INTERNATIONAL

Designation: A 27/A 27M – 03

Standard Specification for Steel Castings, Carbon, for General Application[1]

This standard is issued under the fixed designation A 27/A 27M; 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 carbon steel castings for general applications that require up to 70 ksi [485 MPa] minimum tensile strength.

NOTE 1—The grades covered by this specification represent materials that are suitable for assembly with other steel castings or wrought steel parts by fusion welding. It is not intended to imply that all these grades possess the same degree of weldability or that the same welding techniques can be used on all castings. It is the responsibility of the purchaser to establish for himself a suitable welding technique.

1.2 Several grades and two classes of steel castings are covered, as indicated below. The grade and class desired shall be specified by the purchaser.

1.2.1 *Grade N-1*—Chemical analysis only.

1.2.2 *Grade N-2*—Heat-treated but not mechanically tested.

1.2.3 *Grade U-60-30* [415-205]—Mechanically tested but not heat-treated.

1.2.4 *Grades 60-30* [415-205], *65-35* [450-240], *70-36* [485-250], *and 70-40* [485-275]—Heat-treated and mechanically tested.

1.2.5 Class 1 and Class 2 steel castings shall be specified in accordance with 9.2.

1.3 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 must be used independently of the other. Combining values from the two systems may result in nonconformance with the specification. Inch-pound units are applicable for material ordered to Specification A 27 and SI units for material ordered to Specification A 27M.

2. Referenced Documents

2.1 *ASTM Standards:*

A 370 Test Methods and Definitions for Mechanical Testing of Steel Products[2]

A 732/A 732M Specification for Castings, Investment, Carbon and Low Alloy Steel for General Application, and Cobalt Alloy for High Strength at Elevated Temperatures[3]

A 781/A 781M Specification for Castings, Steel and Alloy, Common Requirements, for General Industrial Use[3]

3. General Conditions for Delivery

3.1 Material furnished to this specification shall conform to the requirements of Specification A 781/A 781M, including any supplementary requirements that are indicated in the purchase order. Failure to comply with the general requirements of Specification A 781/A 781M constitutes nonconformance with this specification. In case of conflict between the requirements of this specification and Specification A 781/A 781M, this specification shall prevail.

4. Ordering Information

4.1 Orders for material under this specification should include the following information in proper sequence.

4.1.1 Quantity,

4.1.2 Specification, grade (1.2), and class (9.2),

4.1.3 Description of the casting by pattern number or drawing,

4.1.4 Options in the specification, and

4.1.5 Supplementary requirements desired, including standards of acceptance.

5. Heat Treatment

5.1 All castings of Grades N-2, 60-30 [415-205], 65-35 [450-240], 70-36 [485-250], and 70-40 [485-275] shall be heat-treated by full annealing, normalizing, normalizing and tempering, or quenching and tempering. Unless otherwise specified in the inquiry, contract, or order, the castings may be heat-treated by any one or combination of these heat-treatments at the option of the manufacturer.

[1] This specification is under the jurisdiction of ASTM Committee A01 on Steel, Stainless Steel and Related Alloys and is the direct responsibility of Subcommittee A01.18 on Castings.

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[2] *Annual Book of ASTM Standards*, Vol 01.03.

[3] *Annual Book of ASTM Standards*, Vol 01.02.

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

TABLE 1 Chemical Requirements

Grade (UNS No.)[A]	Composition, %				
	Carbon,[B] max	Manganese,[B] max	Silicon, max	Sulfur, max	Phosphorus, max
Grade N-1 (J02500)	0.25	0.75	0.80	0.06	0.05
Grade N-2 (J03500)	0.35	0.60	0.80	0.06	0.05
Grade U-60-30 [415-205] (J02500)	0.25	0.75	0.80	0.06	0.05
Grade 60-30 [415-205] (J03000)	0.30	0.60	0.80	0.06	0.05
Grade 65-35 [450-240] (J03001)	0.30	0.70	0.80	0.06	0.05
Grade 70-36 [485-250] (J03501)	0.35	0.70	0.80	0.06	0.05
Grade 70-40 [485-275] (J02501)	0.25	1.20	0.80	0.06	0.05

[A] Specify Class 1 or Class 2 in addition to grade designation (see 9.2).
[B] For each reduction of 0.01 % carbon below the maximum specified, an increase of 0.04 % manganese above the maximum specified will be permitted to a maximum of 1.40 % for Grade 70-40 [485-275] and 1.00 % for the other grades.

TABLE 2 Tensile Requirements

Grade[A]	Tensile Strength, min, ksi [MPa]	Yield Point, min, ksi [MPa]	Elongation in 2 in. [50 mm], min, %[B]	Reduction of Area, min, %
Grade U-60-30 [415-205]	60 [415]	30 [205]	22	30
Grade 60-30 [415-205]	60 [415]	30 [205]	24	35
Grade 65-35 [450-240]	65 [450]	35 [240]	24	35
Grade 70-36 [485-250]	70 [485]	36 [250]	22	30
Grade 70-40 [485-275][C]	70 [485]	40 [275]	22	30

[A] Specify Class 1 or Class 2 in addition to grade designation (see 9.2).
[B] When ICI test bars are used in tensile testing as provided for in this specification, the gage length to reduced section diameter ratio shall be 4 to 1.
[C] Grade 70-40 [485-275] may be used to meet the requirement of Grade 70-36 [485-250], when agreed upon between the manufacturer and the purchaser.

5.1.1 Heat-treatment shall be performed after castings have been allowed to cool from the pouring temperature to below the transformation range.

5.2 Furnace temperatures for heat-treating shall be regulated by the use of pyrometers.

6. Chemical Composition

6.1 The steel shall conform to the requirements as to chemical composition prescribed in Table 1. Product analysis tolerances shall conform to the Product Analysis Tolerances shown in Specification A 781/A 781M. When residual element chemical content is of interest to the purchaser, S54 may be considered.

7. Tensile Properties

7.1 Except for Grades N-1 and N-2, one tension test shall be performed on each heat and the mechanical properties thus determined shall conform to the requirements specified in Table 2. The tension test shall be performed in accordance with Test Methods and Definitions A 370.

7.2 Test bars shall be poured in special blocks similar to those shown in Fig. 1 of Specification A 781/A 781M and from the same heat as the casting represented.

7.3 Test coupons may be cut from the heat-treated (if required) castings or cast integrally with the castings at the producer's option.

7.4 The test bars for heat-treated castings shall be heat-treated in production furnaces to the same procedure as the castings they represent. When specified by the purchaser, the test bars shall be heat-treated with the castings.

7.5 Test specimens shall be machined to the form and dimensions shown in Figs. 4 and 5 of Test Methods and Definitions A 370.

7.6 If any specimen is machined improperly or if flaws are revealed by machining or during testing, the specimen may be discarded and another substituted from the same heat.

7.7 When this specification is applied to investment castings, test coupons and tension test specimens shall be obtained and prepared as directed in S3.2 of Specification A 732/A 732M. Test coupons shall be heat treated as prescribed in 7.4.

8. Retests

8.1 If the results of the mechanical tests for any heat, lot, or casting do not conform to the requirements specified, retests are permitted as outlined in Test Methods and Definitions A 370. At the manufacturer's option, castings may be reheat-treated and retested. When castings are reheat-treated, they may not be reaustenitized more than 3 times without the approval of the purchaser. Testing after reheat treatment shall consist of the full number of specimens taken from locations complying with the specification or order.

9. Rework and Retreatment

9.1 All welds shall be inspected to the same quality standards as were used to inspect the casting.

9.2 If postweld heat-treatment is required, Class 1 must be specified along with the grade, and the welds to be heat-treated must be defined. If postweld heat-treatment is not required, Class 2 must be specified along with the grade.

10. Keywords

10.1 castings; general application; steel

SUPPLEMENTARY REQUIREMENTS

A list of standardized supplementary requirements for use at the option of the purchaser is described in Specification A 781/A 781M. Those which are considered suitable for use with this specification are listed below by title only. Additional supplementary requirements suitable for use with this specification at the option of the purchaser are described below. One or more of the supplementary requirements indicated below may be included in the purchaser's order or contract. When so included, a supplementary requirement shall have the same force as if it were in the body of the specification. Supplementary requirements details not fully described shall be agreed upon between the purchaser and the supplier, but shall not negate any of the requirements in the body of the specification.

S1. Magnetic Particle Examination

S2. Radiographic Examination

S3. Liquid Penetrant Examination

S4. Ultrasonic Examination

S6. Certification

S8. Marking

S9. Charpy Impact Test

S10. Hardness Test

S12. Test Report

S13. Unspecified Elements

S14. Tension Test from Castings

S51. Permissible Variations in Dimensional Tolerances for Castings Made from Mounted Patterns

S51.1 Tolerances for commercial steel castings (S51.1.1) made from mounted patterns and the surfaces that are not to be machined shall be in accordance with Table 3. Metal match plate patterns and precise molding methods can produce closer tolerances than the values shown in Table 3. Complex casting designs may require different permissible variations than those listed in Table 3.

S51.1.1 The term "commercial castings" does not cover castings requiring special fixtures for gaging, or finishing castings by grinding to special tolerance gages beyond the normal requirements as listed in Table 3.

TABLE 3 Normally Expected Deviation of Linear Casting Dimensions from Design Dimensions

Blueprint Dimension, in. [mm]	Tolerances, in. [mm]	
Up to 3 [75], incl	+4⁄32 [3]	−3⁄32 [2]
Over 3 to 7 [75 to 175], incl	+5⁄32 [4]	−4⁄32 [3]
Over 7 to 20 [175 to 500], incl	+6⁄32 [5]	−5⁄32 [4]
Over 20 to 100 [500 to 2500], incl	+8⁄32 [6]	−6⁄32 [5]

S52. Gate and Riser Projections for Castings Made from Mounted Patterns

S52.1 Castings shall have gates and risers removed in such a manner that no riser or gate stub projects or a depression is made beyond or below the casting design contour in an amount that would exceed the values given in Table 4.

S53. Weight Deviation for Castings Made from Mounted Patterns

S53.1 The allowable deviations from the average casting weight are shown in Table 5.

S54. Chemical Analysis for Residual Elements

S54.1 The manufacturer shall determine the percentage of elements specified as follows, using procedures specified in

TABLE 4 Gate and Riser Projection Tolerances

Riser or Gate Maximum Dimension, in. [mm]	Maximum Projection, in. [mm]	Maximum Depression, in. [mm]
Up to 4 [100], incl	1⁄8 [3]	1⁄8 [3]
Over 4 to 8 [100 to 200], incl	1⁄4 [6]	1⁄8 [3]
Over 8 to 20 [200 to 500], incl	3⁄8 [10]	1⁄8 [3]
Over 20 to 30 [500 to 750], incl	1⁄2 [13]	1⁄4 [6]
Over 30 [750]	3⁄4 [19]	1⁄4 [6]

TABLE 5 Allowable Deviation[A] from Average Casting Weight

Casting Weight, lb [kg]	Positive Deviation, %	Negative Deviation, %
Up to 100 [45], incl	8.0	8.0
Over 100 to 500 [45 to 230], incl	6.5	5.0
Over 500 to 10 000 [230 to 4540], incl	5.0	3.0
Over 10 000 [4540]	3.0	2.5

[A] Deviations do not apply to mass as calculated from a design drawing.

Specification A 781/A 781M. The chemical analysis thus determined shall conform to the following requirements:

Copper, max, %	0.50
Nickel, max, %	0.50
Molybdenum, max, %	0.25
Chromium, max, %	0.50

S54.2 Total content of these residual elements, maximum percent 1.00.

SUMMARY OF CHANGES

Committee A01 has identified the location of selected changes to this standard since the last issue (A 27/A 27M – 95 (2000)) that may impact the use of this standard.

(1) Added the UNS Numbers to the grades in Table 1.

Designation: A 47/A 47M – 99

Standard Specification for Ferritic Malleable Iron Castings[1]

This standard is issued under the fixed designation A 47/A 47M; 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[2] covers ferritic malleable castings for general engineering usage at temperatures from normal ambient to approximately 400°C (750°F).

1.2 No precise quantitative relationship can be stated between the properties of the iron in various locations of the same casting and those of a test specimen cast from the same iron (see Appendix X1).

1.3 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.

2. Referenced Documents

2.1 *ASTM Standards:*

A 153 Specification for Zinc Coating (Hot-Dip) on Iron and Steel Hardware[3]

A 247 Test Method for Evaluating the Microstructure of Graphite in Iron Castings[4]

A 644 Terminology Relating to Iron Castings[4]

E 8 Test Methods for Tension Testing of Metallic Materials[5]

E 10 Test Method for Brinell Hardness of Metallic Materials[5]

E 18 Test Methods for Rockwell Hardness and Rockwell Superficial Hardness of Metallic Materials[5]

E 140 Hardness Conversion Tables for Metals[5]

2.2 *Military Standard:*

MIL-STD-129 Marking for Shipment and Storage[6]

2.3 *Federal Standard:*

Fed. Std. No. 123 Marking for Domestic Shipment (Civilian Agencies)[6]

3. Terminology

3.1 *Definitions*—Definitions for many terms common to iron are found in Terminology A 644.

4. Classification

4.1 Castings ordered and produced under this specification are classified under the following grades based on tests on separately cast test bars. Separately cast test bars shall be poured from the same lot of iron as the castings they represent and shall be heat treated with those castings except as provided in 7.2.3.

4.1.1 *Grade 32510 [Grade 22010]*:

4.1.1.1 The first three digits of the grade designation indicate the minimum yield strength (×100 psi [MPa]) and the last two digits indicate the minimum elongation (% in 2 in. [50 mm]).

5. Ordering Information

5.1 The purchase order for castings ordered under this specification shall state the specification designation, the year in which the specification was issued, and the grade of malleable iron to be supplied. Any option or special additions to the basic requirements of this specification shall be clearly and fully stipulated.

6. Chemical Composition

6.1 The chemical composition of the iron shall be such as to produce the structural and mechanical properties required by this specification.

7. Mechanical Properties

7.1 Factors influencing the properties of castings and their relationship to those of test specimens and separate test castings are discussed in Appendix X1.

7.2 *Tension Test Specimens*:

7.2.1 The tension test specimens shall be cast to the form and dimensions shown in Fig. 1 or Fig. 2, in the same kind of molding material used for the production castings. At least

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[1] This specification is under the jurisdiction of ASTM Committee A-4 on Iron Castings and is the direct responsibility of Subcommittee A04.02 on Malleable Iron Castings.

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[2] For ASME Boiler and Pressure Vessel Code applications see related Specification SA-47 in Section II of that code.

[3] *Annual Book of ASTM Standards*, Vol 01.06.

[4] *Annual Book of ASTM Standards*, Vol 01.02.

[5] *Annual Book of ASTM Standards*, Vol 03.01.

[6] Available from Standardization Documents, Order Desk, Building 4, Section D, 700 Robbins Ave., Philadelphia, PA 19111–5094, Attn: NPODS.

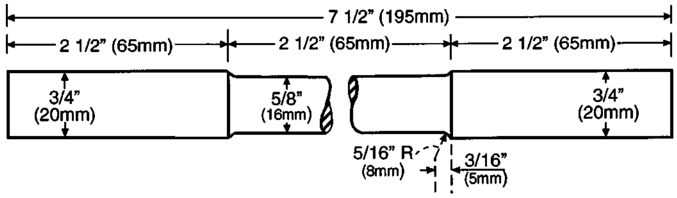
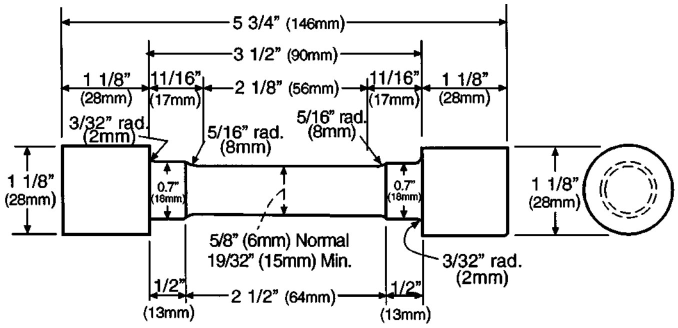
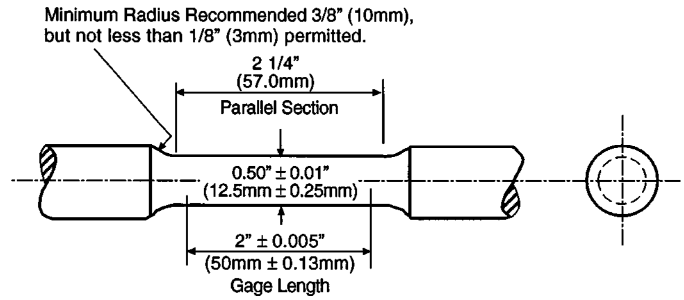


FIG. 1 Tension Test Specimen



NOTE 1—Modifications may be made in the dimensions indicated above for those details of the specimen outside of the gage length as required by testing procedure and equipment.

FIG. 2 Alternative Unmachined Tension Test Specimen



NOTE 1—The gage length and fillets shall be as shown, but the ends may be of any shape to fit the holders of the testing machine in such a way that the load shall be axial. The reduced section shall have a gradual taper from the ends toward the center, with the ends 0.003 to 0.005 in. [0.08 to 0.13 mm] larger in diameter than the center.

FIG. 3 Machined Tension Test Specimen

three such specimens shall be cast from a representative ladle of iron either from each batch-melted heat or, in continuous melting, from each 4-h pour period during which the purchaser's castings were poured, or as otherwise agreed upon between manufacturer and purchaser.

7.2.2 All test specimens shall be suitably identified with the designation of either the batch-melted heat or the pour period of a continuous heat.

7.2.3 All test specimens shall be heat treated in the same production furnaces and in the same cycles as the castings they represent. However, in those instances wherein the critical sections of the production castings differ appreciably from that of the central portion of the test specimens, the time cycle for tempering the test specimens may be altered from that of the production lot in order to obtain similar microstructures or hardness, or both, in both specimen and castings. In such cases the hardness of the specimens shall be tested and reported along with the tensile test results.

7.2.4 The tension test is usually performed on unmachined specimens. However, for referee work, the specimen may be machined from the standard cast bar to the dimensions shown in Fig. 3.

7.3 *Tension Test Method*:

7.3.1 The gage length of the standard tension specimen shall be 2.00 ± 0.01 in. [50.0 ± 0.3 mm].

7.3.2 The diameter used to compute the cross-sectional area shall be the average between the largest and smallest diameters in that section of the 2-in. [50-mm] gage length having the smallest diameter and shall be measured to the nearest 0.001 in. [0.2 mm]. No cast bar having a mean diameter less than 0.590 in. [15.0 mm] shall be accepted for test.

7.3.3 After reaching a stress equivalent to approximately half of the anticipated yield stress, the speed of the moving head of the testing machine shall not exceed 0.50 in./min [12.5 mm/min] through the breaking load.

7.3.4 While the values for yield point and yield strength are not identical, they are sufficiently close for most applications of ferritic malleable irons to be used interchangeably. They may be determined by any of the approved techniques described in the paragraphs on Determination of Yield Strength and Yield Point of Test Methods E 8. If determined as yield strength, that stress producing an extension under load of 0.01 in. [0.25 mm] over the 2-in. [50-mm] gage length (for example, 0.5 % extension) or an offset of 0.2 % shall be taken as the yield stress, which shall be converted to yield strength by dividing by the original cross-sectional area of the gage length found in accordance with 7.3.2. It shall be reported to the nearest 100 psi [MPa]. In referee work, yield strength shall be determined as the stress that produces an extension under load of 0.5 % of the gage length.

7.3.5 The tensile strength shall be the maximum load carried by the specimen during the test divided by the original cross-sectional area of the gage length, as found in accordance with 7.3.2. It shall be reported to the nearest 100 psi [MPa].

7.3.6 The elongation is the increase in gage length after fracture of a tensile specimen, measured to the nearest 0.01 in. [0.25 mm], expressed as a percentage of the original gage length. It shall be reported to the nearest 0.5 %.

7.4 *Retesting*:

7.4.1 If, after testing, a specimen shows evidence of a defect, another tension test may be made on a companion specimen. Also, a retest shall be permitted whenever fracture occurs outside the central 50 % of the gage length.

7.4.2 If the results of a valid test fail to conform to the requirements of this specification, two retests shall be made. If either retest fails to meet the specification, the castings represented by these test specimens shall be rejected. A valid test is one wherein the test specimen has been properly prepared and appears to be sound and on which the approved test procedure has been followed.

7.4.3 If sufficient companion test bars are unavailable, the manufacturer shall have the option of testing a specimen cut from a representative casting. Therefore, as stated in X1.3, the mechanical properties of such tension test specimen removed from a production casting will not necessarily correspond to those of a standard separately cast test specimen, the values in Table 1 do not apply. Instead, the mechanical properties of the test specimen from the casting must equal or exceed the average of those from similar test specimens removed from the same location from two castings of the same design where separately cast test bars meet the requirements of Table 1.

7.4.4 If the first test results indicate that a reheat treatment is needed to meet the test requirements, the entire lot of castings and the representative test specimens shall be reheat treated together. Testing shall then be repeated in accordance with 7.4.1-7.4.3.

7.4.5 The results of all tests, including retests, shall be posted in permanent record, which shall state any abnormalities observed during the test and in the fractured ends. Such records shall be kept for at least 1 year after shipment of the production castings and shall be available for examination by the purchaser or by his authorized representative.

7.4.6 If not covered in the purchase agreement, the frequency of tension testing shall be in accordance with 7.2.1 and sufficiently often to ensure uniformity of product and compliance with minimum test requirements.

7.4.7 Tension test results, obtained in accordance with the above subsections, must conform to the values of Table 1 for acceptance under this specification except as provided in 7.4.3.

7.4.8 When agreed upon between manufacturer and purchaser, tested specimens or unbroken test bars shall be preserved by the manufacturer for a period of three months after the date of the test report.

7.5 *Hardness Test*—If the purchase agreement requires hardness testing, the acceptable hardness range shall be stated and a test location clearly shown on the covering drawing(s).

7.5.1 *Hardness Test Method*—The Brinell method of hardness testing in accordance with Test Method E 10 shall be employed whenever possible.

7.5.2 For castings of such size or shape that do not permit Brinell testing with the standard 3000-kgf load, the 500 kgf may be employed, the hardness number being reported as HB 10/500/15. In very unusual cases where it is impossible to use the Brinell method, the Rockwell test may be substituted, using Test Methods E 18 with an appropriate Rockwell scale. Conversions of hardness values from one method to another according to Standard E 140, which does not specifically cover cast irons, are approximate only and, therefore, are generally inadvisable.

7.5.3 Sufficient material shall be removed from the cast surface to ensure that the measured surface is representative.

7.5.4 Sampling procedures and the frequency of hardness testing shall be fully detailed on the purchase agreement. Otherwise, hardness tests shall be performed at the discretion of the producer.

7.5.5 Castings failing to conform to the required hardness range may be reheat treated and retested. If after reheat treating they still fail the hardness requirements, they shall be rejected.

7.5.6 Typical hardness maximums for this grade of malleable iron are listed in Table 2.

8. Microstructure Requirements

8.1 The microstructure of the malleable iron shall consist of temper carbon nodules distributed through a ferritic matrix and shall be free of excessive pearlite, massive carbides, and primary graphite.

8.2 When agreed upon by the purchaser and producer, the maximum decarburization at any as-cast surface after heat treatment may be stipulated in writing, as measured by visual depletion of combined carbon after polishing, etching in nital, and viewing at 100×.

8.3 In reference work, the metallographic practice recommended in Test Method A 247 shall be followed.

9. Soundness Requirements

9.1 All castings, on visual examination, shall be sound and free of obvious shrinkage and porosity.

9.2 If the purchaser requires soundness tests to be performed, it shall be so stated in the purchase agreement, and the method and soundness requirements shall be detailed.

10. Dimensional Requirements

10.1 The castings shall conform to the dimensions given on drawings furnished by the purchaser, or to the dimensions established by the pattern equipment supplied by the purchaser, or as agreed upon in specific cases to gages supplied by the purchaser. Variations in any solid dimensions will be permitted, as shown in Table 3, unless otherwise agreed upon by the foundry and purchaser.

11. Workmanship, Finish and Appearance

11.1 The surface of the casting shall be inspected visually, particularly in critical areas, for such surface defects as cracks, hot tears, adhering sand and scale, cold shuts, and gas holes.

11.2 No repairing, plugging, or welding of any kind shall be permitted unless written permission is granted by the purchaser.

11.3 Castings that have been repaired by welding shall be reannealed so that their microstructure will comply with Section 8.

