm). See Fig. 1.

*Exception:* All other fixed stationary objects greater than 16 in. (406 mm) from the gate frame shall not be required to comply with this section.

6.1.5 Positive stops shall be required to limit travel to the designed fully open and fully closed positions. These stops shall be installed at either the top of the gate, or at the bottom of the gate where such stops shall horizontally or vertically project no more than is required to perform their intended function.

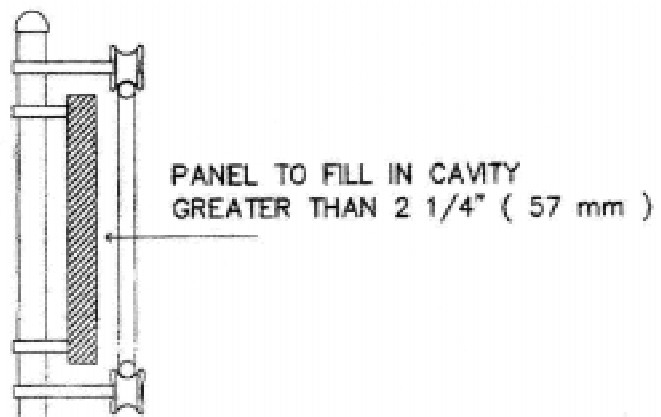
6.1.6 All gates shall be designed with sufficient lateral stability to assure that the gate will enter a receiver guide.

*6.1.6.1 Single Panel:*

Receiver guides shall be recessed behind the leading edge of the receiver post or fixed object.

*Exception:* Receiver guides mounted greater than 8 ft (2.44 m) above grade shall not be required to comply with this section.

*6.1.6.2 Dual Panels:*



**FIG. 1 Vehicular Horizontal Slide Gate- Section View**

Receiver guides, if used, may be installed on either panel, and shall include a cross-sectional area of 9 in.<sup>2</sup>(5806 mm<sup>2</sup>) or greater as measured on the leading edge of each guide.

6.2 The following provisions shall apply to Class IV vehicular horizontal slide gates:

6.2.1 All weight bearing exposed rollers 8 ft (2.44 m), or less, above grade shall be guarded or covered.

6.2.2 Positive stops shall be required to limit travel to the designed fully open and fully closed positions. These stops shall be installed at either the top of the gate, or at the bottom of the gate where such stops shall horizontally or vertically project no more than is required to perform their intended function.

## 7. Vehicular Horizontal Swing Gates

7.1 The following provisions shall apply to Class I, Class II and Class III vehicular horizontal swing gates:

7.1.1 Gates shall be designed, constructed and installed so as not to create an entrapment area between the gate and the supporting structure or other fixed object when the gate moves toward the fully open position, subject to the provisions in 7.1.1.1 and 7.1.1.2.

7.1.1.1 The width of an object (such as a wall, pillar or column) covered by a swing gate when in the open position shall not exceed 4 in. (102 mm), measured from the centerline of the pivot point of the gate.

*Exception:* For a gate that is not in compliance with this provision, the defined area shall be subject to the entrapment protection provisions of UL 325.

7.1.1.2 Except for the zone specified in Section 7.1.1.1, the distance between a fixed object such as a wall, pillar or column, and a swing gate when in the open position shall not be less than 16 in. (406 mm).

*Exception:* For a gate that is not in compliance with this provision, the defined area shall be subject to the entrapment protection provisions of UL 325.

7.2 Class IV vehicular horizontal swing gates shall be designed, constructed and installed in accordance with security related parameters specific to the application in question.

## 8. Vehicular Vertical Lift Gates

8.1 The following provisions shall apply to Class I, Class II and Class III vehicular vertical lift gates:

8.1.1 All openings shall be designed, guarded or screened to prevent a 4 in. (102 mm) diameter sphere from passing through the openings anywhere in the gate.

8.1.2 A gap, measured in the horizontal plane parallel to the roadway, between a fixed stationary object nearest the roadway (such as a gate support post) and the gate frame when the gate is in either the fully open position or the fully closed position, shall not exceed 4 in. (102 mm).

*Exception:* All other fixed stationary objects greater than 16 in. (406 mm) from the gate frame shall not be required to comply with this section.

8.1.3 Horizontal and vertical framing members of a gate shall be smooth, and shall not include horizontal protrusions other than gate hardware.

8.1.4 A positive stop shall be required to limit travel to the designed fully open position.

8.2 Class IV vehicular vertical lift gates shall be designed, constructed and installed in accordance with security related parameters specific to the application in question.

## 9. Vehicular Vertical Pivot Gates

9.1 The following provisions shall apply to Class I, Class II and Class III vehicular vertical pivot gates:

9.1.1 All openings covered by the operator when the gate is in the open position and in that portion of the operator and adjacent fence that the gate covers during the travel of the gate, shall be designed, guarded or screened to prevent a 2 ¼ in. (57 mm) diameter sphere from passing through the openings anywhere in the gate.

9.1.2 A gap, measured in the horizontal plane parallel to the roadway, between a fixed stationary object nearest the roadway (such as a gate support post) and the gate frame when the gate is in either the fully open position or the fully closed position, shall not exceed 4 in. (102 mm).

*Exception:* All other fixed stationary objects greater than 16 in. (406 mm) from the gate frame shall not be required to comply with this section.

9.1.3 Horizontal and vertical framing members of a gate shall be smooth, and shall not include protrusions other than gate hardware.

9.1.4 All gates shall be designed with sufficient lateral stability to assure that the gate will enter a receiver guide.

9.2 Class IV vehicular vertical pivot gates shall be designed, constructed and installed in accordance with security related parameters specific to the application in question.

## 10. Vehicular Overhead Pivot Gates

10.1 The following provisions shall apply to Class I, Class II and Class III vehicular overhead pivot gates:

10.1.1 All weight bearing exposed rollers 8 ft (2.44 m), or less, above grade shall be guarded or covered.

10.1.2 All openings shall be designed, guarded or screened to prevent a 4 in. (102 mm) diameter sphere from passing through the openings anywhere in the gate.

10.1.3 A gap, measured in the horizontal plane parallel to the roadway, between a fixed stationary object nearest the roadway (such as a gate support post) and the gate frame when the gate is in either the fully open position or the fully closed position, shall not exceed 4 in. (102 mm).

*Exception:* All other fixed stationary objects greater than 16 in. (406 mm) from the gate frame shall not be required to comply with this section.

10.1.4 Horizontal and vertical framing members of a gate shall be smooth, and shall not include protrusions other than gate hardware.

10.1.5 Where required, positive stops shall limit travel to the designed fully open position and/or the designed fully closed position.

10.1.6 All jamb materials, track materials and related hardware shall be designed to support the weight of the gate at any position of the gate.

10.2 Class IV vehicular overhead pivot gates shall be designed, constructed and installed in accordance with security related parameters specific to the application in question.

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