TABLE 1 Tension Test Requirements

Inch-Pound Grades			
English Grade	Tensile Strength, min, psi	Yield Strength, min, psi	Elongation in 2 in, min, %
32510	50 000	32 500	10
Metric Grades			
Metric Grade	Tensile Strength, min, MPa	Yield Strength min, MPa	Elongation in 50 mm, min, %
22010	340	220	10

TABLE 2 Typical Hardness

Inch-Pound Grade [Metric Grade]	Hardness, maximum HB	Indentation Value Diameters, mm
325 10 [22010]	156	4.8

TABLE 3 Permissible Variation in Any Solid Dimension

Size, in. [mm]	Tolerance, ± in. [mm]
Up to 1 [up to 25]	0.03 [0.8]
1 to 6 [25 to 150]	0.06 [1.6]
6 to 12 [151 to 300]	0.12 [3.2]
12 to 18 [301 to 460]	0.15 [3.8]
18 to 24 [461 to 600]	0.19 [4.8]
24 to 36 [601 to 900]	0.22 [5.6]

12. Responsibility for Inspection

12.1 Unless otherwise specified in the contract or purchase order, the manufacturer shall be responsible for carrying out all the tests and inspections required by this specification, using his own or other reliable facilities, and he shall maintain complete records of all such tests and inspections. Such records shall be available for review by the purchaser.

12.2 The purchaser reserves the right to perform any inspection set forth in the specification where such inspections are deemed necessary to ensure that supplies and services conform to the prescribed requirements.

13. Rejection and Rehearing

13.1 Any casting or lot of castings failing to comply with the requirements of this specification may, where possible, be reprocessed, retested, and reinspected. If the tests and inspections on the reprocessed casting(s) show compliance with this specification, the castings shall be acceptable; if they do not, they shall be rejected.

13.2 If the purchaser should find that a casting or lot of castings fails to comply with this specification subsequent to receipt at his facility, he shall so notify the manufacturer promptly and in no case later than six weeks after receipt of the shipment, stating clearly his basis for rejection. In case of dissatisfaction with the purchaser's claim, the manufacturer may apply for a hearing before final rejection of the shipment.

14. Certification

14.1 When specified by the purchaser's order or contract, a manufacturer's certification or compliance statement that the casting or lot of castings was made, sampled, tested, and inspected in accordance with this specification, including a report of test results signed by an authorized agent of the manufacturer, shall be furnished at the time of shipment, and such certification or compliance statement shall be the basis for acceptance of the casting or lot of castings.

15. Product Marking

15.1 When the size of the casting permits, each casting shall bear the identifying mark of the manufacturer and the part or pattern number at a location shown on the covering drawing and, if not shown on the drawing, at such a location at the discretion of the producer that the identification will not interfere with subsequent processing and service of the casting.

16. Packaging and Package Marking

16.1 Unless otherwise stated in the contract or order, the cleaning, preservation, and packing of castings for shipment shall be in accordance with the manufacturer's commercial practice. Packaging and marking shall also be adequate to identify the contents and to ensure acceptance and safe delivery by the carrier for the mode of transportation employed.

16.2 *U.S. Government Procurement*—When specified in the contract or purchase order, marking for shipment shall be in accordance with the requirements of Fed. Std. No. 123 and MIL-STD-129.

SUPPLEMENTARY REQUIREMENTS

S1. Special Conditions

S1.1 If agreed upon in writing by the foundry and purchaser, the malleable iron castings may be required to meet special conditions, hardness or other property dimensions, surface quality, or a combination of conditions.

S2. Test Lugs

S2.1 If requested in writing or if included on the pattern(s) or pattern drawing(s), test lugs may be cast on all castings of sufficient size to permit their incorporation. The size of such lugs shall be proportional to the thickness of the casting. On castings over 24 in. [600 mm] in length, a test lug shall be cast near each end such as not to interfere with any subsequent processing of the castings. The purchase order shall stipulate whether the foundry's inspector or the purchaser's inspector shall break, inspect, and pass judgment on the fracture quality of these test lugs.

S3. Destructive Tests

S3.1 At the option of the purchaser or his representative, a casting of each design ordered may be tested to destruction, or otherwise broken up, to determine the presence of any manufacturing condition that might be detrimental to the serviceability of the casting.

S4. Special Tension Specimens

S4.1 If tension specimens are to be machined from castings, their location in the casting, the specimen dimensions, and the required properties shall be agreed upon in writing by the foundry and purchaser.

S5. Zinc-Coated Castings

S5.1 When specified in the contract or purchase order, castings shall be zinc-coated by the hot-dip process in accordance with Specification A 153. Castings shall be of a composition that will preclude the possibility of galvanizing embrittlement, or shall be either cooled from the anneal or subsequently heat treated so as to be immunized against such embrittlement. If regalvanizing is required, procedures for regalvanizing castings and determining the effect on the casting performance must be agreed upon between the purchaser and the seller.

S6. Marking of Casting for Government Procurement

S6.1 When castings are specified for government procurement, the location of the permanent markings specified in 15.1, as well as any special marking for mechanical or physical properties (either permanent or temporary), shall be as indicated on the government drawings or sketches.

APPENDIX

(Nonmandatory Information)

X1. MECHANICAL PROPERTIES OF CASTINGS

X1.1 The mechanical properties of malleable iron castings are influenced by a number of factors, including the cooling rate during solidification, chemical composition, the heat treatment, the design of the casting, section thickness, and the location and effectiveness of gates, risers, and chills.

X1.2 Because of the complexity of these factors in influencing the properties of the final product, no precise quantitative relationship can be stated between the properties of the iron in various locations of the same casting or between the properties of a casting and those of a test specimen cast from the same iron. When such a relationship is important and must be known for a specific application, it may be determined by appropriate experimentation.

X1.3 The specimen specified in 7.2.1 as the standard tensile test bar for malleable iron has a ⅝-in. [16-mm] diameter test section that reasonably represents a typical section of the general run of malleable iron castings. Furthermore, the initial freezing of malleable irons as homogeneous white iron, together with the heat treatment that is inherent in the manufacture of malleable iron, tends to reduce the section-sensitivity effect. Therefore, where experimentation into precise properties within a given casting would be infeasible, this standard test bar, made like any typical casting, should provide a practical approximation of the properties that can be expected in average sound malleable iron casting.

X1.4 If malleable iron castings are welded, the microstructure of the iron is markedly affected, particularly in the heat-affected zone. Therefore, since this may adversely affect the properties of the casting, the welding of malleable iron castings should be done under strict metallurgical control, followed by appropriate post-weld heat treatment, to minimize the substantial reductions in ductility, impact resistance, and machinability that could result, particularly in the vicinity of the weldment. Nevertheless, it is generally considered inadvisable to join castings to similar castings or to other materials, by fusion welding out in the field, or in manufactured assemblies, without fully testing the entire completed part.

Standard Specification for Gray Iron Castings[1]

This standard is issued under the fixed designation A 48/A 48M; 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. This specification replaces Federal Specification QQ-I-652.

1. Scope

1.1 This specification covers gray iron castings intended for general engineering use where tensile strength is a major consideration. Castings are classified on the basis of the tensile strength of the iron in separately cast test bars.

1.1.1 This specification subordinates chemical composition to tensile strength.

1.2 Castings produced to this specification are graded on the basis of minimum tensile strength obtained in special test coupons designed to standardize cooling rate. The tensile strength developed in certain casting sections may vary from test coupon values (see X1.2).

1.3 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.

2. Referenced Documents

2.1 *ASTM Standards:*

A 644 Terminology Relating to Iron Castings

E 8 Test Methods for Tension Testing of Metallic Materials

2.2 *Military Standard:*

MIL-STD-129 Marking for Shipment and Storage[2]

2.3 *Federal Standard:*

Federal Standard No. 123 Marking for Shipment (Civil Agencies)[2]

3. Terminology

3.1 *Definitions:*

3.1.1 Definitions for many terms common to gray iron castings are found in Terminology A 644.

4. Classification

4.1 Castings ordered and produced in accordance with this specification are classified into a number of grades based on the properties of separately cast test bars (Table 1, Table 2). Each class is designated by a number followed by a letter. The number indicates the minimum tensile strength of the separately cast test bar, and the letter indicates the size of the test bar. Examples of proper designations are as follows:

Gray Iron Castings, ASTM Specification A 48, Class 30B.

Gray Iron Castings, ASTM Specification A 48, Class 40C.

5. Ordering Information

5.1 Orders for material to this specification shall include the following information:

5.1.1 ASTM designation number and year of issue,

5.1.2 Class of iron required (see 4.1, Table 1, and Table 2),

5.1.3 The size of the separately cast test bar (letter classification—A, B, C, or S) that best represents the thickness of the controlling section of the casting (see Table 3),

5.1.4 The tension test specimen (B or C) to be machined from test bar C (see 13.3, Table 4, and Fig. 1),

5.1.5 The tension test specimen to be machined from test bar S (see 13.4, Table 4, and Fig. 1),

5.1.6 Lot size (see Section 10),

5.1.7 Special requirements (see Section 6),

5.1.8 Saving tested specimens or unbroken test bars (see 15.1), and

5.1.9 Special preparation for delivery (see Section 19).

6. Special Requirements

6.1 When agreed upon in writing between the manufacturer and the purchaser, it may be necessary for the castings to meet special requirements as to hardness, chemical composition, microstructure, pressure tightness, radiographic soundness, dimensions, surface finish, and so forth.

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[1] This specification is under the jurisdiction of ASTM Committee A04 on Iron Castings and is the direct responsibility of Subcommittee A04.01 on Gray Iron Castings.

Current edition approved Dec. 1, 2003. Published January 2004. Originally approved in 1905. Last previous edition approved in 2000 as A 48 – 00.

[2] Available from Standardization Documents Order Desk, Bldg. 4 Section D, 700 Robbins Ave., Philadelphia, PA 19111-5094, Attn: NPODS.

TABLE 1 Requirements for Tensile Strength of Gray Cast Irons in Separately Cast Test Bars (Inch-Pound)

Class	Tensile Strength, min, ksi	Nominal Test Bar Diameter, in.
No. 20 A	20	0.8
No. 20 B		1.2
No. 20 C		2.0
No. 20 S		Bars S[A]
No. 25 A	25	0.88
No. 25 B		1.2
No. 25 C		2.0
No. 25 S		Bars S[A]
No. 30 A	30	0.88
No. 30 B		1.2
No. 30 C		2.0
No. 30 S		Bars S[A]
No. 35 A	35	0.88
No. 35 B		1.2
No. 35 C		2.0
No. 35 S		Bars S[A]
No. 40 A	40	0.88
No. 40 B		1.2
No. 40 C		2.0
No. 40 S		Bars S[A]
No. 45 A	45	0.88
No. 45 B		1.2
No. 45 C		2.0
No. 45 S		Bars S[A]
No. 50 A	50	0.88
No. 50 B		1.2
No. 50 C		2.0
No. 50 S		Bars S[A]
No. 55 A	55	0.88
No. 55 B		1.2
No. 55 C		2.0
No. 55 S		Bars S[A]
No. 60 A	60	0.88
No. 60 B		1.2
No. 60 C		2.0
No. 60 S		Bars S[A]

[A] All dimensions of test bar S shall be as agreed upon between the manufacturer and the purchaser.

TABLE 2 Requirements for Tensile Strength of Gray Cast Irons in Separately Cast Test Bars (Metric)

Class	Tensile Strength, min, ksi [MPa]	Nominal Test Bar Diameter, in. [mm]
No. 150A	150	20 to 22
No. 150B		30
No. 150C		50
No. 150S		Bars S[A]
No. 175A	175	20 to 22
No. 175B		30
No. 175C		50
No. 175S		Bars S[A]
No. 200A	200	20 to 22
No. 200B		30
No. 200C		50
No. 200S		Bars S[A]
No. 225A	225	20 to 22
No. 225B		30
No. 225C		50
No. 225S		Bars S[A]
No. 250A	250	20 to 22
No. 250B		30
No. 250C		50
No. 250S		Bars S[A]
No. 275A	275	20 to 22
No. 275B		30
No. 275C		50
No. 275S		Bars S[A]
No. 300A	300	20 to 22
No. 300B		30
No. 300C		50
No. 300S		Bars S[A]
No. 325A	325	20 to 22
No. 325B		30
No. 325C		50
No. 325S		Bars S[A]
No. 350A	350	20 to 22
No. 350B		30
No. 350C		50
No. 350S		Bars S[A]
No. 375A	375	20 to 22
No. 375B		30
No. 375C		50
No. 375S		Bars S[A]
No. 400A	400	20 to 22
No. 400B		30
No. 400C		50
No. 400S		Bars S[A]

[A] All dimensions of test bar S shall be as agreed upon between the manufacturer and the purchaser.

7. Tensile Requirements

7.1 Test bars representing castings conforming to this specification shall meet the requirements for tensile strength as described in Table 1 and Table 2.

8. Dimensional Requirements

8.1 The castings shall conform to the dimensions or drawings furnished by the purchaser, or, if there are no drawings, to the dimensions predicted by the pattern equipment supplied by the purchaser.

9. Workmanship and Finish

9.1 The surface of the casting shall be free of adhering sand, scale, cracks, and hot tears, as determined by visual examination.

9.2 No repairing by plugging or welding of any kind shall be permitted unless written permission is granted by the purchaser.

10. Sampling

10.1 A lot shall consist of one of the following:

10.1.1 All the metal poured from a single heating in a batch type melting furnace.

10.1.2 All the metal from two or more batch type melting furnaces poured into a single ladle or a single casting.

10.1.3 All the metal poured from a continuous melting furnace for a given period of time between changes in charge, processing conditions, or aim-for chemistry or 4 h, whichever is the shorter period.

TABLE 3 Separately Cast Test Bars for Use When a Specific Correlation Has Not Been Established Between the Test Bar and the Casting

Thickness of the Wall of the Controlling Section of the Casting, in. [mm]	Test Bar
Under 0.25 [under 5]	S
0.25 to 0.50 [5 to 14]	A
0.51 to 1.00 [15 to 25]	B
1.01 to 2 [26 to 50]	C
Over 2 [over 50]	S

10.1.3.1 The purchaser may agree to extend the 4-h time period to 8 h if the manufacturer can demonstrate sufficient process control to warrant such an extension.

11. Cast Test Bars

11.1 Test bars shall be separate castings poured from the same lot as the castings they represent and shall have dimensions as shown in Table 4. Allowance may be made for reasonable pattern draft within the tolerances shown in Table 4. Test bars A, B, and C are all standard test bars in the form of simple cylinders. Test bar S is special and is intended for use where the standard bars are not satisfactory.

11.2 The test bars shall be cast in dried, baked, or chemically bonded molds made mainly of an aggregate of siliceous sand with appropriate binders. The average grain size of the sand shall approximate that of the sand in which the castings are poured. Molds for the test bars shall be approximately at room temperature when poured. More than one test bar may be cast in a single mold, but each bar in the mold shall be surrounded by a thickness of sand which is not less than the diameter of the bar. A suitable design for a mold is shown in Fig. 2.

NOTE 1—The intent of these provisions is as follows: to prohibit the casting of test bars in molds of metal, graphite, zircon, light-weight aggregates, or other materials which would significantly affect the tensile strength of the iron; to prohibit control of tensile strength of the test bars by manipulation of the grain size of the sand; and to prohibit the casting of test bars in molds preheated substantially above room temperature.

11.3 Test bars that are intended to represent castings that are cooled in the mold to less than 900°F [480°C], before shakeout, shall be cooled in their molds to a temperature less than 900°F [480°C]. They then may be cooled in still air to room temperature.

11.4 Test bars that are intended to represent castings that are hotter than 900°F [480°C], when shaken out of their molds, shall be cooled as described in 11.3 or (by agreement between the manufacturer and the purchaser) may be shaken out of their molds at approximately the same temperature as the castings they represent.

11.5 When castings are stress-relieved, annealed, or otherwise heat-treated, test bars shall receive the same thermal treatment and shall be treated adjacent to the castings they represent.

12. Number of Tests and Retests

12.1 The tension test shall be conducted in accordance with Test Method E 8.

12.2 One tension test shall be performed on each lot and shall conform to the tensile requirements specified.

12.3 If the results of a valid test fail to conform to the requirements of this specification, two retests shall be made. If either retest fails to meet the specification requirements, the castings represented by these test specimens shall be rejected. A valid test is one wherein the specimen has been properly prepared and appears to be sound and on which the approved test procedure has been followed.

12.4 If sufficient separately cast test pieces are not available, the manufacturer shall have the option of removing a test specimen from a location of representative casting, as agreed upon between the manufacturer and purchaser.

12.5 If the first test results indicate that a heat treatment is needed to meet the test requirements, the entire lot of castings and the representative test specimens shall be heat treated together. Testing shall proceed in accordance with 12.1-12.3.

12.6 If, after testing, a test specimen shows evidence of a defect, the results of the test may be invalidated and another made on a specimen from the same lot.

13. Tension Test Specimens

13.1 For test Bar A, the tension-test specimen A, as shown in Fig. 1, shall be machined concentric with the axis of the test bar.

13.2 For test Bar B, the tension test specimen B, as shown in Fig. 1, shall be machined concentric with the axis of the test bar.

13.3 For test Bar C, tension test specimens B or C, as shown in Fig. 1, shall be machined concentric with the axis of the test bar. Unless the size of the tension test specimen to be machined from test bar C is specified in writing by the purchaser, the decision whether to use tension test specimen B or C shall be made by the manufacturer of the castings.

13.4 For test bar S, the nature and dimensions of the tension test specimen shall be determined by agreement between the manufacturer and purchaser.

14. Tension Test

14.1 Tension test specimens shall fit the holders of the testing machine in such a way that the load shall be axial.

14.2 The elapsed time from the beginning of loading in the tension test to the instant of fracture shall be not less than 15 s for test specimen A and not less than 20 s for specimens B and C.

15. Inspection

15.1 Unless otherwise specified in the contract or purchase order, the manufacturer shall be responsible for carrying out all the tests and inspections required by this specification, using his own or other reliable facilities, and he shall maintain complete records of all such tests and inspections. Such records shall be available for review by the purchaser.

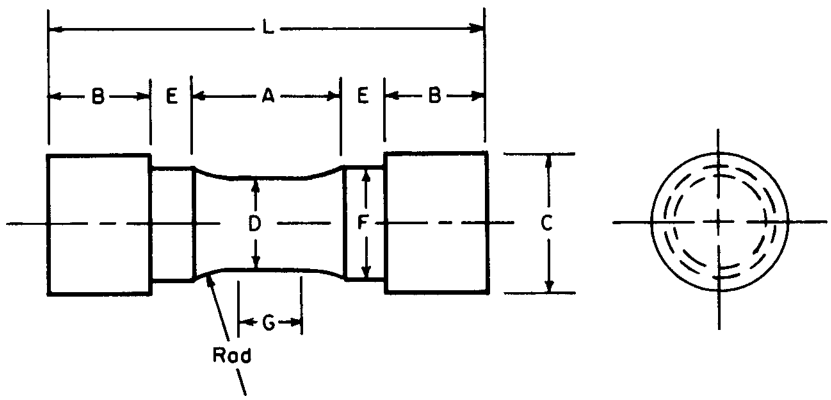
15.1.1 When agreed upon between the manufacturer and purchaser, tested specimens or unbroken test bars from the same lot shall be saved for a period of three months after the date of the test report.

15.2 The purchaser reserves the right to perform any of the inspections set forth in the specification where such inspections

TABLE 4 Diameters and Lengths of Cast Test Bars

Test Bar	As-Cast Diameter, in. [mm]			Length, in. [mm]	
	Nominal (Mid-Length)	Minimum (Bottom)	Maximum (Top)	Minimum (Specified)	Maximum (Recommended)
A	0.88 [22.4]	0.85 [21.6]	0.96 [24.4]	5.0 [125]	6.0 [150]
B	1.20 [30.5]	1.14 [29.0]	1.32 [33.5]	6.0 [150]	9.0 [230]
C	2.00 [50.8]	1.90 [48.3]	2.10 [53.3]	7.0 [175]	10.0 [255]
S[A]	. . .	. . .	. . .	. . .	. . .

[A]All dimensions of test bar S shall be as agreed upon by the manufacturer and the purchaser.



Dimensions, in. [mm]	Tension Test Specimen A	Tension Test Specimen B	Tension Test Specimen C
G—Length of parallel, min	0.50 [13]	0.75 [19]	1.25 [32]
D—Diameter	0.500 ± 0.010 [13 ± 0.25]	0.750 ± 0.015 [20 ± 0.4]	1.25 ± 0.025 [30 ± 0.6]
R—Radius of fillet, min	1 [25]	1 [25]	2 [50]
A—Length of reduced section, min	1¼ [32]	1½ [38]	2¼ [57]
L—Over-all length, min	3¾ [95]	4 [100]	6⅜ [160]
C—Diameter of end section, approx	⅞ [20]	1¼ [20]	1⅞ [47]
E—Length of shoulder, min	¼ [6]	¼ [6]	5/16 [8]
F—Diameter of shoulder	⅝ ± 1/64 [16 ± 0.4]	15/16 ± 1/64 [24 ± 0.4]	1 7/16 ± 1/64 [36 ± 0.4]
B—Length of end section	[A]	[A]	[A]

[A]Optional to fit holders on testing machine. If threaded, root diameter shall not be less than dimension *F*.

FIG. 1 Tension-Test Specimens

are deemed necessary to ensure that supplies and services conform to the prescribed requirements.

16. Rejection and Resubmission

16.1 Any castings or lot of castings failing to comply with the requirements of this specification may, where possible, be reprocessed, retested, and reinspected. If the tests and inspections on the reprocessed casting(s) show compliance with this specification, the castings shall be acceptable; if they do not, they shall be rejected.

16.2 If the purchaser should find that a casting or lot of castings fails to comply with this specification subsequent to receipt at his facility, he shall so notify the manufacturer promptly and in no case later than six weeks after receipt of the shipment, stating clearly the basis for rejection.

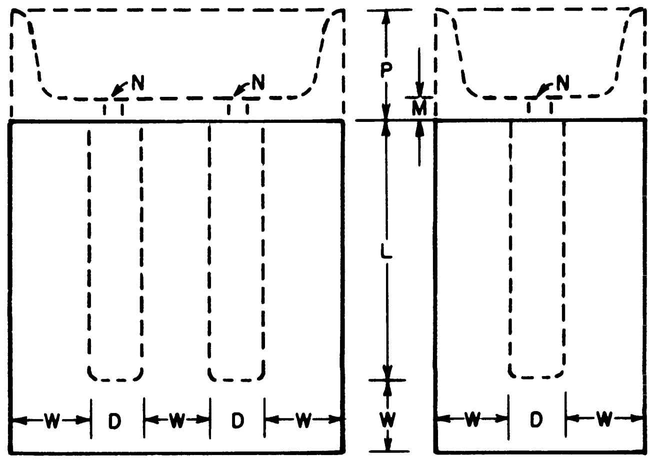
17. Certification

17.1 When specified by the purchaser's order or contract, a manufacturer's certification or compliance statement that the casting or lot of castings was made, sampled, tested, and inspected in accordance with this specification, including a report of test results shall be furnished at the time of shipment, and such certification or compliance statement shall be the basis for acceptance of the casting or lot of castings.

17.2 A signature is not required on the certification or test report. However, the document shall clearly identify the organization submitting the certification and the authorized agent of the manufacturer who certified the test results. Notwithstanding the absence of a signature, the organization submitting the certification is responsible for its content.

18. Product Marking

18.1 When the size of the casting permits, each casting shall bear the identifying mark of the manufacturer and the part or pattern number at a location shown on the covering drawing or, if not shown on the drawing, at a location at the discretion of the producer.



Required Features:

1. Material—Aggregate of dry siliceous sand.
2. Position—Bars vertical.
3. *L*—See Table 4.
4. *D*—See Table 4.
5. *W*—Not less than diameter *D*.

Optional Features:

1. Number of test bars in a single mold—Two suggested.
2. Design of pouring cup.
3. *P*—2 in. [50 mm], suggested.
4. *N*—5⁄16 in. [8 mm] in diameter, suggested.

f5. *M* = 1.5 *N*, suggested.

FIG. 2 Suitable Design and Dimensions for Mold for Separately Cast Cylindrical Test Bars for Gray Iron

19. Preparation for Delivery

19.1 Unless otherwise stated in the contract or order, the cleaning, preservation and packing of castings for shipment shall be in accordance with the manufacturer's commercial practice. Packaging and marking shall also be adequate to identify the contents and to ensure acceptance and safe delivery by the carrier for the mode of transportation employed.

19.2 *U.S. Government Procurement*—When specified in the contract or purchase order, marking for shipment shall be in accordance with the requirements of Fed. Std. No. 123 for civil agencies and MIL-STD-129 for military activities.

20. Keywords

20.1 gray iron castings

APPENDIX

(Nonmandatory Information)

X1. MECHANICAL PROPERTIES OF CASTINGS

X1.1 The mechanical properties of iron castings are influenced by the cooling rate during and after solidification, by chemical composition (particularly carbon equivalent), by the design of the casting, by the design and nature of the mold, by the location and effectiveness of gates and risers, and by certain other factors.

X1.2 The cooling rate in the mold and, hence, the properties developed in any particular section are influenced by the presence of cores; chills and chaplets; changes in section thickness; and the existence of bosses, projections, and intersections, such as junctions of ribs and bosses. Because of the complexity of the interactions of these factors, no precise quantitative relationship can be stated between the properties of the iron in various locations of the same casting or between the properties of a casting and those of a test specimen cast from the same iron. When such a relationship is important and must be known for a specification application, it may be determined by appropriate experimentation.

X1.3 Gray iron castings in Classes 20, 25, 30 and 35 are characterized by excellent machinability, high damping capacity, low modulus of elasticity, and comparative ease of manufacture.

X1.3.1 Castings in Classes 40, 45, 50, 55 and 60 are usually more difficult to machine, have lower damping capacity and a higher modulus of elasticity, and are more difficult to manufacture.

X1.4 When reliable information is unavailable on the relationship between properties in a casting and those in a separately cast test specimen, and where experimentation would be unfeasible, the size of the test casting should be so selected as to approximate the thickness of the main or controlling section of the casting.

X1.5 If iron castings are welded (see 9.2), the microstructure of the iron is usually altered, particularly in the vicinity of the weldment. Therefore, the properties of the casting may be adversely affected by welding. Where practical, appropriate post weld heat treatment may reduce this effect of welding.

Designation: A 74 – 04

Endorsed by the
Cast Iron Soil Pipe Institute
American Association State
Highway and Transportation Officials Standard
AASHTO No.: M 263-77

Standard Specification for Cast Iron Soil Pipe and Fittings[1]

This standard is issued under the fixed designation A 74; 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 cast iron soil pipe and fittings for use in gravity flow plumbing, drain, waste and vent sanitary and storm water applications. It establishes standards covering material, manufacture, mechanical and chemical properties, coating, test methods, inspection, certification, product markings, dimensions, and dimensional tolerances for extra heavy and service cast iron soil pipe and fittings. These pipe and fittings are not intended for pressure applications as the selection of the proper size for sanitary drain, waste, vent, and storm drain systems allows free air space for gravity drainage.

1.2 This specification covers pipe and fittings of the following patterns and, when so designated, shall apply to any other patterns that conform with the applicable requirements given herein.

1.2.1 *Pipe*:

	Tables
Extra heavy, 2½ ft (0.75 m), 3½ ft ((1.0 m), 5 ft (1.5 m), 10 ft (3.0 m) lengths	1, 2
Service, 2½ ft (0.75 m), 3½ ft (1.0 m), 5 ft (1.5 m), 10 ft (3.0 m)	1, 2
Outside dimensions (for detailing)	X1.1

1.2.2 *Fittings*:

	Tables
¼ bends; long ¼ bends	3, 4
¼ bends, long low-hub	5
¼ bends, low heel; high heel	6, 7
¼ bends, short sweep; long sweep	8
¼ bends, reducing long sweep	9
⅕ bends	10
⅙ bends	10
⅛ bends; long ⅛ bends	11
1⁄16 bends	11
Y branches	12, 13
Y branches, cleanout on main	14
Y branches, cleanout on branch	15
Y branches, inverted	16
Y branches, combination ⅛ bends, single	17
Y branches, combination ⅛ bends, double	17
Y branches, combination ⅛ bends, cleanout	18
Y branches, upright	19
Sanitary T branches, single	20
Sanitary T branches, double	20
Sanitary T branches, cleanout	21
Tapped sanitary T branches, single	22
Tapped sanitary T branches, double	22
T branches, single and double	23
Tapped T branches, single	24
Tapped T branches, double	24
Horizontal twin tapped T	25
T branches, cleanout	26
Vent branches, single	27
Offsets, ⅛ bend	28
Double hubs	29
Long double hubs	29
Reducers	30
Increasers	31, 32
S traps	33
P traps	34, 35
Deep seal P traps	36
Running traps	37
Screw plugs (brass)	38
Blind plugs	39
Iron-body ferrules	40
Side inlets	Fig. 3
Closet bends	41
Tapping bosses	42
Hubbed Cleanout Cap	43

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. Metric conversions in Table 1 and Table 2 are to two decimal places; all other metric conversions are rounded to the nearest whole number.

2. Referenced Documents

2.1 *ASTM Standards:* [2]

A 48 Specification for Gray Iron Castings
A 644 Terminology Relating to Iron Castings
E 8 Test Methods for Tension Testing of Metallic Materials
E 23 Test Methods for Notched Bar Impact Testing of Metallic Materials

[1] This specification is under the jurisdiction of ASTM Committee A04 on Iron Castings and is the direct responsibility of Subcommittee A04.12 on Pipes and Tubes.

Current edition approved Jan. 1, 2004. Published February 2004. Originally approved in 1917. Last previous edition approved in 2003 as A 74 – 03b.

[2] 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.

2.2 *Federal Standard:*

Fed. Std. No. 123 Marking for Shipment (Civil Agencies)[3]

2.3 *Military Standard:*

MIL-STD-129 Marking for Shipment and Storage[3]

2.4 *ANSI/ASME Standard:*

B2.1.1 Pipe Threads[4]

3. Terminology

3.1 *Definitions of Terms Specific to This Standard:*

3.2 *Manufacturer*, *n*—the entity that casts the pipe and fittings covered by this standard.

4. Materials and Manufacture

4.1 The pipe and fittings shall be iron castings suitable for installation and service for sanitary, storm drain, waste, and vent piping applications. The pipe and fittings shall meet all applicable requirements and tests given herein.

4.2 The castings shall be made of cast iron, produced by an established commercial method that provides adequate control over chemical and physical properties. Cast iron is a generic term for a series of alloys as defined in Terminology A 644 and includes gray iron as well as ductile iron. The castings shall be sound, true to pattern, and of compact close grain that permits drilling and cutting by ordinary methods. The interior surface shall be reasonably smooth and free from defects which would make the castings unfit for the use for which they are intended.

5. Mechanical Properties

5.1 *Mechanical Tests for Gray Iron*—When requested, tests to determine mechanical properties of the gray iron used in the manufacture of gray iron soil pipe and fittings. Either transverse (flexure) test bars, or tension test specimens shall be employed.

5.1.1 *Transverse Bend Test*—The breaking load shall not be less than 1750 lb (7800 N) and the deflection at the point of application of the load shall be not less than 0.20 in. (5.1 mm).

5.1.2 *Tensile Strength Test*—The tensile strength shall be not less than 21 000 psi (145 MPa).

6. Dimensions and Permissible Variations

6.1 *Pipe*:

6.1.1 Single-hub pipe shall have a hub at one end and a spigot at the other. Double hub pipe shall have a hub at each end. Hubs shall have lead grooves. The inner end of hub shall be either with or without a centering recess, all combinations of which shall make a satisfactory leakproof joint. Hub and barrel shall be cast in one piece (see Fig. 1).

6.1.2 Single-hub pipe shall be of 2½-ft (0.75-m), 3½-ft (1.00-m), 5-ft (1.5-m), and 10-ft (3.0-m) nominal laying lengths. The laying length shall be as shown in Table 1 and shall be within the tolerances on laying length specified in Table 2. Double-hub pipe shall be of the same overall length as single-hub pipe of the same size. Its laying length shall be 5 ft minus the two telescoping lengths (dimension *Y*), or 10 ft minus the telescoping length (dimension *Y*). Other dimensions shall be as specified in Table 1 as applicable, and be within the tolerances specified in Table 2. The dimensions shall apply to pipe before any coating is applied.

6.1.3 Pipe shall be straight to the extent that any deflections in the barrel of a 2½-ft, 3½-ft, and 5-ft length of pipe shall not exceed ¼ in. (6.4 mm) for sizes 4 in. (102 mm) and larger, and shall not exceed 5⁄16 in. (7.9 mm) for smaller sizes: for 10-ft lengths, deflections in the barrel shall not exceed ½ in. (12.7 mm) for sizes 4 in. and larger, nor exceed ⅝ in. (15.9 mm) for smaller sizes.

6.2 *Fittings*:

6.2.1 *Dimensions of Fittings*—All fittings shall conform to the dimensions specified for hub and spigot ends in Table 1 and Table 2, as applicable. Fittings of the patterns specified herein shall conform to the applicable dimensions in Tables 3-35 inclusive, and to the tolerances in Table 2. Other patterns (Note 1) shall conform to Table 1, as applicable, for hub and spigot dimensions, and for wall thickness throughout, and to dimension *R′*, Tables 16-18, for the minimum radius of any drainage inlets that such fittings may provide. All fittings shall have spigot ends of sufficient length to provide adequate room for making joints. All dimensions given herein shall apply to fittings before any coating is applied.

NOTE 1—Such as, for example, fittings known in the trade as “specials,” when designated as being in conformity with this specification.

6.2.2 *Water Seal and Traps*—Traps shall have water seals as follows:

Trap Size, in. (mm)	Minimum Water seal, in. (mm)
2 (50)	2 (50)
3 to 6 (80 to 150), incl	2½ (64)
8 to 12 (200 to 300), incl	3 (80)

6.2.3 *Ends of Fittings*—Hubs shall have lead grooves. The inner end of hub shall be permitted to be either with or without a centering recess, all combinations of which shall enable the installer to make a satisfactory joint. Tapped openings shall conform to 6.2.4. It is permissible to increase the wall thickness on the inside surface of fittings having one or more plain ends. The increased thickness shall not reduce the minimum *B* dimension in Table 1 in excess of 0.10 in. and shall not extend more than 4 ¼ in. from the plain end. The increased thickness shall be tapered and offer no obstruction to flow. Inside diameters complying with service or extra heavy inside diameters shall be permitted on 12 and 15 in.sizes only.

6.2.4 *Pipe Threads*—Screw plugs and tapped openings in fittings shall have American Standard taper pipe threads. The threads shall be in accordance with the American National Standard for Pipe Threads, B2.1of the current issue.

6.2.5 Internal threads shall be chamfered of the entering end approximately to the major diameter of the thread, at an angle of approximately 45° with the axis of the thread, and the entering end of external threads shall be similarly chamfered approximately to be minor diameter of the thread, for easy entrance in making a joint and for protection of the thread. The chamfer shall be concentric with the thread and shall be included in measurements of thread length.

[3] Available from Standardization Documents Order Desk, Bldg. 4 Section D, 700 Robbins Ave., Philadelphia, PA 19111-5094, Attn: NPODS.

[4] Available from American National Standards Institute (ANSI), 25 W. 43rd St., 4th Floor, New York, NY 10036.

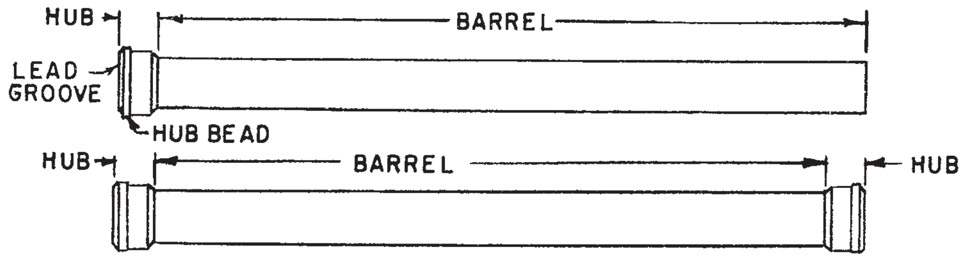


FIG. 1 Single-Hub and Double-Hub Cast Iron Soil Pipe Laying Lengths

7. Methods of Specifying Fittings

7.1 *Method of Specifying Sizes of Fittings of More than One Size*—The sizes are designated by the order of listing, as follows:

7.1.1 Branch and tapped fittings:

7.1.1.1 Size of run (Note 2), and

7.1.1.2 Size of branch.

7.1.2 Reducers, increasers, and offset fittings:

7.1.2.1 Size of inlet or run (Note 2),

7.1.2.2 Size of outlet or offset distance,

7.1.2.3 Length, if supplied in more than one length.

NOTE 2—The run is that portion of the fitting which forms part of the main drain, waste or vent line. The spigot end is ordinarily the outlet.

7.2 *Method of Specifying Hand of Fittings with Side Inlets and Outlets*—When placed in the position described below, if the side inlet or outlet appears on the right, it is a right-hand fitting; if on the left, it is a left-hand fitting.

7.2.1 *Bends and Offsets*—Place the fitting with hub facing toward the observer and the spigot end lower than the hub.

7.2.2 *Branch Fittings*—Place the branch toward the observer and the spigot end lower than the hub.

7.2.3 *Traps*—Place in the position in which the trap is installed, with the hub toward the observer.

7.2.4 The fittings shown in Fig. 2 have right-hand inlet or cleanout. Left-hand fittings have these openings on the side opposite to that shown. For details of side inlets, see Fig. 3.

8. Coating

8.1 The pipe and fittings shall be uniformly coated with a material suitable for the purpose, that is adherent, not brittle, and without a tendency to scale. The coating shall not contain asbestos above current MSDS reportable levels. Material safety data sheets shall be furnished by the coating manufacturer when requested. The coating shall be evenly and smoothly applied to all surfaces except threaded openings.

9. Sampling

9.1 Chemical and mechanical tests shall be made regularly and at sufficiently close intervals for adequate determinations

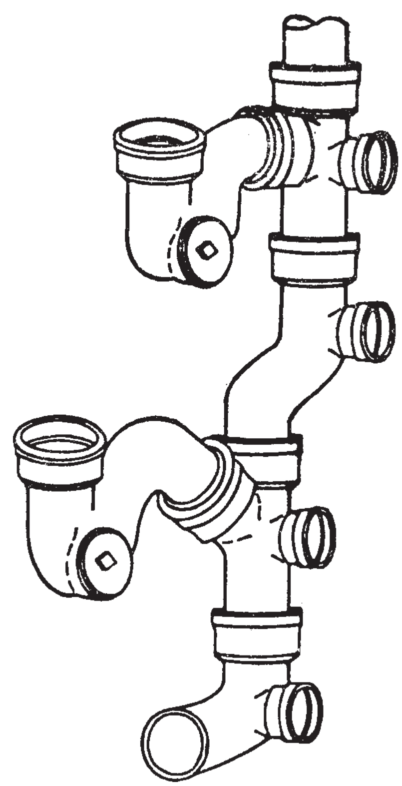
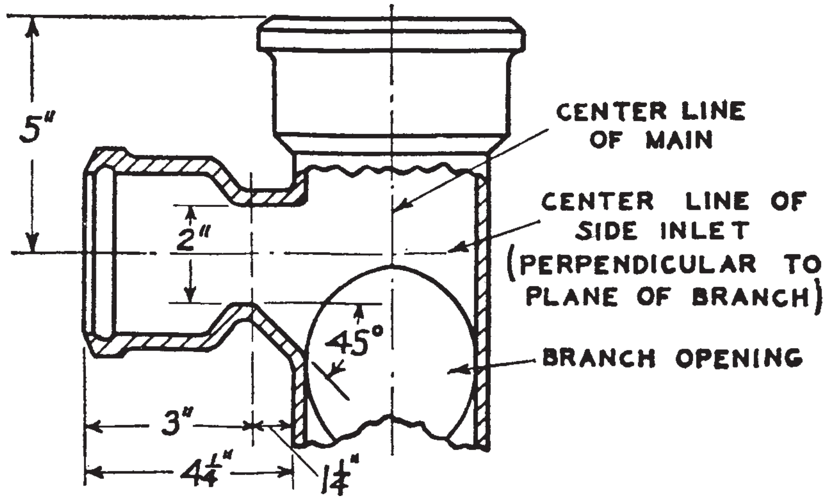


FIG. 2 Fittings with Right-Hand Inlet or Cleanout



NOTE 1—1 in. = 25.4 mm.

NOTE 2—Dimensions and location of 2-in. side inlet for single or double sanitary **T** branches and **Y** branches are shown above. Single and double sanitary **T** branches and single and double **Y** branches with 2-in. side inlets are standard in the following sizes only: 4 by 3 by 2-in; 4 by 4 by 2-in.; 5 by 4 by 2-in; 6 by 4 by 2-in.

FIG. 3 Dimensions and Locations for 2-in. Side Inlets

of the significant chemical constituents and properties of the cast iron. Records of chemical analysis shall be maintained by the manufacturer. Copies of these analyses shall be furnished to the purchaser when requested.

9.2 A lot shall consist of one of the following:

9.2.1 All the metal poured from a single heating a batch type furnace,

9.2.2 All the metal from two or more batch type melting furnaces poured into a single ladle or a single casting.

9.2.3 All the metal poured from a continuous melting furnace for a given period of time between changes in charge, processing conditions, aim-for chemistry, or 4 hours, whichever is the shorter period.

9.2.3.1 The purchaser shall be permitted to agree to extend the 4 hours time period to 8 hours if the manufacturer is able to demonstrate sufficient process control to warrant such an extension.

10. Test Methods

10.1 *Gray Iron*:

10.1.1 *Tensile Strength Test*—Test bars shall be cast in accordance with the requirements of Specification A 48. See Fig. 4 (Tension Test Specimens) for the test bar dimensions and drawing. The tensile strength shall be determined in accordance with Test Methods E 8.

10.1.2 Tension test reports shall include breaking load of test bars, machined diameter of test bar, and calculated tensile strength.

11. Inspection

11.1 *Inspection and Test by the Manufacturer*—Pipe and fittings shall be inspected by the manufacturer to verify compliance with this standard. The manufacturer shall maintain a record of all inspections for a period of 7 years.

12. Certification

12.1 *Certification by Manufacturer*—Upon request the purchaser shall be furnished certification by the manufacturer, stating samples representing each lot have been tested and inspected as indicated in this specification and the requirements have been met. If requested by the purchaser, certification shall be accompanied by test reports as prepared in accordance with the Test Methods section of this standard (see 10) . Certification shall include the legal name and address of the manufacturer.

13. Product Marking

13.1 Each length of pipe and each fitting shall be plainly marked with the country of origin, the manufacturer's name or registered trademark by which the manufacturer can be readily identified after installation, and with letters to indicate the proper classification, as follows:

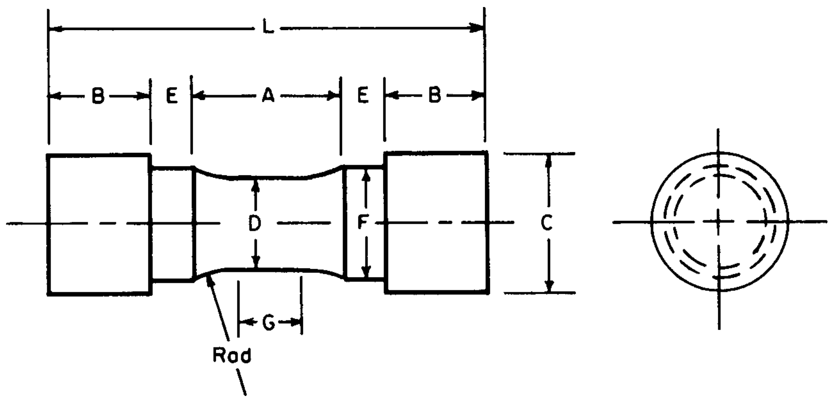
XH	Extra Heavy
SV	Service

The marking shall be cast, stenciled, or otherwise applied on the pipe so as to be clear and legible after installation. The marking shall be cast in raised letters on fittings and shall be clear and legible after installation and located away from the spigot end so as not to interfere with proper joining upon installation.

13.2 Each pipe shall be marked with the date of manufacture. The marking shall be stenciled on the pipe or otherwise applied to be clear and legible.

14. Packaging and Package Marking

14.1 *Government Procurement*—Unless otherwise specified in the contract, the material shall be packaged in accordance with the supplier's standard practice which will be acceptable to the carrier at lowest rates. Containers and packing shall



Dimensions, in. [mm]	Tension Test Specimen B
G—Length of parallel, min	0.75 [19]
D—Diameter	0.750 ± 0.015 [19.0 ± 0.38]
R—Radius of fillet, min	1 [25]
A—Length of reduced section, min	1½ [38]
L—Over-all length, min	4 [100]
C—Diameter of end section, approx	1¼ [32]
E—Length of shoulder, min	¼ [6]
F—Diameter of shoulder	15⁄16 ± 1⁄64 [25 ± 0.4]
B—Length of end section	[A]

[A] Optional to fit holders on testing machine. If threaded, root diameter shall not be less than dimension *F*.

FIG. 4 Tension-Test Specimens

comply with Uniform Freight Classification Rules[5] or National Motor Freight Classification Rules.[6] Marking for shipment of such material shall be in accordance with Fed. Std. No. 123 for civil agencies and MIL-STD-129 for military agencies.

15. Keywords

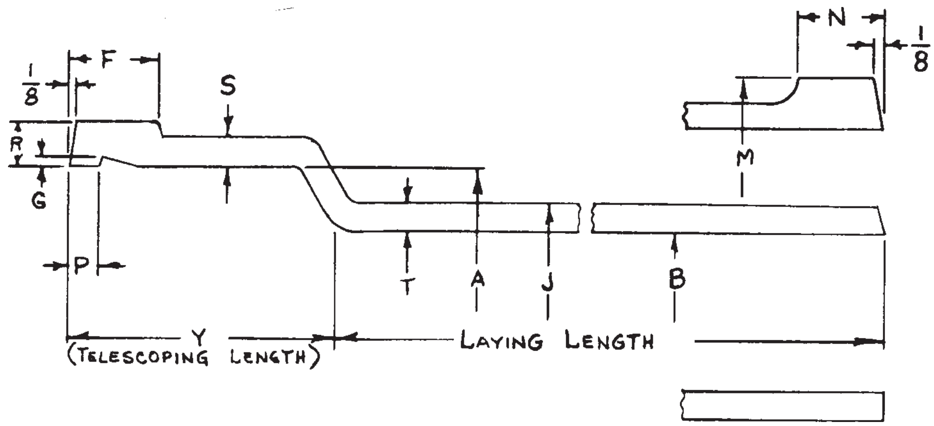
15.1 cast iron; hub and spigot pipe; pipe; soil pipe

[5] Available from The Uniform Classification Commission, Room 1106, 222 S. Riverside Plaza, Chicago, IL 60606.

[6] Available from National Motor Freight Inc., 1616 P. St., N.W., Washington, DC 20036.

TABLE 1 Dimensions of Hubs, Spigots, and Barrels for Extra-Heavy and Service Cast Iron Soil Pipe and Fittings, in.

NOTE—1 in. = 25.4 mm; 1 ft = 0.3 m throughout tables.



Extra-Heavy Cast Iron Soil Pipe and Fittings:

Size[A] Availability	Inside Diameter of Hub[B]	Outside Diameter of Barrel[B]	Telescoping Length[B]	Inside Diameter of Barrel[B]	Thickness of Barrel[B]	
	A	J	Y	B	T	
					Nom	Min
2*	3.06 [77.72]	2.38 [60.45]	2.50 [63.5]	2.00 [50.8]	0.19 [4.83]	0.16 [4.06]
3*	4.19 [106.43]	3.50 [88.9]	2.75 [69.85]	3.00 [76.2]	0.25 [6.35]	0.22 [5.59]
4*	5.19 [131.83]	4.50 [114.3]	3.00 [76.2]	4.00 [101.6]	0.25 [6.35]	0.22 [5.59]
5*	6.19 [131.83]	5.50 [139.7]	3.00 [76.2]	5.00 [127]	0.25 [6.35]	0.22 [5.59]
6*	7.19 [182.63]	6.50 [165.1]	3.00 [76.2]	6.00 [152.4]	0.25 [6.35]	0.22 [5.59]
8*	9.50 [241.30]	8.62 [218.5]	3.50 [88.9]	8.00 [203.2]	0.31 [7.87]	0.25 [6.35]
10*	11.62 [295.15]	10.75 [273.05]	3.50 [88.9]	10.00 [254]	0.37 [9.40]	0.31 [7.87]
12*	13.75 [349.25]	12.75 [323.85]	4.25 [107.95]	12.00 [304.8]	0.37 [9.40]	0.31 [7.87]
15*	16.95 [430.53]	15.88 [403.35]	4.25 [107.95]	15.00 [381]	0.44 [11.18]	0.38 [9.65]

Size[A]	Thickness of Hub		Width of Hub Bead[B,C]	Distance from Lead Groove to End, Pipe and Fittings[B]	Depth of Lead Groove	
	Hub Body	Over Bead				
	S (min)	R (min)	F	P	G (min)	G (max)
2	0.18 [4.57]	0.37 [9.40]	0.75 [19.05]	0.22 [5.59]	0.10 [2.54]	0.19 [4.83]
3	0.25 [6.35]	0.43 [10.92]	0.81 [20.57]	0.22 [5.59]	0.10 [2.54]	0.19 [4.83]
4	0.25 [6.35]	0.43 [10.92]	0.88 [22.35]	0.22 [5.59]	0.10 [2.54]	0.19 [4.83]
5	0.25 [6.35]	0.43 [10.92]	0.88 [22.35]	0.22 [5.59]	0.10 [2.54]	0.19 [4.83]
6	0.25 [6.35]	0.43 [10.92]	0.88 [22.35]	0.22 [5.59]	0.10 [2.54]	0.19 [4.83]
8	0.34 [8.64]	0.59 [14.99]	1.19 [30.23]	0.38 [9.65]	0.15 [3.81]	0.22 [5.59]
10	0.40 [10.16]	0.65 [16.51]	1.19 [30.23]	0.38 [9.65]	0.15 [3.81]	0.22 [5.59]
12	0.40 [10.16]	0.65 [16.51]	1.44 [36.54]	0.47 [11.94]	0.15 [3.81]	0.22 [5.59]
15	0.46 [11.68]	0.71 [18.03]	1.44 [36.54]	0.47 [11.94]	0.15 [3.81]	0.22 [5.59]

Service Cast Iron Soil Pipe:

Size[A] Availability[B]	Inside Diameter of Hub[B]	Outside Diameter of Barrel[D]	Telescoping Length[D]	Inside Diameter of Barrel[D]	Thickness of Barrel[D]	
	A	J	Y	B	T	
					Nom	Min
2O	2.94 [74.68]	2.30 [58.42]	2.50 [63.5]	1.96 [49.78]	0.17 [4.32]	0.14 [3.56]
3O	3.94 [100.08]	3.30 [83.82]	2.75 [69.85]	2.96 [75.18]	0.17 [4.32]	0.14 [3.56]
4O	4.94 [125.48]	4.30 [109.22]	3.00 [76.2]	3.94 [100.08]	0.18 [4.57]	0.15 [3.81]
5O	5.94 [150.88]	5.30 [134.62]	3.00 [76.2]	4.94 [125.48]	0.18 [4.57]	0.15 [3.81]
6O	6.94 [176.28]	6.30 [160.02]	3.00 [76.2]	5.94 [150.88]	0.18 [4.57]	0.15 [3.81]
8O	9.25 [234.95]	8.38 [212.85]	3.50 [88.9]	7.94 [201.68]	0.23 [5.84]	0.17 [4.32]
10O	11.38 [289.05]	10.50 [266.70]	3.50 [88.9]	9.94 [252.48]	0.28 [6.86]	0.22 [5.59]
12O	13.50 [342.9]	12.50 [317.5]	4.25 [107.95]	11.94 [303.28]	0.28 [6.86]	0.22 [5.59]
15O	16.95 [430.53]	15.88 [403.35]	4.25 [107.95]	15.16 [385.06]	0.36 [9.14]	0.30 [7.62]

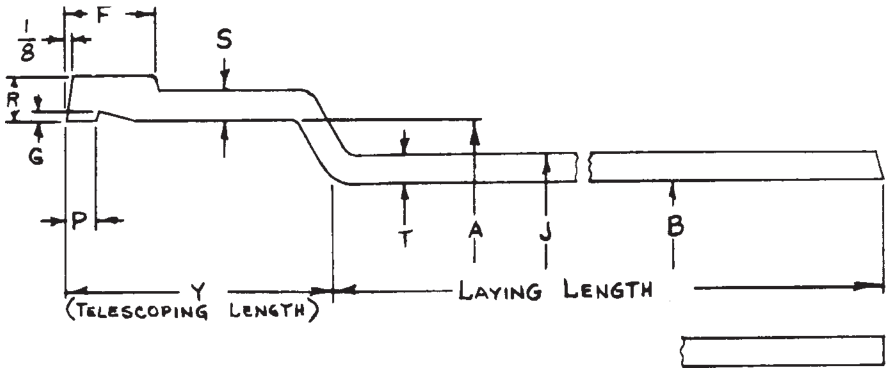
Size^A	Thickness of Hub		Width of Hub Bead^D	Distance from Lead Groove to End, Pipe and Fittings^B	Depth of Lead Groove	
	Hub Body	Over Bead				
	S (min)	*R* (min)	*F* (min)	*P*	*G* (min)	*G* (max)
2	0.13 [3.30]	0.34 [8.64]	0.75 (0.63) [19.05] (16.00)	0.22 [5.59]	0.10 [2.54]	0.19 [4.83]
3	0.16 [4.06]	0.37 [9.40]	0.81 (0.63) [20.57] (16.00)	0.22 [5.59]	0.10 [2.54]	0.19 [4.83]
4	0.16 [4.06]	0.37 [9.40]	0.88 (0.63) [22.35] (16.00)	0.22 [5.59]	0.10 [2.54]	0.19 [4.83]
5	0.16 [4.06]	0.37 [9.40]	0.88 (0.63) [22.35] (16.00)	0.22 [5.59]	0.10 [2.54]	0.19 [4.83]
6	0.18 [4.57]	0.37 [9.40]	0.88 (0.63) [22.35] (16.00)	0.22 [5.59]	0.10 [2.54]	0.19 [4.83]
8	0.19 [4.83]	0.44 [11.26]	1.19 (1.06) [30.23] (26.92)	0.38 [9.65]	0.15 [3.81]	0.22 [5.59]
10	0.27 [6.86]	0.53 [13.46]	1.19 (1.06) [30.23] (26.92)	0.38 [9.65]	0.15 [3.81]	0.22 [5.59]
12	0.27 [6.86]	0.53 [13.46]	1.44 (1.31) [36.58] (33.27)	0.47 [11.94]	0.15 [3.81]	0.22 [5.59]
15	0.30 [7.62]	0.58 [14.73]	1.44 (1.31) [36.58] (33.27)	0.47 [11.94]	0.15 [3.81]	0.22 [5.59]

^A Nominal inside diameter.
* Indicates this item is made in extra heavy.
^B For tolerances, see Table 2.
^C Hub ends and spigot ends can be made with or without draft.
^D Hub ends and spigot ends shall be permitted to be made with or without draft.
O Indicates this item is made in service weight.

TABLE 2 Dimensional Tolerances for Extra-Heavy and Service Cast Iron Soil Pipe and Fittings, in.

NOTE 1—1 in. = 25.4 mm.

NOTE 2—The tolerances set forth in Table 2 are intended for pipe and fittings designed for use with lead and oakum joints; however, these same tolerances shall apply to pipe and fittings designed for use with a compression type gasket joint.



Size[A]	Inside Diameter of Hub	Outside Diameter of Barrel	Inside Diameter of Barrel	Tele-scoping Length	Laying Length			
					Pipe, 2½-, 3½-, 5-ft Lengths	Pipe, 10-ft Lengths	Fittings	
	A′	*J*	*B*	*Y*			Regular	Extra Long[B]
2	±0.06 [1.52]	±0.09 [±2.29]	±0.09 [±2.29]	±0.06 [±1.52]	±¼ [±6.35]	±½ [±12.7]	±⅛ [±3.18]	±1⁄16 [±1.59]
3	±0.09 [2.29] −0.06 [1.52]	±0.09 [±2.29]	±0.06 [±1.52]	±¼ [±6.35]	±½ [±12.7]	±½ [±12.7]	±⅛ [±3.18]	±1⁄16 [±1.59]
4	+0.09 [2.29] −0.06 [1.52]	±0.09 [±2.29]	±0.09 [±2.29]	±0.06 [±1.52]	±¼ [±6.35]	±½ [±12.7]	±⅛ [±3.18]	±1⁄16 [±1.59]
5	+0.09 [2.29] −0.06 [1.52]	±0.09 [±2.29]	±0.09 [±2.29]	±0.06 [±1.52]	±5⁄16 [±7.94]	±⅝ [±15.88]	±3⁄16 [±4.76]	±3⁄32 [±2.38]
6	+0.09 [2.29] −0.06 [1.52]	±0.09 [±2.29]	±0.09 [±2.29]	±0.06 [±1.52]	±5⁄16 [±7.94]	±⅝ [±15.88]	±3⁄16 [±4.76]	±3⁄32 [±2.38]
8	±0.13 [3.30]	±0.13 [±3.30]	±0.13 [±3.30]	±0.13 [±3.30]	±5⁄16 [±7.94]	±⅝ [±15.88]	±3⁄16 [±4.76]	±3⁄32 [±2.38]
10	±0.13 [3.30]	±0.13 [±3.30]	±0.13 [±3.30]	±0.13 [±3.30]	±⅜ [±9.53]	±¾ [±19.05]	±¼ [±6.35]	±⅛ [±3.18]
12	±0.13 [3.30]	±0.19 [±4.83]	±0.19 [±4.83]	±0.19 [±4.83]	±⅜ [±9.53]	±¾ [±19.05]	±¼ [±6.35]	±⅛ [±3.18]
15	±0.13 [3.30]	±0.19 [±4.83]	±0.19 [±4.83]	±0.19 [±4.83]	±⅜ [±9.53]	±¾ [±19.05]	±¼ [±6.35]	±⅛ [±3.18]

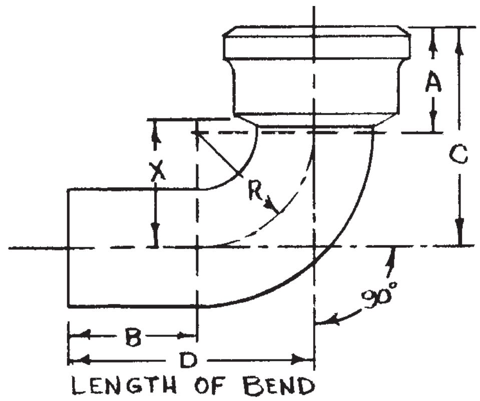
Size	Distance from Lead Groove to End, Pipe and Fittings
	P
2	±0.09 [±1.52]
3	±0.09 [±1.52]
4	±0.09 [±1.52]
5	±0.09 [±1.52]
6	±0.09 [±1.52]
8	±0.09 [±1.52]
10	±0.09 [±1.52]
12	±0.11 [±2.79]
15	±0.11 [±2.79]

[A] Nominal inside diameter.

[B] These tolerances apply to each foot of extra-long fittings in excess of regular laying lengths specified herein.

TABLE 3 Dimensions of One-Quarter Bends

NOTE 1—1 in. = 25.4 mm.
NOTE 2—Dimensions *D* and *X* are laying lengths.

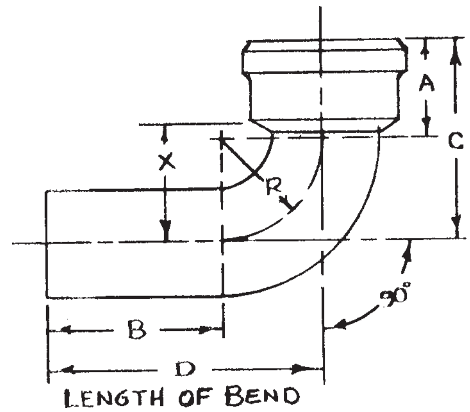


Size, in., Availability[A]	Dimensions in in.[B]					
	A	*B*	*C*	*D*	*R*	*X*
2*O	2¾ [70]	3 [76]	5¾ [146]	6 [152]	3 [76]	3¼ [83]
3*O	3¼ [83]	3½ [89]	6¾ [171]	7 [178]	3½ [89]	4 [102]
4*O	3½ [89]	4 [102]	7½ [191]	8 [203]	4 [102]	4½ [114]
5*O	3½ [89]	4 [102]	8 [203]	8½ [216]	4½ [114]	5 [127]
6*O	3½ [89]	4 [102]	8½ [216]	9 [229]	5 [127]	5½ [140]
8*O	4⅛ [105]	5½ [140]	10⅛ [257]	11½ [292]	6 [152]	6⅝ [168]
10*O	4⅛ [105]	5½ [140]	11⅛ [283]	12½ [318]	7 [178]	7⅝ [194]
12*O	5 [127]	7 [178]	13 [330]	15 [381]	8 [203]	8¾ [222]
15*O	5 [127]	7 [178]	14½ [368]	16½ [419]	9½ [241]	10¼ [260]

[A] * indicates this item is made in extra heavy.
O indicates this item is made in service weight.
[B] For details of hubs and spigots, see Table 1.

TABLE 4 Dimensions of Long One-Quarter Bends

NOTE 1—1 in. = 25.4 mm.
NOTE 2—Dimensions *D* and *X* are laying lengths.

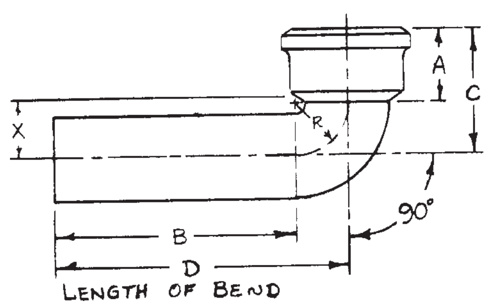


Size, in., Availability[A]	Dimensions in in.[B]					
	A	*B*	*C*	*D*	*R*	*X*
2 by 12*O	2¾ [76]	9 [229]	5¾ [146]	12 [305]	3 [76]	3¼ [83]
2 by 18*O	2¾ [76]	15 [381]	5¾ [146]	18 [457]	3 [76]	3¼ [83]
2 by 24*O	2¾ [76]	21 [533]	5¾ [146]	24 [610]	3 [76]	3¼ [83]
3 by 12*O	3¼ [83]	8½ [216]	6¾ [171]	12 [305]	3½ [89]	4 [102]
3 by 18*O	3¼ [83]	14½ [368]	6¾ [171]	18 [457]	3½ [89]	4 [102]
3 by 24*O	3¼ [83]	20½ [521]	6¾ [171]	24 [610]	3½ [89]	4 [102]
4 by 12*O	3½ [89]	8 [203]	7½ [191]	12 [305]	4 [102]	4½ [114]
4 by 18*O	3½ [89]	14 [356]	7½ [191]	18 [457]	4 [102]	4½ [114]
4 by 24*O	3½ [89]	20 [508]	7½ [191]	24 [610]	4 [102]	4½ [114]

[A] * indicates this item is made in extra heavy.
O indicates this item is made in service weight.
[B] For details of hubs and spigots, see Table 1.

TABLE 5 Dimensions of Long Low-Hub One-Quarter Bends

NOTE 1—1 in. = 25.4 mm.
NOTE 2—Dimensions *D* and *X* are laying lengths.

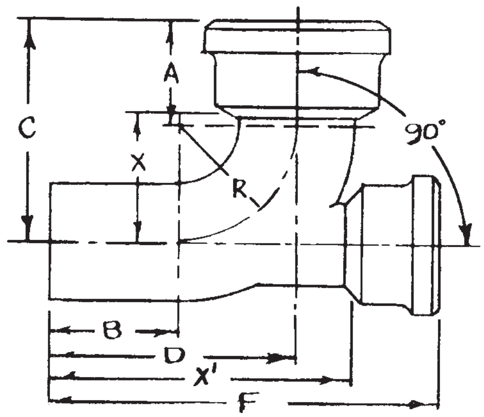


Size, in., Availability[A]	Dimensions in in.[B]					
	A	*B*	*C*	*D*	*R*	*X*
4 by 12O	3 [76]	9¼ [235]	5¾ [146]	12 [305]	2¾ [70]	2¾ [70]
4 by 14O	3 [76]	11¼ [286]	5¾ [146]	14 [356]	2¾ [70]	2¾ [70]
4 by 16O	3 [76]	13¼ [337]	5¾ [146]	16 [406]	2¾ [70]	2¾ [70]
4 by 18O	3 [76]	15¼ [387]	5¾ [146]	18 [457]	2¾ [70]	2¾ [70]

[A] O indicates this item is made in service weight.
[B] For details of hubs and spigots, see Table 1.

TABLE 6 Dimensions of One-Quarter Bends with Low Heel Inlet

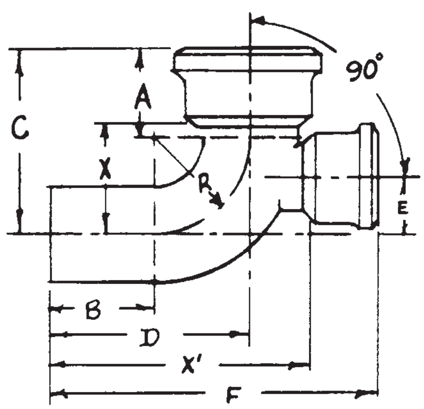
NOTE 1—1 in. = 25.4 mm.
NOTE 2—Dimensions *D*, *X*, and *X′* are laying lengths



Size, in.,	Dimensions in in.[B]							
Availability[A]	*A*	*B*	*C*	*D*	*F*	*R*	*X*	*X′*
3 by 2O	3¼ [83]	3½ [89]	6¾ [172]	7 [178]	11½ [292]	3½ [89]	4 [102]	9 [229]
4 by 2*O	3½ [89]	4 [102]	7½ [191]	8 [203]	13 [330]	4 [102]	4½ [114]	10½ [267]

[A] * indicates this item is made in extra heavy.
O indicates this item is made in service weight.
[B] For details of hubs and spigots, see Table 1.

TABLE 7 Dimensions of Quarter Bends with High Heel Inlet

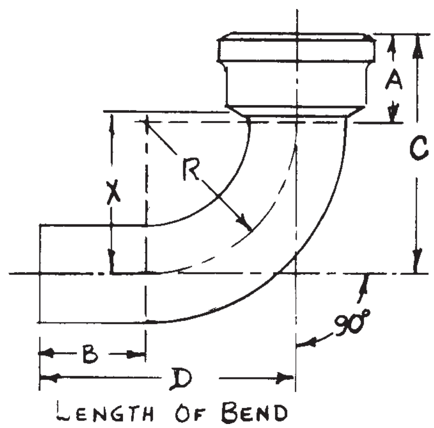


Size, in.,	Dimensions in in.[B]								
Availability[A]	*A*	*B*	*C*	*D*	*E*	*F*	*R*	*X*	*X′*
4 by 2*O	3½ [89]	4 [102]	7½ [191]	8 [203]	2¾ [70]	13 [330]	4 [102]	4½ [114]	10½ [267]

[A] * indicates this item is made in extra heavy.
O indicates this item is made in service weight.
[B] For details of hubs and spigots, see Table 1.

TABLE 8 Dimensions of Short and Long Sweep Bends

NOTE 1—1 in. = 25.4 mm.
NOTE 2—Dimensions *D* and *X* are laying lengths.



Short Sweep Bends:

Size, in.	Dimensions in in.[A]					
	A	*B*	*C*	*D*	*R*	*X*
2*O	2¾ [70]	3 [76]	7¾ [197]	8 [203]	5 [127]	5¼ [133]
3*O	3¼ [83]	3½ [89]	8¾ [222]	9 [229]	5½ [140]	6 [152]
4*O	3½ [89]	4 [102]	9½ [241]	10 [254]	6 [152]	6½ [165]
5*O	3½ [89]	4 [102]	10 [254]	10½ [267]	6½ [165]	7 [178]
6*O	3½ [89]	4 [102]	10½ [267]	11 [279]	7 [178]	7½ [191]
8*O	4⅛ [105]	5½ [140]	12⅛ [308]	13½ [343]	8 [203]	8⅝ [219]
10*O	4⅛ [105]	5½ [140]	13⅛ [333]	14½ [368]	9 [229]	9⅝ [244]
12*O	5 [127]	7 [178]	15 [381]	17 [432]	10 [254]	10¾ [273]
15*O	5 [127]	7 [178]	16½ [419]	18½ [470]	11½ [292]	12¼ [311]

[A] For details of hubs and spigots, see Table 1.

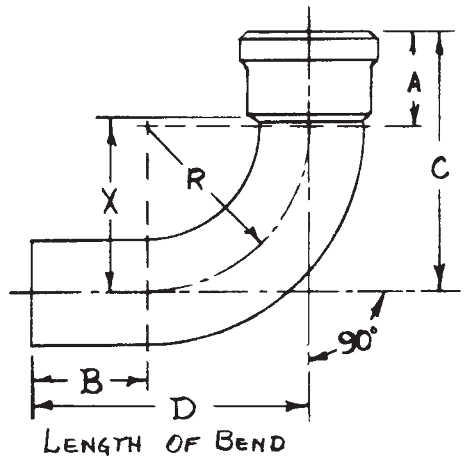
Long Sweep Bends:

Size, in., Availability[A]	Dimensions in in.[B]					
	A	*B*	*C*	*D*	*R*	*X*
2*O	2¾ [70]	3 [76]	10¾ [273]	11 [279]	8 [203]	8¼ [210]
3*O	3¼ [83]	3½ [89]	11¾ [298]	12 [305]	8½ [216]	9 [229]
4*O	3½ [89]	4 [102]	12½ [318]	13 [330]	9 [229]	9½ [241]
5*O	3½ [89]	4 [102]	13 [330]	13½ [343]	9½ [241]	10 [254]
6*O	3½ [89]	4 [102]	13½ [343]	14 [356]	10 [254]	10½ [267]
8*O	4⅛ [105]	5½ [140]	15⅛ [384]	16½ [419]	11 [279]	11⅝ [295]
10*O	4⅛ [105]	5½ [140]	16⅛ [410]	17½ [445]	12 [305]	12⅝ [321]
12*O	5 [127]	7 [178]	18 [457]	20 [508]	13 [330]	13¾ [349]
15O	5 [127]	7 [178]	19½ [495]	21½ [546]	14½ [368]	15¼ [387]

[A] * indicates this item is made in extra heavy.
O indicates this item is made in service weight.
[B] For details of hubs and spigots, see Table 1.

TABLE 9 Dimensions of Reducing Long Sweep Bends

NOTE 1—1 in. = 25.4 mm.
NOTE 2—Dimensions *D* and *X* are laying lengths.

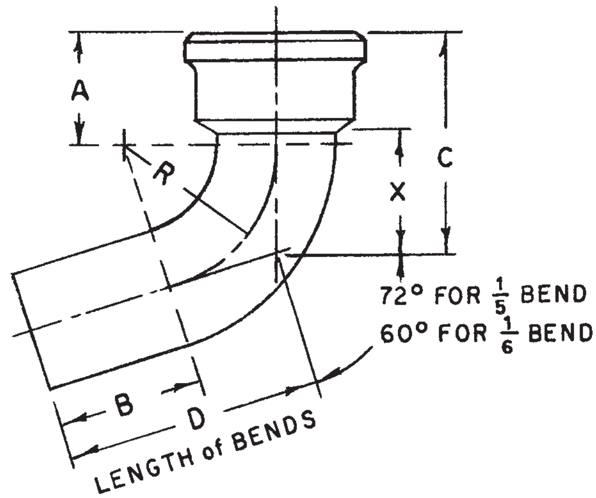


Size, in., Availability[A]	Dimensions in in.[B]					
	A	*B*	*C*	*D*	*R*	*X*
3 by 2*O	3 [76]	3½ [89]	11½ [292]	12 [305]	8½ [216]	9 [229]
4 by 3*O	3¼ [83]	4 [102]	12¼ [311]	13 [330]	9 [229]	9½ [241]

[A] * indicates this item is made in extra heavy.
O indicates this item is made in service weight.
[B] For details of hubs and spigots, see Table 1.

TABLE 10 Dimensions of One-Fifth and One-Sixth Bends

NOTE 1—1 in. = 25.4 mm.
NOTE 2—Dimensions *D* and *X* are laying lengths.



One-Fifth Bends:

Size, in. Availability[A]	Dimensions in in.[B]					
	A	*B*	*C*	*D*	*R*	*X*
3*O	3¼ [83]	3½ [89]	5$\frac{13}{16}$ [148]	6$\frac{1}{16}$ [154]	3½ [89]	3$\frac{1}{16}$ [78]
4*O	3 ⅓ [85]	4 [102]	6$\frac{7}{16}$ [164]	6$\frac{15}{16}$ [176]	4 [102]	3$\frac{7}{16}$ [87]

[A]* indicates this item is made in extra heavy.
O indicates this item is made in service weight.
[B]For details of hubs and spigots, see Table 1.

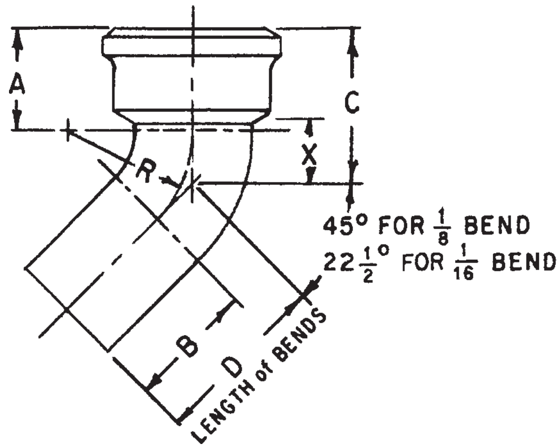
One Sixth Bends:

Size, in., Availability[A]	Dimensions in in.[B]					
	A	*B*	*C*	*D*	*R*	*X*
2*O	2¾ [70]	3 [76]	4½ [114]	4¾ [121]	3 [76]	2 [51]
3*O	3¼ [83]	3½ [89]	5¼ [133]	5½ [140]	3½ [89]	2½ [64]
4*O	3½ [89]	4 [102]	5$\frac{13}{16}$ [147]	6$\frac{5}{16}$ [160]	4 [102]	2$\frac{13}{16}$ [71]
5*O	3½ [89]	4 [102]	6⅛ [156]	6⅝ [168]	4½ [114]	3⅛ [79]
6*O	3½ [89]	4 [102]	6⅜ [161]	6⅞ [175]	5 [127]	3⅜ [86]
8*O	4⅛ [105]	5½ [140]	7⅝ [194]	9 [229]	6 [152]	4⅛ [105]
10*O	4⅛ [105]	5½ [140]	8$\frac{3}{16}$ [208]	9$\frac{9}{16}$ [243]	7 [179]	4$\frac{11}{16}$ [119]

[A] For details of hubs and spigots, see Table 1.
[B] * indicates this item is made in extra heavy.
O indicates this item is made in service weight.

TABLE 11 Dimensions of One-Eighth, Long One-Eighth Bends, and One-Sixteenth Bends

NOTE 1—1 in. = 25.4 mm.
NOTE 2—Dimensions *D* and *X* are laying lengths.

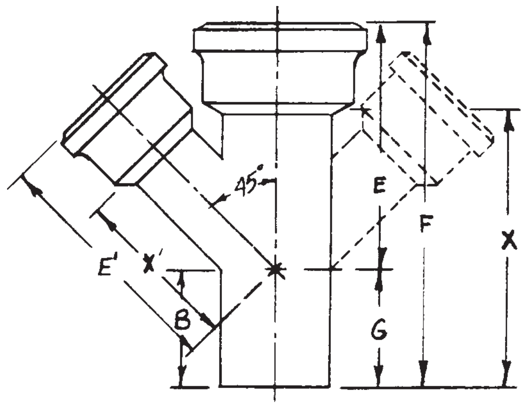


Size, In., Availability[A]	Dimensions in in.[B]					
	A	*B*	*C*	*D*	*R*	*X*
One-Eighth Bends						
2*O	2 3/4 [70]	3 [76]	4 [102]	4 1/4 [108]	3 [76]	1 1/2 [38]
3*O	3 1/4 [83]	3 1/2 [89]	4 1/16 [103]	4 15/16 [125]	3 1/2 [89]	1 15/16 [49]
4*O	3 1/2 [89]	4 [102]	5 3/16 [132]	5 11/16 [145]	4 [102]	2 3/16 [56]
5*O	3 1/2 [89]	4 [102]	5 3/8 [137]	5 7/8 [149]	4 1/2 [114]	2 3/8 [60]
6*O	3 1/2 [89]	4 [102]	5 9/16 [142]	6 1/16 [154]	5 [127]	2 9/16 [65]
8*O	4 1/8 [105]	5 1/2 [140]	6 5/8 [168]	8 [203]	6 [152]	3 1/8 [79]
10*O	4 1/2 [114]	5 1/2 [140]	7 [178]	8 3/8 [213]	7 [178]	3 1/2 [89]
12*O	5 [127]	7 [178]	8 5/16 [211]	10 5/16 [262]	8 [203]	4 1/16 [103]
15*O	5 [127]	7 [178]	8 15/16 [227]	10 15/16 [278]	9 1/2 [241]	4 11/16 [119]
Long One-Eighth Bends						
2 by 12*O	2 3/4 [70]	10 3/4 [273]	4 [102]	12 [305]	3 [76]	1 1/2 [38]
2 by 18*O	2 3/4 [70]	16 3/4 [425]	4 [102]	18 [457]	3 [76]	1 1/2 [38]
2 by 24*O	2 3/4 [70]	22 3/4 [578]	4 [102]	24 [610]	3 [76]	1 1/2 [38]
3 by 12*O	3 1/4 [83]	10 9/16 [269]	4 11/16 [119]	12 [305]	3 1/2 [89]	1 15/16 [49]
3 by 18*O	3 1/4 [83]	16 9/16 [421]	4 11/16 [119]	18 [457]	3 1/2 [89]	1 15/16 [49]
3 by 24*O	3 1/4 [83]	22 9/16 [573]	4 11/16 [119]	24 [610]	3 1/2 [89]	1 15/16 [49]
4 by 12*O	3 1/2 [89]	10 5/16 [261]	5 3/16 [12]	12 [305]	4 [102]	2 3/16 [56]
4 by 18*O	3 1/2 [89]	16 5/16 [414]	5 3/16 [132]	18 [457]	4 [102]	2 3/16 [56]
4 by 24*O	3 1/2 [89]	22 5/16 [567]	5 3/16 [132]	24 [610]	4 [102]	2 3/16 [56]
One-Sixteenth Bends						
2*O	2 3/4 [70]	3 [76]	3 3/8 [86]	3 5/8 [92]	3 [76]	7/8 [22]
3*O	3 1/4 [83]	3 1/2 [89]	3 15/16 [100]	4 3/16 [107]	3 1/2 [89]	1 3/16 [30]
4*O	3 1/2 [90]	4 [102]	4 5/16 [109]	4 13/16 [122]	4 [102]	1 5/16 [33]
5*O	3 1/2 [90]	4 [102]	4 3/8 [111]	4 7/8 [124]	4 1/2 [114]	1 3/8 [35]
6*O	3 1/2 [90]	4 [102]	4 1/2 [114]	5 [127]	5 [127]	1 1/2 [38]
8*O	4 1/8 [105]	5 1/2 [140]	5 5/16 [135]	6 11/16 [170]	6 [152]	1 13/16 [46]
10*O	4 1/8 [105]	5 1/2 [140]	5 1/2 [140]	6 7/8 [175]	7 [178]	2 [51]
12*O	5 [127]	7 [178]	6 5/8 [168]	8 5/8 [219]	8 [203]	2 3/8 [60]
15*O	5 [127]	7 [178]	6 7/8 [175]	8 7/8 [225]	9 1/2 [241]	2 5/8 [67]

[A] For details of hubs and spigots, seeTable 1.
[B] * indicates this item is made in extra heavy.
O indicates this item is made in service weight.

TABLE 12 Dimensions of Y Branches, Single

NOTE 1—1 in. = 25.4 mm.
NOTE 2—Dimensions X^1 and X are laying lengths.

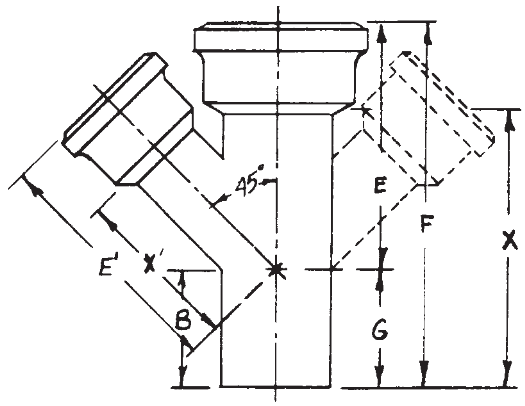


Size, in., Availability [A]	Single Dimensions in in. [B]						
	B (min)	E	E'	F	G	X	X'
2*O	3½ [88]	6½ [165]	6½ [165]	10½ [267]	4 [102]	8 [203]	4 [102]
3*O	4 [102]	8¼ [210]	8¼ [210]	13¼ [337]	5 [127]	10½ [267]	5½ [140]
4*O	4 [102]	9¾ [248]	9¾ [248]	15 [381]	5¼ [133]	12 [305] [305]	6¾ [171]
5*O	4 [102]	11 [279]	11 [279]	16½ [409]	5½ [140]	13½ [343]	8 [203]
6*O	4 [102]	12¼ [311]	12¼ [311]	18 [457]	5¾ 16]	15 [381]	9¼ [235]
8*O	5½ [140]	15 5/16 [389]	15 5/16 [389]	23 [584]	7 11/16 [195]	19½ [495]	11 13/16 [300]
10*O	5½ [10]	18 [457]	18 [457]	26 [660]	8 [203]	22½ [572]	14½ [368]
12*O	7 [178]	21⅛ [537]	21⅛ [537]	31¼ [794]	10⅛ [257]	27 [686]	16⅞ [429]
15*O	7 [178]	25 [635]	25 [635]	35¾ [908]	10¾ [273]	31½ [800]	20¾ [527]
3 by 2*O	4 [102]	7 9/16 [192]	7½ [191]	11¾ [298]	4 3/16 [106]	9 [229]	5 [127]
4 by 2*O	4 [102]	8⅜ [213]	8¼ [210]	12 [305]	3⅝ [92]	9 [229]	5¾ [146]
4 by 3*O	4 [102]	9 1/16 [230]	9 [229]	13½ [343]	4 7/16 [113]	10½ [267]	6¼ [159]
5 by 2*O	4 [102]	8⅞ [255]	9 [229]	12 [305]	3⅛ [79]	9 [229]	6½ [165]
5 by 3*O	4 [102]	9⅝ [244]	9¾ [248]	13½ [343]	3⅞ [98]	10½ [267]	7 [178]
5 by 4*O	4 [102]	10 5/16 [262]	10½ [267]	15 [381]	4 11/16 [119]	12 [305]	7½ [191]
6 by 2*O	4 [102]	9 7/16 [240]	9¾ [248]	12 [305]	2 9/16 [65]	9 [229]	7¼ [184]
6 by 3*O	4 [102]	10⅛ [257]	10½ [267]	13½ [343]	3⅜ [86]	10½ [267]	7¾ [197]
6 by 4*O	4 [102]	10 13/16 [275]	11¼ [286]	15 [381]	4 3/16 [106]	12 [305]	8¼ [210]
6 by 5*O	4 [102]	11 9/16 [294]	11¾ [298]	16½ [419]	4 15/16 [125]	13½ [343]	8¾ [222]
8 by 2*O	5½ [140]	10⅞ [276]	11 [279]	14 [356]	3⅛ [79]	10½ [267]	8½ [216]
8 by 3*O	5½ [140]	11 9/16 [294]	11¾ [298]	15½ [394]	3 15/16 [100]	12 [305]	9 [229]
8 by 4*O	5½ [140]	12¼ [311]	12½ [318]	17 [432]	4¾ [121]	13½ [343]	9½ [241]
8 by 5*O	5½ [140]	13 [330]	13 [330]	18½ [470]	5½ [140]	15 [381]	10 [254]
8 by 6*O	5½ [140]	13 11/16 [348]	13½ [343]	20 [508]	6 5/16 [160]	16½ [419]	10½ [267]
10 by 4*O	5½ [140]	13 7/16 [341]	14⅛ [359]	17 [432]	3 9/16 [90]	13½ [343]	11⅛ [283]
10 by 5*O	5½ [140]	14 3/16 [360]	14⅝ [371]	18½ [470]	4 5/16 [110]	15 [381]	11⅝ [296]
10 by 6*O	5½ [140]	14⅞ [378]	15⅛ [384]	20 [508]	5⅛ [130]	16½ [419]	12⅛ [308]
10 by 8*O	5½ [140]	16½ [419]	16 15/16 [430]	23 [584]	6½ [165]	19½ [495]	13 7/16 [341]
12 by 4*O	7 [178]	15⅛ [384]	15 7/16 [392]	19¼ [489]	4⅛ [105]	15 [381]	12 7/16 [316]
12 by 5*O	7 [178]	15⅞ [430]	15 15/16 [405]	20¾ [527]	4⅞ [124]	16½ [419]	12 15/16 [329]
12 by 6*O	7 [178]	16 9/16 [421]	16 7/16 [418]	22¼ [565]	5 11/16 [144]	18 [457]	13 7/16 [341]
12 by 8*O	7 [178]	18 3/16 [462]	18¼ [464]	25¼ [641]	7 1/16 [179]	21 [533]	14¾ [375]
12 by 10*O	7 [178]	19 11/16 [500]	19 5/16 [491]	28¼ [718]	8 9/16 [217]	24 [610]	15 13/16 [402]
15 by 6*O	7 [178]	18¼ [464]	18¾ [476]	22¼ [565]	4 [102]	18 [457]	15¾ [400]
15 by 8*O	7 [178]	19⅞ [505]	20 9/16 [522]	25¼ [641]	5⅜ [137]	21 [533]	17 1/16 [433]
15 by 10*O	7 [178]	21⅜ [543]	21⅝ [549]	28¼ [718]	6⅞ [175]	24 [610]	18⅛ [460]
15 by 12*O	7 [178]	22 13/16 [579]	23 7/16 [595]	31¼ [794]	8 7/16 [214]	27 [686]	19 3/16 [487]

[A] * indicates this item is made in extra heavy.
O indicates this item is made in service weight.
[B] For details of hubs and spigots, see Table 1. For details of side inlets see Fig. 3.

TABLE 13 Dimensions of Y Branches, Double

NOTE 1—1 in. = 25.4 mm.
NOTE 2—X and X^1 are laying lengths.

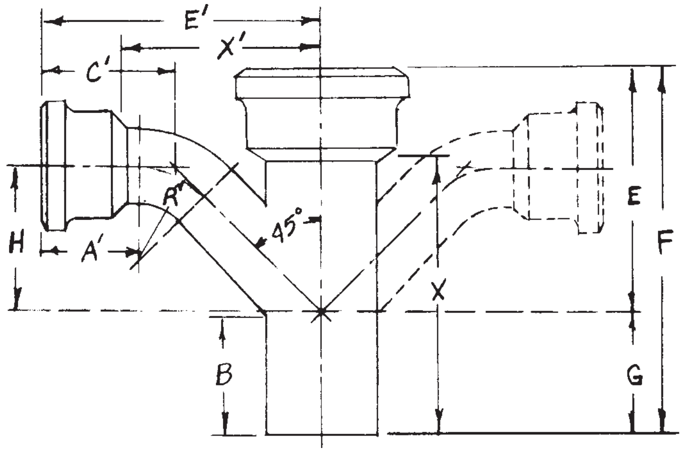


Size, in., Availability [A]	Double Dimensions in in. [B]						
	B (min)	*E*	*E'*	*F*	*G*	*X*	*X'*
2*O	3½ [89]	6½ [165]	6½ [165]	10½ [267]	4 [102]	8 [203]	4 [102]
3*O	4 [102]	8¼ [210]	8¼ [210]	13¼ [337]	5 [127]	10½ [267]	5½ [140]
4*O	4 [102]	9¾ [248]	9¾ [248]	15 [381]	5¼ [133]	12 [305]	9¼ [235]
5*O	4 [102]	11 [279]	11 [279]	16½ [419]	5½ [140]	13½ [343]	8 [203]
6*O	4 [102]	12¼ [311]	12¼ [311]	18 [457]	5¾ [146]	15 [381]	9¼ [235]
8*O	5½ [140]	15⁵⁄₁₆ [389]	15⁵⁄₁₆ [389]	23 [584]	7¹¹⁄₁₆ [195]	19½ [495]	11¹³⁄₁₆ [300]
10*O	5½ [140]	18 [457]	18 [457]	26 [660]	8 [203]	22½ [572]	14½ 368]
12*O	7 [178]	21⅛ [537]	21⅛ [537]	31¼ [794]	10⅛ [257]	27 [686]	16⅞ [429]
15*O	7 [178]	25 [635]	25 [635]	35¾ [908]	10¾ [273]	31½ [800]	20¾ [527]
3 by 2*O	4 [102]	7⁹⁄₁₆ [192]	7½ [191]	11¾ [298]	4³⁄₁₆ [106]	9 [229]	5 [127]
4 by 2*O	4 [102]	8⅜ [213]	8¼ [210]	12 [305]	3⅜ [86]	9 [229]	5¾ [146]
4 by 3*O	4 [102]	9¹⁄₁₆ [230]	9 [229]	13½ [343]	4⁷⁄₁₆ [113]	10½ [267]	6¼ [159]
6 by 3*O	4 [102]	10⅛ [257]	10½ [267]	13½ [343]	3⅜ [86]	10½ [267]	7 [178]
6 by 4*O	4 [102]	10¹³⁄₁₆ [275]	11¼ [286]	15 [381]	4³⁄₁₆ [106]	12 [305]	8¼ [210]
8 by 4*O	5½ [140]	12¼ [311]	12½ [318]	17 [432]	4¾ [121]	13½ [343]	9½ [241]
8 by 6*O	5½ [140]	13¹¹⁄₁₆ [348]	13½ [343]	20 [208]	6⁵⁄₁₆ [160]	16½ [419]	10½ [267]
10 by 3	5½ [140]	12¾ [324]	13½ [343]	15½ [394]	2¾ [70]	12 [305]	10¾ [273]
10 by 6*O	5½ [140]	14⅞ [378]	15⅛ [384]	20 [508]	5⅛ [130]	16½ [419]	12⅛ [308]
10 by 8*O	5½ [140]	16½ [419]	16¹⁵⁄₁₆ [430]	23 [584]	6½ [165]	19½ [495]	13⁷⁄₁₆ [341]
12 by 6*	7 [178]	16⁹⁄₁₆ [421]	16⁷⁄₁₆ [418]	22¼ [565]	5¹¹⁄₁₆ [144]	18 [457]	13⁷⁄₁₆ [341]
12 by 8*O	7 [178]	18³⁄₁₆ [462]	18¼ [464]	25¼ [641]	7¹⁄₁₆ [179]	21 [533]	14¾ [375]
15 by 4	7¼ [184]	17 [432]	18 [457]	19½ [495]	2½ [64]	15¼ [387]	15 [381]

[A] * indicates this item is made in extra heavy.
O indicates this item is made in service weight.
[B] For details of hubs and spigots, see Table 1. For details of side inlets see Fig. 3.

TABLE 14 Dimensions of Combination Y and One-Eighth Bend, Single and Double

NOTE 1—1 in. = 25.4 mm.
NOTE 2—Dimensions *X* and *X* ' are laying lengths.

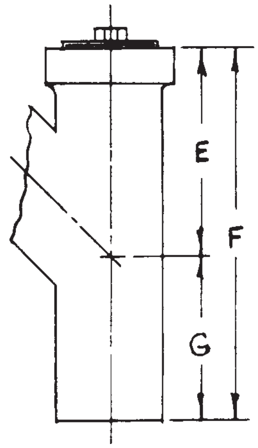


Size, in., Availability[A]	Dimensions in in.[B]										
	A '	*B* (min)	*C* '	*E*	*E* '	*F*	*G*	*H*	*R* '	*X*	*X* '
Single:											
2*O	2¾ [70]	3½ [89]	4 [102]	6½ [165]	7⅜ [187]	10½ [267]	4 [102]	3⅜ [86]	3 [76]	8 [203]	4⅞ [124]
3*O	3¼ [83]	4 [102]	4 11/16 [119]	8¼ [210]	9¾ [248]	13¼ [337]	5 [127]	5 1/16 [129]	3½ [89]	10½ [267]	7 [178]
4*O	3½ [89]	4 [102]	5 3/16 [132]	9¾ [248]	12 [305]	15 [381]	5¼ [133]	6 13/16 [173]	4 [102]	12 [305]	9 [229]
5*O	3½ [89]	4 [102]	5⅜ [137]	11 [279]	14 [356]	16½ [419]	5½ [140]	8⅝ [219]	4½ [114]	13½ [343]	11 [279]
6*O	3½ [89]	4 [102]	5 9/16 [141]	12¼ [311]	15⅞ [403]	18 [457]	5¾ [146]	10 5/16 [262]	5 [127]	15 [381]	12⅞ [327]
8*O	4⅛ [105]	5½ [140]	6⅝ [168]	15 5/16 [389]	20½ [521]	23 [584]	7 11/16 [195]	13⅞ [352]	6 [152]	19½ [495]	17 [432]
3 by 2*O	3 [76]	4 [102]	4¼ [108]	7 9/16 [192]	8¼ [209]	11¾ [299]	4 3/16 [106]	4 [102]	3 [76]	9 [229]	5¾ [146]
4 by 2*O	3 [76]	4 [102]	4¼ [108]	8 5/16 [211]	8¾ [222]	12 [305]	3 11/16 [94]	4½ [114]	3 [76]	9 [229]	6¼ [159]
4 by 3*O	3¼ [83]	4 [102]	4 11/16 [119]	9 [229]	10¼ [260]	13½ [343]	4½ [114]	5 9/16 [141]	3½ [89]	10½ [267]	7½ [191]
5 by 2*O	3 [76]	4 [102]	4¼ [108]	8⅝ [219]	9¼ [235]	12 [305]	3⅜ [86]	5 [127]	3 [76]	9 [229]	6¾ [171]
5 by 3*O	3¼ [83]	4 [102]	4 11/16 [119]	9½ [241]	10¾ [273]	13½ [343]	4 [102]	6 1/16 [154]	3½ [89]	10½ [267]	8 [203]
5 by 4*O	3½ [89]	4 [102]	5 3/16 [132]	10¼ [260]	12½ [318]	15 [381]	4¼ [108]	7 5/16 [185]	4 [102]	12 [305]	9½ [241]
6 by 2*O	3 [76]	4 [102]	4¼ [108]	9 5/16 [237]	9¾ [248]	12 [305]	2 11/16 [68]	5½ [140]	3 [76]	9 [229]	7¼ [184]
6 by 3*O	3¼ [83]	4 [102]	4 11/16 [119]	10 [257]	11¼ [286]	13½ [343]	3⅛ [79]	6 9/16 [167]	3½ [89]	10¼ [260]	8½ [216]
6 by 4*O	3½ [89]	4 [102]	5 3/16 [132]	10¾ [237]	13 [330]	15 [381]	4¼ [108]	7 13/16 [198]	4 [102]	12 [305]	10 [254]
6 by 5*O	3½ [89]	4 [102]	5⅜ [137]	11 7/16 [291]	14½ [368]	16½ [419]	5 1/16 [129]	9⅛ [232]	4½ [114]	13½ [343]	11½ [292]
8 by 2*O	3 [76]	5½ [140]	4¼ [108]	10⅞ [276]	10¾ [273]	14 [356]	3⅛ [79]	6½ [165]	3 [76]	10½ [267]	8¼ [210]
8 by 4*O	3½ [89]	5½ [140]	5 3/16 [132]	12¼ [311]	14 [356]	17 [432]	4¾ [121]	8 13/16 [224]	4 [102]	13½ [343]	11 [279]
8 by 5*O	3½ [89]	5½ [140]	5⅜ [137]	13 [330]	15½ [394]	18½ [470]	5½ [140]	10⅛ [257]	4½ [114]	15 [381]	12½ [318]
8 by 6*O	3½ [89]	5½ [140]	5 9/16 [141]	13 11/16 [348]	16⅞ [429]	20 [508]	6 5/16 [160]	11 5/16 [287]	5 [127]	16½ [419]	13⅞ [352]
Double:											
2*O	2¼ [57]	3½ [89]	4 [102]	6½ [165]	7⅜ [187]	10½ [267]	4 [102]	3⅜ [86]	3 [76]	8 [203]	4⅞ [124]
3*O	3¼ [83]	4 [102]	4 11/16 [119]	8¼ [210]	9¾ [248]	13¼ [337]	5 [127]	5 1/16 [129]	3½ [89]	10½ [267]	7 [178]
4*O	3½ [89]	4 [102]	5 3/16 [132]	9¾ [248]	12 [305]	15 [381]	5¼ [133]	6 13/16 [173]	4 [102]	12 [305]	9 [229]
6*O	3½ [89]	4 [102]	5 9/16 [141]	12¼ [311]	15⅞ [403]	18 [457]	5¾ [146]	10 5/16 [262]	5 [127]	15 [381]	12⅞ [327]
3 by 2*O	3 [76]	4 [102]	4¼ [108]	7 9/16 [192]	8¼ [210]	11¾ [298	4 3/16 [106]	4 [102]	3 [76]	9 [229]	5¾ [146]
4 by 2*O	3 [76]	4 [102]	4¼ [108]	8 5/16 [211]	8¾ [222]	12 [305]	3 11/16 [94]	4½ [114]	3 [76]	9 [229]	6¼ [146]
4 by 3*O	3¼ [83]	4 [102]	4 11/16 [119]	9 [229]	10¼ [260]	13½ [343]	4½ [114]	5 9/16 [141]	3½ [89]	10½ [267]	7½ [191]
5 by 4*O	3½ [89]	4 [102]	5 3/16 [132]	10¼ [260]	12½ [318]	15 [381]	4¾ [121]	7 5/16 [186]	4 [102]	12 [305]	9½ [241]
6 by 4*O	3½ [89]	4 [102]	5 3/16 [132]	10¾ [273]	13 [330]	15 [381]	4¼ [108]	7 13/16 [198]	4 [102]	12 [305]	10 [254]

[A] * indicates this item is made in extra heavy.
O indicates this item is made in service weight.
[B] For details of hubs and spigots, see Table 1; for details of side inlets, see Fig. 3.

TABLE 15 Dimensions of Combination Y and One-Eighth Bend Cleanout with Screw Plug on Main

NOTE 1—1 in. = 25.4 mm.

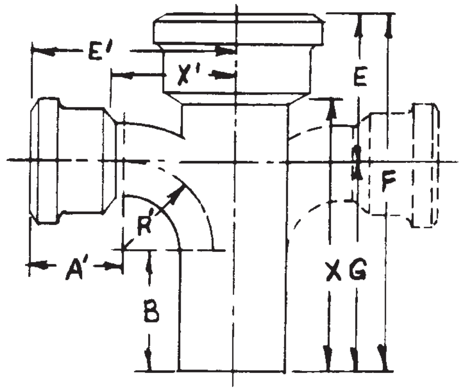


Size, in., Availability[A]	Dimensions in in. [B]		Min. I.P.S. tapping [C]	Size (in.)	Dimensions in in. [B]		Min. I.P.S. tapping [A]
	E	*F*			*E*	*F*	
2*O	5¼ [133]	9¼ [235]	1½ [38]	5 [127]	9⅛ [232]	14⅝ [371]	4 [102]
3*O	6⅝ [168]	11⅝ [295]	2½ [64]	6 [152]	10⅜ [264]	16⅛ [410]	5 [127]
4*O	7⅛ [181]	13⅛ [333]	3½ [89]				

[A] * indicates this item is made in extra heavy.
O indicates this item is made in service weight.
[B] For dimensions not given in this table see Table 14. For details of hubs and spigots, see Table 1.
[C] For details of tapping bosses, see Table 35 and for details of screw plugs, see Table 31.

TABLE 16 Dimensions of Sanitary T Branches, Single and Double

NOTE 1—1 in. = 25.4 mm.
NOTE 2—Dimensions *X* and *X′* are laying lengths.

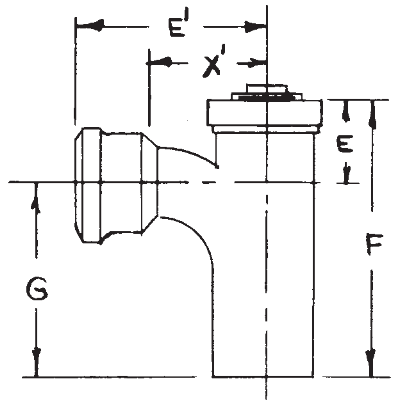


Size, in., Availability [A]	Dimensions in in. [B]							
	A′	*B*	*E*	*E′*	*F*	*G*	*R′*	*X*	*X′*
Single:									
2*O	2¾ [70]	3¾ [95]	4¼ [108]	5¼ [133]	10½ [267]	6¼ [159]	2½ [64]	8 [203]	2¾ [70]
3*O	3¼ [83]	4 [102]	5¼ [133]	6¾ [171]	12¾ [324]	7½ [191]	3½ [89]	10 [254]	4 [102]
4*O	3½ [89]	4 [102]	6 [152]	7½ [190]	14 [356]	8 [203]	4 [102]	11 [279]	4½ [114]
5*O	3½ [89]	4 [102]	6½ [165]	8 [203]	15 [381]	8½ [216]	4½ [114]	12 [305]	5 [127]
6*O	3½ [89]	4 [102]	7 [178]	8½ [216]	16 [406]	9 [229]	5 [127]	13 [330]	5½ [140]
8*O	4⅛ [105]	5¾ [146]	8¾ [222]	10⅛ [257]	20½ [521]	11¾ [298]	6 [152]	17 [432]	6⅝ [168]
10*O	4⅛ [105]	5¾ [146]	9¾ [248]	11⅛ [283]	22½ [572]	12¾ [324]	7 [178]	19 [483]	7⅝ [194]
12*O	5 [127]	7 [178]	11¾ [298]	13 [330]	26¾ [679]	15 [381]	8 [203]	22½ [572]	8¾ [222]
15*O	5 [127]	7 [178]	13¼ [337]	14½ [368]	29¾ [755]	16½ [419]	9½ [241]	25½ [648]	10¼ [260]
3 by 2*O	3 [76]	4 [102]	4¾ [121]	6½ [165]	11¾ [298]	7 [178]	3 [76]	9 [229]	4 [102]
4 by 2*O	3 [76]	4 [102]	5 [127]	7 [178]	12 [305]	7 [178]	3 [76]	9 [229]	4½ [114]
4 by 3*O	3¼ [83]	4 [102]	5½ [140]	7¼ [184]	13 [330]	7½ [191]	3½ [89]	10 [254]	4½ [114]
5 by 4*O	3½ [89]	4 [102]	6 [152]	8 [203]	14 [356]	8 [203]	4 [102]	11 [279]	5 [127]
6 by 2*O	3 [76]	4 [102]	5 [127]	8 [203]	12 [305]	7 [178]	3 [76]	9 [229]	5½ [140]
6 by 3*O	3¼ [83]	4 [102]	5½ [140]	8¼ [210]	13 [330]	7½ [191]	3½ [89]	10 [254]	5½ [140]
6 by 4*O	3½ [89]	4 [102]	6 [152]	8½ [216]	14 [356]	8 [203]	4 [102]	11 [279]	5½ [140]
8 by 4*O	3½ [89]	5¾ [146]	6¾ [171]	9½ [241]	16½ [419]	9¾ [248]	4 [102]	13 [330]	6½ [165]
8 by 6*O	3½ [89]	5¾ [146]	7¾ [197]	9½ [241]	18½ [470]	10¾ [273]	5 [127]	15 [381]	6½ [165]
10 by 4*O	3½ [89]	5¾ [146]	6¾ [171]	10½ [267]	16½ [419]	9¾ [240]	4 [102]	13 [330]	7½ [191]
10 by 6*O	3½ [89]	5¾ [146]	7¾ [197]	10½ [267]	18½ [470]	10¾ [273]	5 [127]	15 [381]	7½ [191]
10 by 8*O	4⅛ [105]	5¾ [146]	8¾ [222]	11⅛ [283]	20½ [521]	11¾ [298]	6 [152]	17 [432]	7⅝ [194]
12 by 6*O	3½ [89]	7 [178]	8¾ [222]	11½ [292]	20¾ [527]	12 [305]	5 [127]	16½ [419]	8½ [216]
12 by 8*O	4⅛ [105]	7 [178]	9¾ [248]	12⅛ [308]	22¾ [578]	13 [330]	6 [152]	18½ [470]	8⅝ [219]
12 by 10*O	4⅛ [105]	7 [178]	10¾ [273]	12⅛ [308]	24¾ [629]	14 [356]	7 [178]	20½ [521]	8⅝ [219]
15 by 6*O	3½ [89]	7 [178]	8¾ [222]	13 [330]	20¾ [527]	12 [305]	5 [127]	16½ [419]	10 [254]
15 by 8*O	4⅛ [105]	7 [178]	9¾ [248]	13⅝ [346]	22¾ [578]	13 [330]	6 [152]	18½ [470]	10⅛ [257]
15 by 10*O	4⅛ [105]	7 [178]	10¾ [273]	13⅝ [346]	24¾ [629]	14 [356]	7 [178]	20½ [521]	10⅛ [257]
15 by 12*O	5 [127]	7 [178]	11¾ [298]	14½ [368]	26¾ [679]	15 [381]	8 [203]	22½ [572]	10¼ [260]
Double:									
2*O	2¾ [70]	3¾ [95]	4¼ [108]	5¼ [133]	10½ [267]	6¼ [159]	2½ [64]	8 [203]	2¾ [70]
3*O	3¼ [83]	4 [102]	5¼ [133]	6¾ [171]	12¾ [324]	7½ [191]	3½ [89]	10 [254]	4 [102]
4*O	3½ [89]	4 [102]	6 [152]	7½ [191]	14 [356]	8 [203]	4 [102]	11 [279]	4½ [114]
6*O	3½ [89]	4 [102]	7 [178]	8½ [216]	16 [406]	9 [229]	5 [127]	13 [330]	5½ [140]
8*O	4⅛ [105]	5¾ [146]	8¾ [222]	10⅛ [257]	20½ [521]	11¾ [298]	6 [152]	17 [432]	6⅝ [168]
3 by 2*O	3 [76]	4 [102]	4¾ 121]	6½ [165]	11¾ [298]	7 [178]	3 [76]	9 [229]	4 [102]
4 by 2*O	3 [76]	4 [102]	5 [127]	7 [178]	12 [305]	7 [178]	3 [76]	9 [229]	4½ [114]
4 by 3*O	3¼ [83]	4 [102]	5½ [140]	7¼ [184]	13 [330]	7½ [191]	3½ [89]	10 [254]	4½ [114]
5 by 4*O	3½ [89]	4 [102]	6 [152]	8 [203]	14 [356]	8 [203]	4 [102]	11 [279]	5 [127]
6 by 4*O	3½ [89]	4 [102]	6 [152]	8½ [216]	14 [356]	8 [203]	4 [102]	11 [279]	5½ [140]
8 by 4*O	3½ [89]	5¾ [146]	6¾ [171]	9½ [241]	16½ [419]	9¾ [248]	4 [102]	13 [330]	6½ [165]
8 by 6*O	3½ [89]	5¾ [146]	7¾ [197]	9½ [241]	18½ [470]	10¾ [273]	5 [127]	15 [381]	6½ [165]

[A] * indicates this item is made in extra heavy.
O indicates this item is made in service weight.
[B] For details of hubs and spigots, see Table 1. For details of side inlets see Fig. 3.

TABLE 17 Dimensions of Sanitary T Branches, Cleanout Plug on Main

NOTE—1 in. = 25.4 mm.

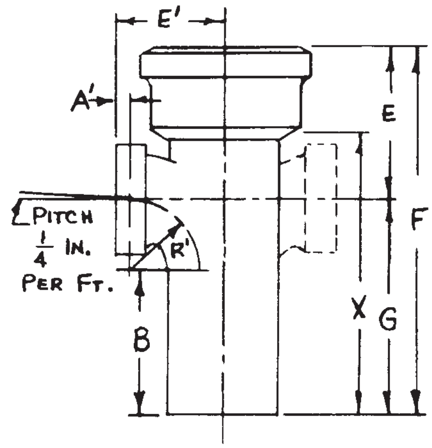


Size, in., Availability [A]	Dimensions in in. [B]					Minimum I.P.S. Tapping [C]
	E	*E'*	*F*	*G*	*X'*	
4*O	4⅛ [105]	7½ [191]	12⅛ [308]	8 [203]	4½ [114]	3½ [89]

[A] * indicates this item is made in extra heavy.
O indicates this item is made in service weight.
[B] For details of hubs and spigots see Table 1. For dimensions not given in this table, see Table 16.
[C] For details of tapping bosses, see Table 35; and for details of screw plugs, see Table 31.

TABLE 18 Dimensions of Sanitary T Branches, Tapped, Single and Double

NOTE 1—1 in. = 25.4 mm.
NOTE 2—Dimension *X* is the laying length.



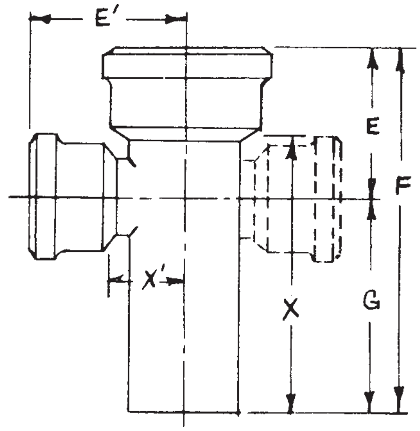
Size, in.,[A] Availability[B]	Dimensions in in.[C]							
	A'	*B*	*E*	*E'*	*F*	*G*	*R'*	*X*
2 by 2*O	13⁄16 [21]	4 [102]	4½ [114]	3 1⁄16 [78]	10½ [267]	6¼ [159]	2¼ [57]	8 [203]
3 by 2*O	13⁄16 [21]	4¾ [121]	4¾ [121]	3 9⁄16 [90]	11¾ [298]	7 [178]	2¼ [57]	9 [229]
4 by 2*O	13⁄16 [21]	4¾ [121]	5 [127]	4 1⁄16 [103]	12 [305]	7 [178]	2¼ [57]	9 [229]
2*O[D]	...	4½ [114]	...	2 13⁄16 [71]	...	...	1¾ [44]	...
3*O[D]	...	5¼ [133]	...	3 5⁄16 [84]	...	...	1¾ [44]	...
4*O[D]	...	5¼ [133]	...	3 13⁄16 [97]	...	...	1¾ [44]	...

Size, in.,[A] Availability[B]	Dimensions in in.[C]							
	A'	*B*	*E*	*E'*	*F*	*G*	*R'*	*X*
Double:								
2 by 2*O	13⁄16 [21]	4 [102]	4½ [114]	3 1⁄16 [78]	10½ [267]	6¼ [159]	2¼ [57]	8 [203]
3 by 2*O	13⁄16 [21]	4¾ [121]	4¾ [121]	3 9⁄16 [90]	11¾ [298]	7 [178]	2¼ [57]	9 [229]
4 by 2*O	13⁄16 [21]	4¾ [121]	5 [127]	4 1⁄16 [103]	12 [305]	7 [178]	2¼ [57]	9 [229]
2*O[D]	...	4½ [114]	...	2 13⁄16 [71]	...	...	1¾ [44]	...
3*O[D]	...	5¼ [133]	...	3 5⁄16 [84]	...	...	1¾ [44]	...
4*O[D]	...	5¼ [133]	...	3 13⁄16 [97]	...	...	1¾ [44]	...

[A] All sizes of branches are furnished with 1¼ and 1½ in. tappings, in addition to the 2 in. tapping.
[B] * indicates this item is made in extra heavy.
O indicates this item is made in service weight.
[C] For details of hubs and spigots, see Table 1. For details of tapping bosses, see Table 35.
[D] Dimensions for 1¼ in. and 1½ in. tapping only.

TABLE 19 Dimensions of T Branches, Single and Double

NOTE 1—1 in. = 25.4 mm.
NOTE 2—T branches are intended for venting and cleanout purposes only, and branch openings are not intended for use as waste inlets.
NOTE 3—Dimensions *X* and *X′* are laying lengths.



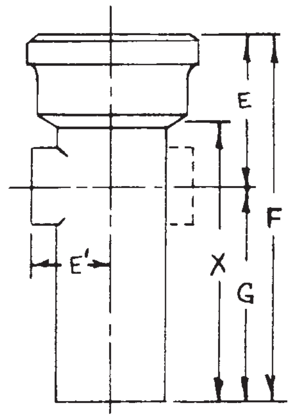
Size, in., Availability [A]	Dimensions in in.[B]					
	E	*E′*	*F*	*G*	*X*	*X′*
Single:						
2*O	4¼ [108]	4¼ [108]	10½ [267]	6¼ [159]	8 [203]	1¾ [44]
3*O	5¼ [133]	5¼ [133]	12¾ [324]	7½ [191]	10 [254]	2½ [64]
4*O	6 [152]	6 [152]	14 [356]	8 [203]	11 [279]	3 [76]
5*O	6½ [165]	6½ [165]	15 [381]	8½ [216]	12 [306	3½ [89]
6*O	7 [178]	7 [178]	16 [406]	9 [229]	13 [330]	4 [102]
3 by 2*O	4¾ [121]	5 [127]	11¾ [298]	7 [178]	9 [229]	2½ [64]
4 by 2*O	5 [127]	5½ [140]	12 [305]	7 [178]	9 [229]	3 [76]
4 by 3*O	5½ [140]	5¾ [146]	13 [330]	7½ [191	10 [254]	3 [76]
6 by 4*O	6 [152]	7 [178]	14 [356]	8 [203]	11 [279]	4 [102]

Size, in., Availability[A]	Dimensions in in.[B]					
	E	*E′*	*F*	*G*	*X*	*X′*
Double:						
4*O	6 [152]	6 [152]	14 [356]	8 [203]	11 [279]	3 [76]
4 by 2*O	5 [127]	5½ [140]	12 [305]	7 [178]	9 [229]	3 [76]

[A] * indicates this item is made in extra heavy.
O indicates this item is made in service weight.
[B] For details of hubs and spigots, see Table 1.

TABLE 20 Dimensions of Tapped T Branches, Single and Double

NOTE 1—1 in. = 25.4 mm.
NOTE 2—Tapped T branches are intended for venting and cleanout purposes only, and branch openings are not intended for use as waste inlets.
NOTE 3—Dimension *X* is the laying length.
NOTE 4—Dimensions given apply to branches tapped 1¼ , 1½ and 2 in., I.P.S.



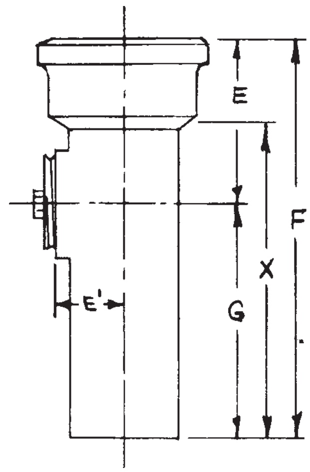
Size, in., Availability[A]	Dimensions in in.[B]					I.P.S. Tapping
	E	*E′*	*F*	*G*	*X*	
Single:						
2*O	4¼ [108]	2 [51]	10½ [267]	6¼ [159]	8 [203]	1¼ –1½ –2 [32-38-51]
3*O	4¾ [121]	2½ [64]	11¾ [298]	7 [178]	9 [229]	1¼ –1½ –2 [32-38-51]
4*O	5 [127]	3 [76]	12 [305]	7 [178]	9 [229]	1¼ –1½ –2 [32-38-51]
5*O	5 [127]	3½ [89]	12 [305]	7 [178]	9 [229]	1¼ –1½ –2 [32-38-51]
6O	5 [127]	4 [102]	12 [305]	7 [178]	9 [229]	1¼ –1½ –2 [32-38-51]
4 by 3*O	6 [152]	3 [76]	14 [356]	8 [203]	11 279]	3 [76]
5 by 4*O	6½ [165]	3½ [89]	15 [381]	8½ [215]	12 [305]	4 [102]
6 by 4*O	7 [178]	4 [102]	16 [406]	9 [229]	13 [330]	4 [102]

Size, in., Availability[A]	Dimensions in in.[B]					I.P.S. Tapping
	E	*E′*	*F*	*G*	*X*	
Double:						
2O	4¼ [108]	2 [51]	10½ [267]	6¼ [159]	8 [103]	1¼ –1½ –2 [32-38-51]
3*O	4¾ [121]	2½ [64]	11¾ [298]	7 [178]	9 [229]	1¼ –1½ –2 [32-38-51]
4*O	5 [127]	3 [76]	12 [305]	7 [178]	9 [229]	1¼ –1½ –2 [32-38-51]
5 by 2*O	3½ [189]	5 [127]	12 [305]	7 [178]	9 [229]	2 [51]

[A] * indicates this item is made in extra heavy.
O indicates this item is made in service weight.
[B] For details of hubs and spigots, see Table 1. For details of tapping bosses, see Table 35.

TABLE 21 Dimensions of T Branch Cleanout with Screw Plug

NOTE 1—1 in. = 25.4 mm.
NOTE 2—Dimension *X* is the laying length.

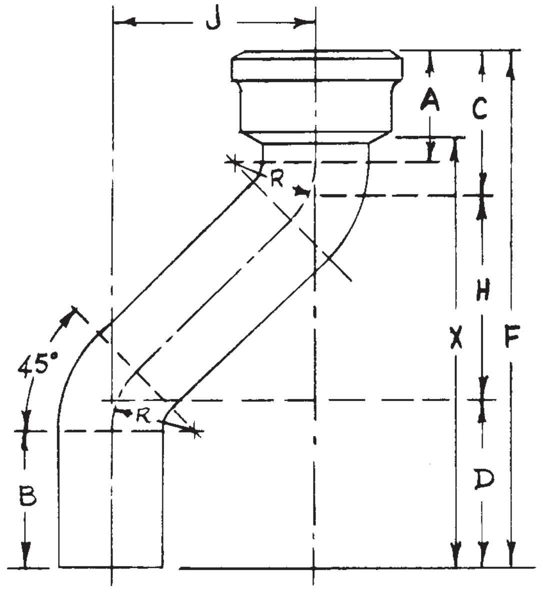


Size, in., Availability[A]	Dimensions in in.[B]					I.P.S. Tapping
	E	*E'*	*F*	*G*	*X*	
2 by 1½ *O	4¼ [108]	2 [51]	10½ [267]	6¼ [159]	8 [203]	1½ [38]
3 by 2½ *O	5¼ [133]	2½ [64]	12¾ [324]	7½ [191]	10 [254]	2½ [64]
4 by 3½ *O	6 [152]	3 [76]	14 [356]	8 [103]	11 [279]	3½ [89]
5 by 4*O	6½ [165]	3½ [89]	15 [381]	8½ [216]	12 [305]	4 [102]
6 by 4*O	7 [178]	4 [102]	16 [406]	9 [229]	13 [330]	4 [102]

[A] * indicates this item is made in extra heavy.
O indicates this item is made in service weight.
[B] For details of hubs and spigots, see Table 1. For details of topping bosses, see Table 35.

TABLE 22 Dimensions of One-Eighth Bend Offset (2 in., 3 in., 4 in., 5 in., and 6 in.)

NOTE 1—1 in. = 25.4 mm.
NOTE 2—Dimension *X* is the laying length.



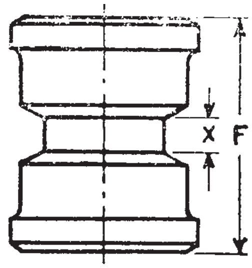
One-Eighth Bend Offset (2 in.):

Size, in., Availability [A]	Dimensions in in. [B]								
	A′	*B*	*E*	*E′*	*F*	*G*	*R′*	*X*	*X′*
One-Eighth Bend Offset (4 in.):									
4 by 4*O	3½ [89]	4 [102]	4¾ [121]	5¼ [133]	14 [356]	4 [102]	4 [102]	3 [76]	11 [279]
4 by 6*O	3½ [89]	4 [102]	4¾ [121]	5¼ [133]	16 [406]	6 [152]	6 [152]	3 [76]	13 [330]
4 by 8*O	3½ [89]	4 [102]	4¾ [121]	5¼ [133]	18 [456]	8 [203]	8 [203]	3 [76]	15 [381]

[A] * indicates this item is made in extra heavy.
O indicates this item is made in service weight.
[B] For details of hubs and spigots, see Table 1.

TABLE 23 Dimensions of Double Hub and Long Double Hub

NOTE 1—1 in. = 25.4 mm.
NOTE 2—Dimension *X* is the laying length.



Double Hub:

Size, in.[A] Availability[B]	*F*, in.	*X*, in.	Size, in.[A]	*F*, in.	*X*, in.
2*O	6 [152]	1 [25]	8 [203]	8¼ [210]	1¼ [32]
3*O	6½ [165]	1 [25]	10 [254]	8¼ [210]	1¼ [32]
4*O	7 [178]	1 [25]	12 [305]	10 [254]	1½ [38]
5*O	7 [178]	1 [25]	15 [381]	10 [254]	1½ [38]
6*O	7 [178]	1 [25]			

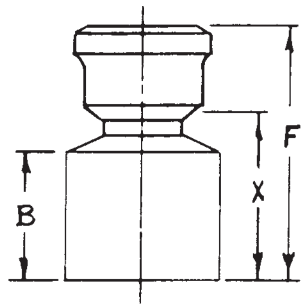
Long Double Hubs:

Size, in.[A]	*F*, in.	*X*, in.
2 by 30*O	30 [762]	25 [635]
3 by 30*O	30 [762]	24½ [622]
4 by 30*O	30 [762]	24 [610]

[A] For details of hubs and spigots, see Table 1.
[B] * indicates this item is made in extra heavy.
O indicates this item is made in service weight.

TABLE 24 Dimensions of Reducers

NOTE 1—1 in. = 25.4 mm.
NOTE 2—Dimension *X* is the laying length.

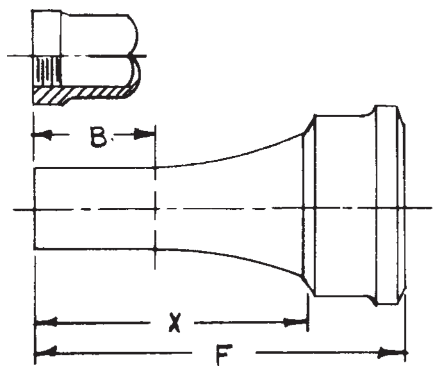


Size, in. Availability[A]	*B*, in.	*F*, in.	*X*, in.	Size, in. Availability[B]	*B*, in.	*F*, in.	*X*, in.
3 by 2*O	3¾ [95]	7¼ [184]	4¾ [121]	8 by 6*O	4½ [114]	9 [229]	6 [152]
4 by 2*O	4 [102]	7½ [191]	5 [127]	10 by 4*O	4½ [114]	9 [229]	6 [152]
4 by 3*O	4 [102]	7¾ [197]	5 [127]	10 by 5*O	4½ [114]	9 [229]	6 [152]
5 by 2*O	4 [102]	7½ [191]	5 [127]	10 by 6*O	4½ [114]	9 [229]	6 [152]
5 by 3*O	4 [102]	7¾ [197]	5 [127]	10 by 8*O	4½ [114]	9½ [241]	6 [152]
5 by 4*O	4 [102]	8 [203]	5 [127]	12 by 4*O	5¼ [133]	9½ [241]	6½ [165]
6 by 2*O	4 [102]	7½ [192]	5 [127]	12 by 5*O	5¼ [133]	9½ [241]	6½ [165]
6 by 3*O	4 [102]	7¾ [197]	5 [127]	12 by 6*O	5¼ [133]	9½ [241]	6½ [165]
6 by 4*O	4 [102]	8 [203]	5 [127]	12 by 8*O	5¼ [133]	10 [254]	6½ [165]
6 by 5*O	4 [102]	8 [203]	5 [127]	12 by 10*O	5¼ [133]	10 [254]	6½ [165]
8 by 2*O	4½ [114]	8½ [216]	6 [152]	15 by 6*O	5¼ [133]	9½ [241]	6½ [165]
8 by 3*O	4½ [114]	8¾ [222]	6 [152]	15 by 8*O	5¼ [133]	10 [254]	6½ [165]
8 by 4*O	4½ [114]	9 [229]	6 [152]	15 by 10*O	5¼ [133]	10 [254]	6½ [165]
8 by 5*O	4½ [114]	9 [229]	6 [152]	15 by 12*O	5¼ [133]	10¾ [273]	6½ [165]

[A] * indicates this item is made in extra heavy.
O indicates this item is made in service weight.
[B] For details of hubs and spigots, see Table 1.

TABLE 25 Dimensions of Increaser

NOTE 1—1 in. = 25.4 mm.
NOTE 2—Dimension *X* is the laying length.

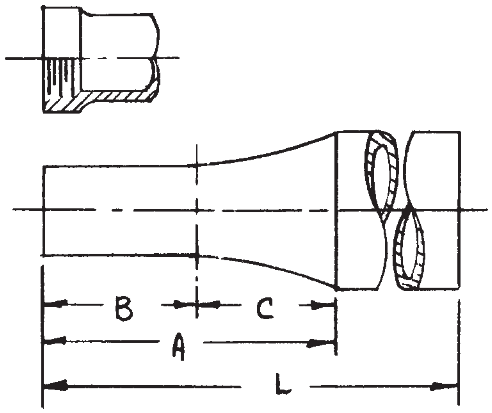


Size, in. Availability[A]	*B*,[B] in.	*F*,[B] in.	*S*,[B] in.
2 by 3*O	4 [102]	11¾ [298]	9 [229]
2 by 4*O	4 [102]	12 [305]	9 [229]
3 by 4*O	4 [102]	12 [305]	9 [229]
3 by 5*O	4 [102]	12 [305]	9 [229]
3 by 6*O	4 [102]	12 [305]	9 [229]
4 by 5*O	4 [102]	12 [305]	9 [229]
4 by 6*O	4 [102]	12 [305]	9 [229]
4 by 8*O	4 [102]	15½ [394]	12 [305]
6 by 8*O	4 [102]	15½ [394]	12 [305]
10 by 12*O	7 [178]	16¼ [413]	12 [305]

[A] * indicates this item is made in extra heavy.
O indicates this item is made in service weight.
[B] For details of hubs and spigots, see Table 1.

TABLE 26 Dimensions of Long Increasers, Spigot and Tapped

NOTE 1—1 in. = 25.4 mm.
NOTE 2— First size given for long increasers is spigot size. First size given for long increasers, tapped, is tapping size.
NOTE 3—All markings shall be on small end and in space indicated by dimension *C*.
NOTE 4—Dimension *L* is the laying length.

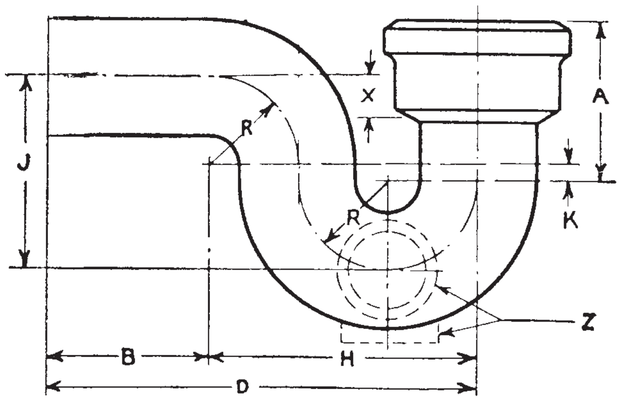


Size, in. Availability[A]	Dimensions in in.[B]			
	A	*B*	*C*	*L*
2 by 4 by 24*O	8½ [216]	4 [102]	4½ [114]	24 [610]
2 by 4 by 30*O	8½ [216]	4 [102]	4½ [114]	30 [762]
3 by 4 by 24O	8½ [216]	4 [102]	4½ [114]	24 [610]
4 by 5 by 30O	11¼ [286]	4 [102]	7¼ [184]	30 [762]
4 by 6 by 30*O	12½ [318]	4 [102]	8½ [216]	30 [762]

[A] * indicates this item is made in extra heavy.
O indicates this item is made in sevice weight.
[B] For details of hubs and spigots, see Table 1. For details of tapping bosses, see Table 35.

TABLE 27 Dimensions of P Traps with Cleanout

NOTE 1—1 in. = 25.4 mm.
NOTE 2—A minimum water seal of 2 in. is provided for the 2-in. size; of 2½ in. for sizes 3 to 6 in., inclusive.
NOTE 3—Dimensions *D* and *X* are laying lengths. Dimension *X* is measured below the horizontal center line.
NOTE 4—Traps with tapped cleanout shall have tappings of sizes indicated below.
NOTE 5—Tap at position *Z* shall be specified as right side, left side, or bottom.



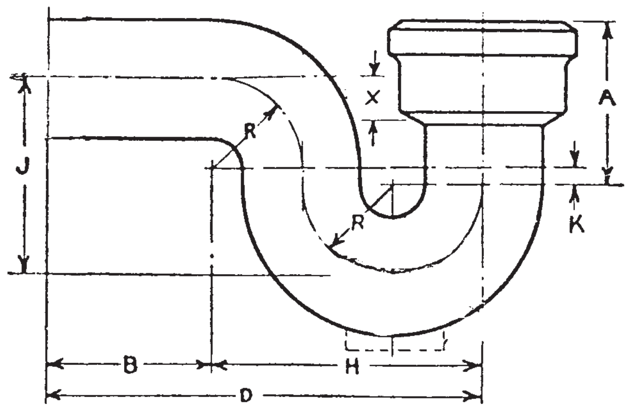
Size, in.	Availability[A]	Dimensions in in.[B]									
		A	*B*	*C*	*D*	*F′*	*H*	*J*	*K*	*R*	*X*
4	*O	5½ [140]	5 [140]	6 [152]	14 [356]	6 [152]	9 [229]	6½ [165]	½ [13]	3 [76]	1 [25]

Size, in.	IPS Tapping at *Z*, in.
2	1¼ [32]
3	1½ [38]
4	3 [76]

[A] * indicates this item is made in extra heavy.
O indicates this item is made in service weight.
[B] For details of hubs and spigots, see Table 1. For details of tapping bosses, see Table 35.

TABLE 28 Dimensions of Plain P Trap

NOTE 1—1 in. = 25.4 mm.
NOTE 2—A minimum water seal of 2 in. is provided for the 2-in. size, of 2½ in. for sizes 3 to 6 in., inclusive.
NOTE 3—Dimensions *D* and *X* are laying lengths. Dimension *X* is measured below the horizontal center line on sizes 5 by 5 in. and smaller.

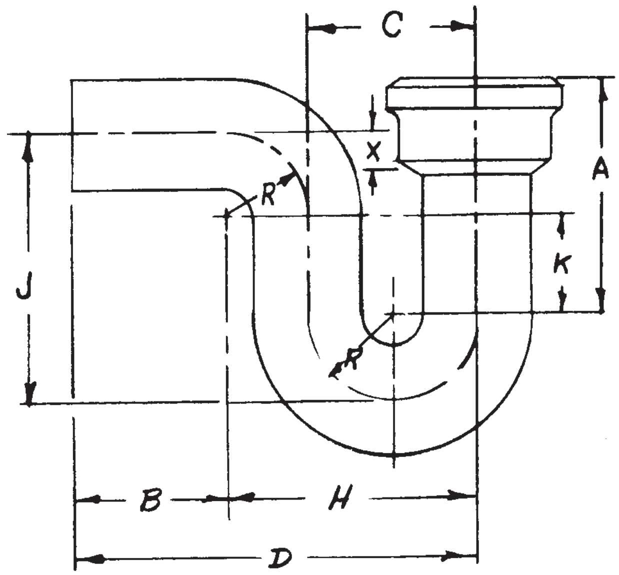


Size, in Trap by Vents	Availability[A]	Dimensions in in.[B]							
		A	B	D	H	J	K	R	X
2	*O	3 [76]	3½ [89]	9½ [241]	6 [152]	4 [102]	...	2 [51]	1½ [38]
3	*O	4½ [114]	4½ [114]	12 [305]	7½ [191]	5½ [135]	½ [13]	2½ [64]	1¼ [32]
4	*O	5½ [140]	5 [127]	14 [356]	9 [229]	6½ [165]	½ [13]	3 [76]	1 [25]
5	*O	6½ [165]	5 [127]	15½ [394]	10½ [267]	7½ [191]	½ [13]	3½ [89]	½ [13]
6	*O	7½ [191]	5 [127]	17 [432]	12 [305]	8½ [216]	½ [13]	4 [102]	...
10	O	13 [330]	7 [178]	25 [635]	18 [457]	14 [356]	2 [51]	6 [152]	½ [38]

[A] * indicates this item is made in extra heavy.
O indicates this item is made in service weight.
[B] For details of hubs and spigots, see Table 1. For details of topping bosses, see Table 34.

TABLE 29 Dimensions of Deep Seal P Trap

NOTE 1—1 in. = 25.4 mm.
NOTE 2—Dimension D is the laying length.



Size, in., Availability[A]	Dimensions in in.[B]								
	A	B	C	D	H	J	K	R	X
2*O	5 [127]	3½ [89]	4 [102]	9½ [241]	6 [152]	6 [152]	2 [51]	2 [51]	1½ [38]
3*O	6 [152]	4½ [114]	5 [127]	12 [305]	7½ [191]	7 [178]	2 [51]	2½ [64]	1¼ [32]
4*O	7 [178]	5 [127]	6 [152]	14 [356]	9 [229]	8 [203]	2 [51]	3 [76]	1¼ [32]

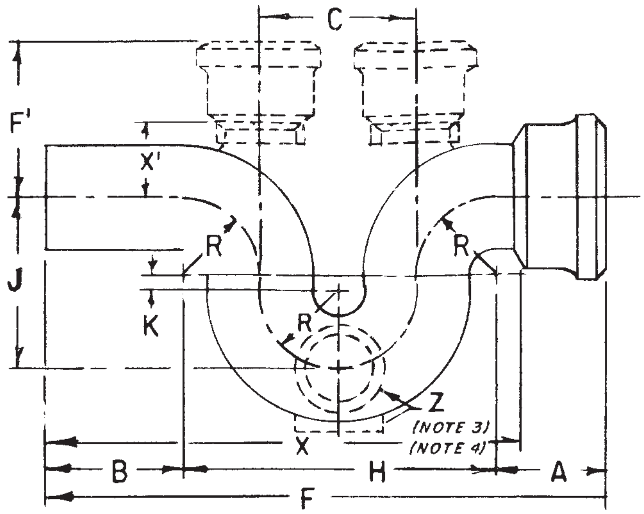
[A] * indicates this item is made in extra heavy.
O indicates this item is made in service weight.
[B] For details of hubs and spigots, see Table 1.

TABLE 30 Dimensions of Running Traps With or Without Single or Double Vents and Cleanout

NOTE 1—1 in. = 25.4 mm.

NOTE 2—A minimum water seal of 2 in. is provided for the 2-in. size; of 2½ in. for sizes 3 to 6 in., inclusive; of 3 in. for sizes 8 to 12 in., inclusive; and of 3½ in. for the 15-in. size.

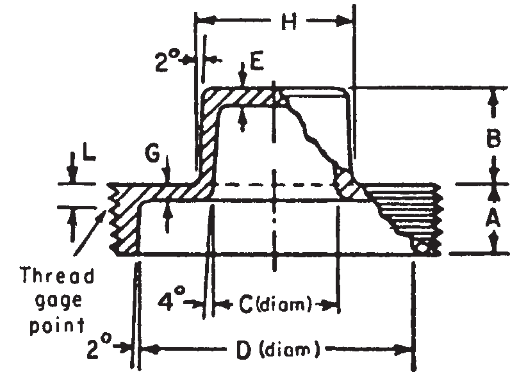
NOTE 3—Dimensions *X* and *X*' are laying lengths.



Size, in. Trap by Vent	Dimensions in in.[A]									
	A	*B*	*C*	*F*	*F*′	*H*	*K*	*R*	*X*	*X*′
3 by 3	3¼ [83]	4½ [114]	5 [127]	17¾ [451]	5¼ [133]	10 [254]	½ [13]	2½ [64]	15 [381]	2½ [64]
4 by 4	3½ [83]	5 [127]	6 [152]	20½ [521]	6 [152]	12 [305]	½ [13]	3 [76]	17½ [445]	3 [76]
5 by 4	3½ [83]	5 [127]	7 [178]	22½ [572]	6½ [165]	14 [356]	½ [13]	3½ [89]	19½ [495]	3½ [89]
6 by 4	3½ [83]	5 [127]	8 [203]	24½ [622]	7 [178]	16 [406]	½ [13]	4 [102]	21½ [546]	4 [102]
6 by 6	3½ [83]	5 [127]	8 [203]	24½ [622]	7 [178]	16 [406]	½ [13]	4 [102]	21½ [546]	4 [102]
8 by 4	4⅛ [105]	7 [178]	10 [254]	31⅛ [791]	8¼ [210]	20 [508]	1 [25]	5 [127]	27⅝ [702]	5¼ [133]
8 by 6	4⅛ [105]	7 [178]	10 [254]	31⅛ [791]	8¼ [210]	20 [508]	1 [25]	5 [127]	27⅝ [702]	5¼ [133]
10 by 8	4⅛ [105]	7 [178]	12 [305]	35⅛ [892]	9¼ [235]	24 [610]	1 [25]	6 [152]	31⅝ [803]	6¼ [159]
12 by 6	5 [127]	8 [203]	15 [381]	43 [1092]	10¼ [260]	30 [762]	. . .	7½ [191]	38¾ [984]	7¼ [184]
12 by 10	5 [127]	8 [203]	15 [381]	43 [1092]	10¼ [260]	30 [762]	. . .	7½ [191]	38¾ [984]	7¼ [184]
15 by 12	5 [127]	8 [203]	18½ [470]	50 [1270]	13 [330]	37 [940]	. . .	9¼ [235]	45¾ [1162]	8¾ [222]

[A] For details of hubs and spigots, see Table 1. For details of tapping bosses, see Table 35.

TABLE 31 Dimensions of Screw Plugs (Brass) for ′XH’ and ′SV’



NOTE 1—1 in. = 25.4 mm.

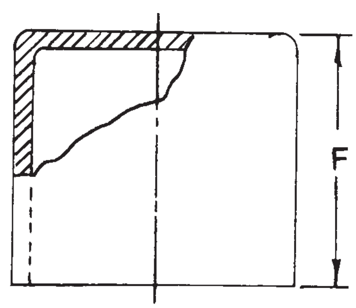
NOTE 2—When thread gage is screwed tightly on plug by hand, large end of gage shall be the distance $L \pm 1½$ turns from surface of plug.

Size, in.	Dimensions, in.[A]							
	A	*B*	*C*	*D*	*E*	*G*	Across flats *H*	*L*
1¼	½ [13]	½ [13]	¾ [19]	1 5/16 [33]	5/32 [4]	⅛ [3]	1 [25]	5/32 [4]
1½	⅝ [16]	¾ [19]	¾ [19]	1½ [38]	3/16 [5]	⅛ [3]	1 [25]	3/16 [5]
2	⅝ [16]	¾ [19]	1 [25]	2 [51]	3/16 [5]	⅛ [3]	1¼ [32]	3/16 [5]
2½	¾ [19]	¾ [19]	15/16 [24]	2⅜ [60]	3/16 [5]	5/32 [4]	1¼ [32]	¼ [6]
3	¾ [19]	1 [25]	1 15/16 [49]	2 15/16 [75]	3/16 [5]	5/32 [4]	1⅝ [42]	¼ [6]
3½	¾ [19]	1 [25]	1¼ [32]	3 7/16 [87]	¼ [6]	3/16 [5]	1⅝ [42]	¼ [6]
4	⅞ [22]	1 [25]	1⅝ [41]	3 15/16 [100]	¼ [6]	3/16 [5]	2 [51]	5/16 [8]
5	1 [25]	1 [25]	1 15/16 [49]	4 15/16 [125]	⅝ [8]	7/32 [6]	2⅜ [60]	⅜ [10]3]
6	1 [25]	1 [25]	1⅞ [48]	5 15/16 [151]	⅜ [10]	¼ [6]	2⅜ [60]	⅜ [10]

[A]Heads of plugs shall be either square or hexagonal. Dimension *H* is taken between opposite sides of either style used.

TABLE 32 Dimensions of Blind Plugs

NOTE—1 in. = 25.4 mm.



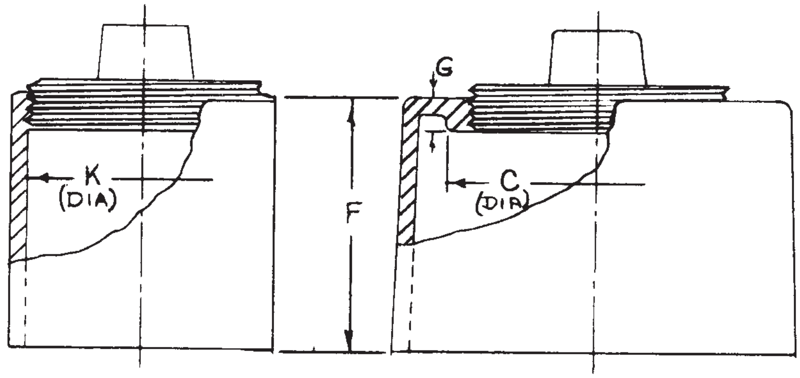
Size, in.[A] Availability[B]	*F*, in.
2*O	3½ [89]
3*O	3¾ [95]
4*O	4 [102]
5*O	4 [102]
6*O	4 [102]
8*O	4½ [114]
10*O	4½ [114]
12*O	5¼ [133]
15*O	5¼ [133]

[A] For dimensions of open end (spigot) and wall thickness, see Table 1.
[B] * indicates this item is made in extra heavy.
O indicates this item is made in service weight.

TABLE 33 Dimensions of Iron Body Ferrules With Screw Plugs

NOTE 1—1 in. = 25.4 mm.

NOTE 2—Tappings for sizes 2 in. to 6 in., inclusive, allow entrance for testing plugs. See Table 31 for screw plugs.



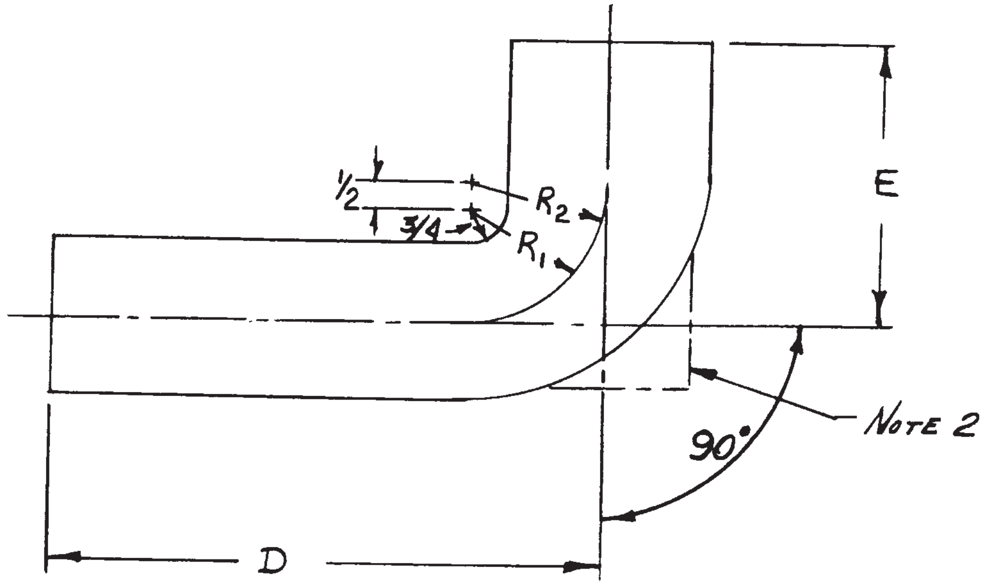
Size, in., Availability[A]	Dimensions, in.[B]					
	C	*F*	I.P.S. Tapping	Tapping Depth of *G*	*K*	*R*
2*O	...	3½ [89]	1½ [38]	½ [13]	2 [51]	1¼ [32]
3*O	...	3¾ [95]	2½ [64]	9⁄16 [14]	3 [76]	1⅜ [35]
4*O	...	4¼ [108]	3½ [89]	9⁄16 [14]	4 [102]	1½ [38]
5*O	...	4¼ [108]	4 [102]	⅝ [16]	5 [127]	1½ [38]
6*O	...	4¼ [108]	5 [127]	⅝ [16]	6 [152]	1½ [38]
8*O	7⅜ [187]	4½ [114]	6 [152]	¾ [19]	8 [203]	1⅞ [48]
10*O	7½ [191]	4½ [114]	6 [152]	¾ [19]	10 [254]	1⅞ [48]
12*O	7½ [191]	5¼ [133]	6 [152]	¾ [19]	12 [305]	2⅜ [60]
15*O	7½ [191]	5¼ [133]	6 [152]	¾ [19]	15 [381]	2⅜ [60]

[A] * indicates this item is made in extra heavy.
O indicates this item is made in service weight.

[B] For dimensions of open end (spigot) and wall thickness, see Table 1.

TABLE 34 Dimensions of Closet Bends

NOTE 1—1 in. = 25.4 mm.
NOTE 2—Laying lengths determined by the manufacturer standard interval for lengths is 2 in.
NOTE 3—Optional features are: Break off grooves, driving lugs, tapping bosses, plug inlets and screw joints.

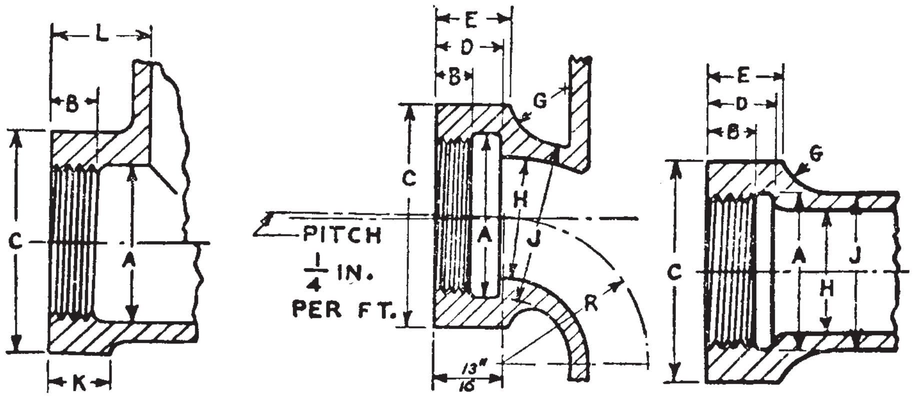


Size, in., Availability[A]	Dimensions in in.[B,C]			
	D	*E*	*R1*	*R2*
3 by 3*O	Various	Various	2½ [64]	
3 by 4*O	Various	Various		3 [76]
4 by 4*O	Various	Various	3 [76]	

[A]* indicates this item is made in extra heavy.
O indicates this item is made in service weight.
[B] For details of spigot and barrel dimensions see Table 1.
[C] For details of tapping bosses, see Table 35.

TABLE 35 Dimensions of Tapping Bosses for 'XH' and 'SV'

NOTE— in. = 25.4 mm.



Details of tapping bosses, 1¼- to 5-in. sizes.
a

Details of tapping bosses, 1¼- to 2-in. sizes.
b

Details of tapping bosses, 1¼- to 4-in. sizes.
c

Size, in.	Dimensions, in.										
	A	B	C	D	E	G	H	J	K	L	R
1¼	1 15/16	7/16	2 11/16	3/4	7/8	1/2	1½	1 7/8	...	1	1¾
1½	1 15/16	7/16	2 11/16	3/4	7/8	1/2	1½	1 7/8	3/4	1	1¾
2	2 7/16	7/16	3¼	3/4	15/16	5/8	2	2 3/8	...	1	2¼
2½	2 15/16	3/4	3 7/8	...	...	...	...	...	1	...	...
3	3 9/16	3/4	4 5/8	1 3/16	1 5/16	1	3	3½	1	...	...
3½	4 1/16	3/4	5 1/8	...	...	...	...	...	1 1/8	...	...
4	4 9/16	13/16	5¾	1¼	1 7/16	1 1/8	4	4½	1 1/8	...	...
5	5 5/8	15/16	7 1/16	...	...	...	...	...	1 3/8	...	...

SUPPLEMENTARY REQUIREMENTS

The following supplementary requirements shall be applied only when specified by the purchaser. Details of the supplementary requirements shall be agreed upon by the manufacturer and the purchaser. The specified tests shall be performed by the manufacturer prior to shipment of the castings.

S1. Leak Tests on Pipe

S1.1 Sample lengths of pipe shall be checked for leaks by subjecting them to an internal hydrostatic pressure of 20 psi (138 kpa).

S1.2 Samples shall be taken at substantially regular intervals in the course of production so as to be representative of the material delivered, and shall consist of at least 20 % of the lengths ordered in each size. For every sample which leaks, four or more additional samples shall be taken. Each additional sample shall be representative of the same material as that of the defective sample.

S1.3 Pipe which leak shall be rejected.

APPENDIXES

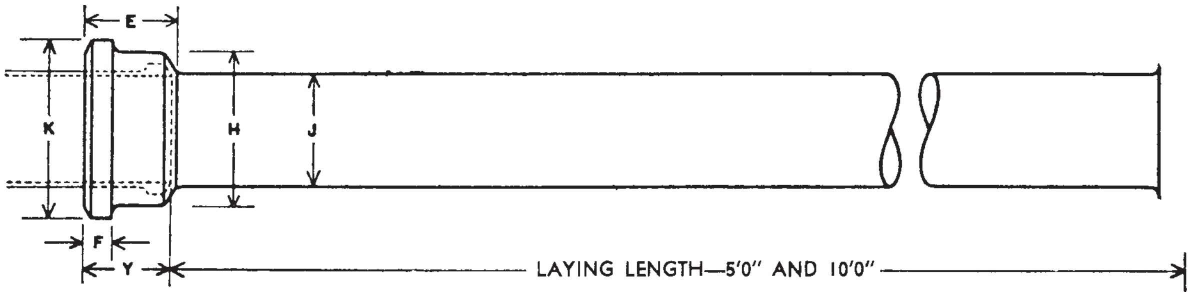
(Nonmandatory Information)

X1. DIMENSIONS FOR INFORMATION ONLY

X1.1 The dimensions in Table X1.1 are given for use as and are not requirements of this specification.

TABLE X1.1 Outside Dimensions of Hub, Barrel, and Spigot for Detailing, in.

NOTE—1 in. = 25.4 mm.



Size (nominal ID)	Extra-Heavy Pipe 'XH'					
	K max	*H* max	*J*	*F*	*Y*	*E*
2	4 1/8 [105]	3 5/8 [92]	2 3/8 [60]	3/4 [19]	2 1/2 [64]	2 3/4 [70]
3	5 3/8 [137]	4 15/16 [125]	3 1/2 [89]	13/16 [21]	2 3/4 [70]	3 1/4 [83]
4	6 3/8 [162]	5 15/16 [151]	4 1/2 [114]	7/8 [22]	3 [76]	3 1/2 [89]
5	7 3/8 [187]	6 15/16 [176]	5 1/2 [140]	7/8 [22]	3 [76]	3 1/2 [89]
6	8 3/8 [213]	7 15/16 [202]	6 1/2 [165]	7/8 [22]	3 [76]	3 1/2 [89]
8	11 1/16 [281]	10 7/16 [265]	8 5/8 [219]	1 3/16 [30]	3 1/2 [89]	4 1/8 [105]
10	13 5/16 [338]	12 11/16 [322]	10 3/4 [273]	1 3/16 [30]	3 1/2 [89]	4 1/8 [105]
12	15 7/16 [392]	14 13/16 [376]	12 3/4 [324]	1 7/16 [37]	4 1/4 [108]	5 [127]
15	18 13/16 [478]	18 3/16 [462]	15 7/8 [403]	1 7/16 [37]	4 1/4 [108]	5 [127]
Size (nominal ID)	Service-Pipe 'SV'					
	K max	*H* max	*J*	*F*	*Y*	*E*
2	3 15/16 [100]	3 3/8 [86]	2 1/4 [57]	3/4 [19]	2 1/2 [64]	2 3/4 [70]
3	5 [127]	4 1/2 [114]	3 1/4 [83]	13/16 [21]	2 3/4 [70]	3 1/4 [83]
4	6 [152]	5 1/2 [140]	4 1/4 [108]	7/8 [22]	3 [76]	3 1/2 [89]
5	7 [178]	6 1/2 [165]	5 1/4 [133]	7/8 [22]	3 [76]	3 1/2 [89]
6	8 [203]	7 1/2 [191]	6 1/4 [159]	7/8 [22]	3 [76]	3 1/2 [89]
8	10 1/2 [267]	9 7/8 [251]	8 3/8 [213]	1 3/16 [30]	3 1/2 [89]	4 1/8 [105]
10	12 13/16 [325]	12 3/16 [310]	10 1/2 [267]	1 3/16 [30]	3 1/2 [89]	4 1/8 [105]
12	14 15/16 [379]	14 5/16 [364]	12 1/2 [318]	1 7/16 [37]	4 1/4 [108]	5 [127]
15	18 5/16 [465]	17 5/8 [448]	15 5/8 [397]	1 7/16 [37]	4 1/4 [108]	5 [127]

convenient information on details of the hub barrel, and spigot,

X2. PROCEDURES FOR SOIL SURVEY TESTS AND OBSERVATIONS AND THEIR INTERPRETATION TO DETERMINE WHETHER CAST IRON PIPE FOR WASTE WATER OR OTHER LIQUIDS REQUIRES POLYETHYLENE ENCASEMENT

X2.1 Scope

X2.1.1 In the appraisal of soil and other conditions that affect the corrosion rate of cast iron pipe, a minimum number of factors must be considered. They are outlined in the following sections. A method of evaluating and interpreting each factor and a method of weighting each factor to determine whether polyethylene encasement should be used are subsequently described.

X2.2 Earth Resistivity

X2.2.1 There are three methods for determining earth resistivity: four-pin, single-probe, and soil-box. In the field, a four-pin determination should be made with pins spaced at approximate pipe depth. This method yields an average of resistivity from the surface to a depth equal to pin spacing. However, results are sometimes difficult to interpret where dry top soil is underlaid with wetter soils and where soil types vary with depth. The Wenner configuration is used in conjunction with a resistivity meter. For all-around use, a unit with a capacity of up to 10^4 ohms is suggested because of its versatility in permitting both field and laboratory testing in most soils.

X2.2.2 Because of the aforementioned difficulty in interpretation, the same unit may be used with a single probe that yields resistivity at the point of the probe. A boring is made into the subsoil so that the probe may be pushed into the soil at the desired depth.

X2.2.3 Inasmuch as the soil may not be typically wet, a sample should be removed for resistivity determination, which may be accomplished with any one of several laboratory units that permits the introduction of water to saturation, thus simulating saturated field conditions. Each of these units is used in conjunction with a soil resistivity meter.

X2.2.4 Interpretation of resistivity results is extremely important. To base an opinion on a four-pin reading with dry top soil averaged with wetter subsoil would probably result in an inaccurate premise. Only by reading the resistivity in soil at pipe depth can an accurate interpretation be made. Also, every effort should be made to determine the local situation concerning ground-water table, presence of shallow ground water, and approximate percentage of time the soil is likely to be water saturated.

X2.2.5 With cast iron pipe, corrosion protection provided by products of corrosion is enhanced if there are dry periods during each year. Such periods seem to permit hardening or toughening of the corrosion scale or products, which then become impervious and serve as better insulators.

X2.2.6 In making field determinations of resistivity, temperature is important. The result obtained increases as temperature decreases. As the water in the soil approaches freezing, resistivity increases greatly, and, therefore, is not reliable. Field determinations under frozen soil conditions should be avoided. Reliable results under such conditions can be obtained only by collection of suitable subsoil samples for analysis under laboratory conditions at suitable temperature.

X2.2.7 *Interpretation of Resistivity*—Because of the wide variance in results obtained under the methods described, it is difficult specifically to interpret any single reading without knowing which method was used. It is proposed that interpretation be based on the lowest reading obtained with consideration being given to other conditions, such as normal moisture content of the soil in question. Because of the lack of exact correlation between experiences and resistivity, it is necessary to assign ranges of resistivity rather than specific numbers. In Table X2.1, points are assigned to various ranges of resistivity. These points, when considered along with points assigned to other soil characteristics, are meaningful.

X2.3 pH

X2.3.1 In the pH range from 0.0 to 4.0, the soil serves well as an electrolyte, and total acidity is important. In the pH range from 6.5 to 7.5, soil conditions are optimum for sulfate reduction. In the pH range from 8.5 to 14.0, soils are generally quite high in dissolved salts, yielding a low soil resistivity.

X2.3.2 In testing pH, glass and reference electrodes are pushed into the soil sample and a direct reading is made following suitable temperature setting on the instrument. Normal procedures are followed for standardization.

TABLE X2.1 Soil-Test Evaluation[A]

Soil Characteristics	Points
Resistivity, ohm-cm (based on single probe at pipe depth or water-saturated soil-box):	
<700	10
700–1000	8
1000–1200	5
1200–1500	2
1500–2000	1
>2000	0
pH:	
0–2	5
2–4	3
4–6.5	0
6.5–7.5	0[B]
7.5–8.5	0
>8.5	3
Redox potential:	
> + 100 mV	0
+ 50 tp + 100 mV	3.5
0 to + 50 mV	4
Negative	5
Sulfides:	
Positive	3.5
Trace	2
Negative	0
Moisture:	
Poor drainage, continuously wet	2
Fair drainage, generally moist	1
Good drainage, generally dry	0

[A] Ten Points = corrosive to cast iron pipe; protection indicated.
[B] If sulfides are present and low or negative redox potential results are obtained, three points shall be given for this range.

X2.4 Oxidation-Reduction (Redox) Potential

X2.4.1 The oxidation-reduction (redox) potential of a soil is significant because the most common sulfate-reducing bacteria can live only under anaerobic conditions. A redox potential greater than +100 mV shows the soil to be sufficiently aerated so that it will not support sulfate reducers. Potentials of zero to +100 mV may or may not indicate anaerobic conditions under which sulfate reducers thrive. This test also is accomplished using a portable pH meter, with platinum and reference electrodes inserted into the soil sample, which permits a reading of potential between the two electrodes. It should be noted that soil samples removed from a boring or excavation can undergo a change in redox potential on exposure to air. Such samples should be tested immediately on removal from the excavation. Experience has shown that heavy clays, muck, and organic soils are often anaerobic, and these soils should be regarded as potentially corrosive.

X2.5 Sulfides

X2.5.1 The sulfide determination is recommended because of its field expediency. A positive sulfide reaction reveals a potential problem due to sulfate-reducing bacteria. The sodium azide-iodine qualitative test is used. In this determination, a solution of 3 % sodium azide in a 0.1 *N* iodine solution is introduced into a test tube containing a sample of the soil in question. Sulfides catalyze the reaction between sodium azide and iodine, with the resulting evolution of nitrogen. If strong bubbling or foaming results, sulfides are present, and the presence of sulfate-reducing bacteria is indicated. If very slight bubbling is noted, sulfides are probably present in small concentration and the result is noted as a trace.

X2.6 Moisture Content

X2.6.1 Since prevailing moisture content is extremely important to all soil corrosion, every effort must be made to determine this condition. It is not proposed, however, to determine specific moisture content of a soil sample, because of the probability that content varies throughout the year, but to question local authorities who are able to observe the conditions many times during the year. (Although mentioned in X2.2, this variability factor is being reiterated to emphasize the importance of notation.)

X2.7 Soil Description

X2.7.1 In each investigation, soil types should be completely described. The description should include color and physical characteristics, such as particle size, plasticity, friability, and uniformity. Observation and testing will reveal whether the soil is high in organic content; this should be noted. Experience has shown that in a given area, corrosivity may often be reflected in certain types and colors of soil. This information is valuable for future investigations or for determining the most likely soils to suspect. Soil uniformity is important because of the possible development of local corrosion cells due to the difference in potential between unlike soil types, both of which are in contact with the pipe. The same is true for uniformity of aeration. If one segment of soil contains more oxygen than a neighboring segment, a corrosion cell can develop from the difference in potential. This cell is known as a differential aeration cell.

X2.7.2 There are several basic types of soil that should be noted: sand, loam, silt, clay, muck. Unusual soils, such as peat or soils high in foreign material, should also be noted and described.

X2.8 Potential Stray Direct Current

X2.8.1 Any soil survey should include consideration of possible stray direct current with which the cast iron pipe installation might interfere. The widespread use of rectifiers and ground beds for cathodic protection of underground structures has resulted in a considerable threat from this source. Proximity of such cathodic protection systems should be noted. Among other potential sources of stray direct current are electric railways, industrial equipment, including welding and mine transportation equipment.

X2.9 Experience With Existing Installations

X2.9.1 The best information on corrosivity of soil with respect to cast iron pipe is the result of experience with these materials in the area in question. Every effort should be made to acquire such data by questioning local officials and, if possible, by actual observation of existing installations.

X2.10 Soil-Test Evaluation

X2.10.1 Using the soil-test procedures described herein, the following tests are considered in evaluating corrosivity of the soil: resistivity, pH, redox potential, sulfides, and moisture. For each of these tests, results are categorized according to their contribution to corrosivity. Points are assigned based on experience with gray and ductile cast iron pipe. When results of these five test observations are available, the assigned points are totaled. If the sum is equal to ten or more, the soil is corrosive to cast iron pipe, and protection against exterior corrosion should be provided. This system is limited to soil corrosion and does not include consideration of stray direct current. Table X2.1 lists points assigned to the various test results.

X2.11 General

X2.11.1 These notes deal only with cast iron pipe, the soil environment in which they will serve, and methods of determining the need for polyethylene encasement. When it is determined that a soil environment is corrosive to cast iron, Appendix X3 should be used.

X3. POLYETHYLENE ENCASEMENT FOR CAST IRON PIPE FOR WASTE WATER

X3.1 Scope

X3.1.1 This practice covers materials and installation procedures for polyethylene encasement to be applied to underground installations of cast iron pipe. It is also used for polyethylene encasement of fittings, and other appurtenances to cast iron pipe systems.

X3.1.2 *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.*

X3.2 Referenced Documents

X3.2.1 *ASTM Standard*:

D 1248 Specification for Polyethylene Plastics Extrusion Materials for Wire and Cable[7]

X3.3 Terminology

X3.3.1 *Definitions*:

X3.3.1.1 *polyethylene encasement*—polyethylene material, in tube or sheet form, that is used to encase cast iron pipe.

X3.3.1.2 *securing overlap*—any one of various methods of holding polyethylene encasement in place at the point of overlap until backfilling operations are completed, such as with adhesive tape, plastic string, or tie straps or other suitable material.

[7] *Annual Book of ASTM Standards*, Vol 08.01.

X3.4 Requirements

X3.4.1 *Materials*:

X3.4.1.1 *Low-Density Polyethylene Film*—Low-density polyethylene film shall be manufactured of virgin polyethylene material conforming to the requirements of Specification D 1248 as shown in Table X3.1.

TABLE X3.1 Polyethylene Characteristics

Raw Material Used to Manufacture Polyethylene Encasement Material	
Type, class, grade, other characteristics in accordance with the latest revision of Specification D 1248	
Type	I
Class	A-natural color or C-black
Grade	E1
Flow rate, g/10 min	0.4 max
Dielectric strength, volume resistivity	10^{15}·cm^3, min
High-Density Cross-Laminated Polyethylene Encasement Material	
Tensile strength	1200 psi (8 MPa), min
Elongation	300 %, min
Dielectric strength	800 V/mil (31.5 V/µm) thickness, min

(a) Thickness—Low-density polyethylene film shall have a minimum nominal thickness of 0.008 in. (0.20 mm). The minus tolerance on thickness shall not exceed 10 % of the nominal thickness.

X3.4.1.2 *High-Density Cross-Laminated Polyethylene Film* High-density cross-laminated polyethylene film shall be manufactured of virgin polyethylene material conforming to the requirements of Specification D 1248 as shown in Table X3.2.

(a) Thickness—High-density cross-laminated polyethylene film shall have a minimum nominal thickness of 0.004 in. (0.10 mm). The minus tolerance on thickness shall not exceed 10 % of the nominal thickness.

X3.4.2 *Tube Size*—The tube size for each pipe diameter shall be as listed in Table X3.2.

X3.5 Installation

X3.5.1 *General*:

X3.5.1.1 The polyethylene encasement shall prevent contact between the pipe and the surrounding backfill and bedding material, but is not intended to be a completely airtight or watertight enclosure. All lumps of clay, mud, cinders, etc. that are on the pipe surface shall be removed prior to installation of the polyethylene encasement. During installation, care shall be exercised to prevent soil or embedment material from becoming entrapped between the pipe and the polyethylene.

TABLE X3.2 Polyethylene Tube Sizes

Nominal Pipe Diameter, in.	Recommended Polyethylene Flat Tube Width, in. (cm)[A]
1½ , 2, 3	14 (35)
4	16 (41)
6	20 (51)
8	24 (61)
10	27 (69)
12	30 (76)
14	34 (86)
15	37 (94)

[A] For flat sheet polyethylene, see X3.5.2.3.

X3.5.1.2 The polyethylene film shall be fitted to the contour of the pipe to effect a snug, but not tight, encasement with minimum space between the polyethylene and the pipe. Sufficient slack shall be provided in contouring to prevent stretching the polyethylene, bridging irregular surfaces such as hub-spigot interfaces, coupled joints, or fittings, and to prevent damage to the polyethylene due to backfilling operations. Overlaps and ends shall be secured by the use of adhesive tape, plastic string, plastic tie straps, or any other material capable of holding the polyethylene encasement in place until backfilling operations are completed.

X3.5.1.3 For installations below the water table or in areas subject to tidal actions, or both, it is recommended that tube-form polyethylene be used with both ends sealed as thoroughly as possible with adhesive tape or plastic tie straps at the joint overlap. It is also recommended that circumferential wraps of tape or plastic tie straps be placed at 2-ft (0.6-m) intervals along the barrel of the pipe to help minimize the space between the polyethylene and the pipe.

X3.5.2 *Pipe*—This appendix includes three different methods for the installation of polyethylene encasement. Methods A and B are for use with polyethylene tubes and Method C is for use with polyethylene sheets.

X3.5.2.1 *Method A (see* Fig. X3.1*)*:

(a) Cut the polyethylene tube to a length approximately 2 ft (0.6 m) longer than the length of the pipe section. Slip the tube around the pipe, centering it to provide a 1-ft (0.3-m) overlap on each adjacent pipe section, and bunching it accordion fashion lengthwise until it clears the pipe ends.

(b) Lower the pipe into the trench and make up the pipe joint with the preceding section of pipe. A shallow bell hole must be made at joints to facilitate installation of the polyethylene tube.

(c) After assembling the pipe joint, make the overlap of the polyethylene tube. Pull the bunched polyethylene from the preceding length of pipe, slip it over the end of the new length of pipe, and secure in place. Then slip the end of the polyethylene from the new pipe section over the end of the first wrap until it overlaps the joint at the end of the preceding length of pipe. Secure the overlap in place. Take up the slack width at the top of the pipe as shown in Fig. X3.2, to make a snug, but not tight, fit along the barrel of the pipe, securing the fold at quarter points.

(d) Repair any rips, punctures, or other damage to the polyethylene with adhesive tape or with a short length of polyethylene tube cut open, wrapped around the pipe, and secured in place. Confirm and adjust any necessary grade on the piping section. Proceed with installations of the next section of pipe in the same manner.

X3.5.2.2 Cut the polyethylene tube to a length approximately 1 ft (0.3 m) shorter than the length of the pipe section. Slip the tube around the pipe, centering it to provide 6 in. (150 mm) of bare pipe at each end. Make the polyethylene snug, but not tight, as shown in Fig. X3.2; secure ends as described in X3.5.2.1.

(a) Before making up a joint, slip a 3-ft (0.9-m) length of polyethylene tube over the end of the preceding pipe section, bunching it accordion fashion lengthwise. After completing the

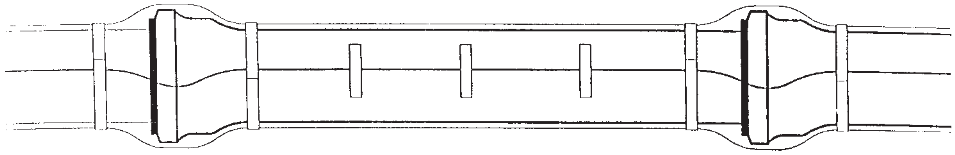


FIG. X3.1 Method A Hub Pipe

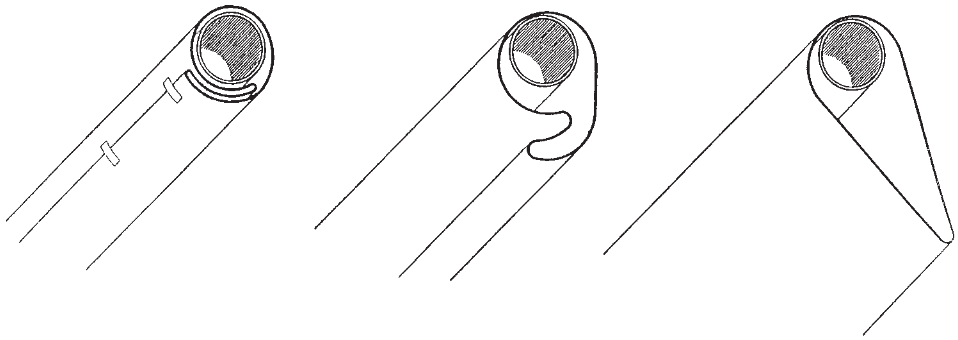


FIG. X3.2 Method A Slack Reduction Procedure

joint, pull the 3-ft length of polyethylene previously installed on each adjacent section of pipe y at least 1 ft (0.3 m); make snug and secure each end as described in X3.5.2.1.

(b) Repair any rips, punctures, or other damage to the polyethylene as described in X3.5.2.1. Reaffirm grade on the piping, as required. Proceed with installation of the next section of pipe in the same manner.

X3.5.2.3 Flat sheet polyethylene shall have a minimum width twice the flat tube width shown in Table X3.3.

TABLE X3.3 High-Density Cross-Laminated Polyethylene Characteristics

Raw Material Used to Manufacture Polyethylene Encasement Material	
Type, class, grade, other characteristics in accordance with the latest revision of Specification D 1248	
Type	111
Class	A-natural color, B-colors, or C-black
Grade	P33
Flow rate, g/10 min	0.4 to 0.5 g/10, min
Dielectric strength, volume resistivity	10^{15} ohm-cm, min
High-Density Cross-Laminated Polyethylene Encasement Material	
Tensile strength	5000 psi (34.6 MPa), min
Elongation	100 %, min
Dielectric strength	800 V/mil (31.5 V/μm) thickness, min

(a) Cut the polyethylene sheet to a length approximately 2 ft (0.6 m) longer than the length of pipe section. Center the cut length to provide a 1-ft (0.3-m) overlap on each adjacent pipe section, bunching it until it clears the pipe ends. Wrap the polyethylene around the pipe so that it overlaps circumferentially over the top quadrant of the pipe. Secure the cut edge of polyethylene sheet at approximately 3-ft (0.9-m) intervals along the pipe length.

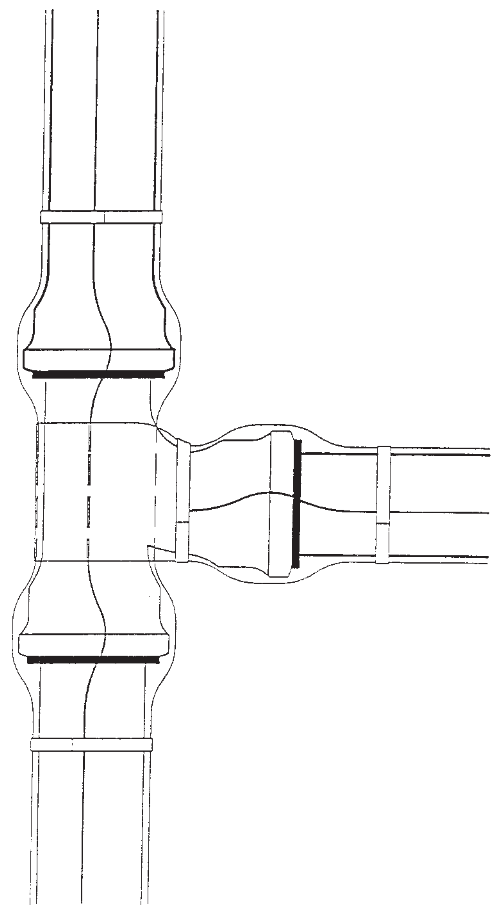


FIG. X3.3 Method A Installation on Odd-Shaped Appurtenances, Hub Pipe, and Fittings

(b) Lower the wrapped pipe into the trench and make up the pipe joint with the preceding section of pipe. A shallow hub hole must be made at joints to facilitate installation of the

polyethylene. After completing the joint, make the overlap as described in X3.5.2.1.

(c) Repair any rips, punctures, or other damage to the polyethylene as described in X3.5.2.1. Confirm and adjust any necessary grade of the piping section. Proceed with installation of the next section of pipe in the same manner.

X3.5.3 *Pipe-Shaped Appurtenances*—Bends, reducers, offsets, and other pipe-shaped appurtenances shall be covered with polyethylene in the same manner as the pipe.

X3.5.4 *Odd-Shaped Appurtenances*—Wrap tees, crosses, and other odd-shaped pieces that cannot practically be wrapped in a tube, with a flat sheet or split length of polyethylene tube. Pass the sheet under the appurtenance and bring up around the body. Make seams by bringing the edges together, folding over twice, and taping down (see Fig. X3.3). Handle slack width and overlaps at joints as described in X3.5.2.1. Tape polyethylene securely in place.

X3.5.5 *Repairs*—Repair any cuts, tears, punctures, or damage to polyethylene with adhesive tape or with a short length of polyethylene tube cut open, wrapped around the pipe covering the damaged area, and secured in place.

X3.5.6 *Junctions Between Wrapped and Unwrapped Pipe*—Where polyethylene wrapped pipe joins a pipe that is not wrapped, extend the polyethylene tube to cover the unwrapped pipe a distance of at least 3 ft (0.9 m). Secure the end with circumferential turns of tape.

X3.5.7 *Backfill for Polyethylene Wrapped Pipe*—Backfill material shall be the same as specified for pipe without polyethylene wrapping. Take special care to prevent damage to the polyethylene wrapping when placing backfill. Backfill material shall be free of cinders, refuse, frozen earth, boulders, rocks, stones, job site debris, or other material that could damage polyethylene.

Designation: A 99 – 03

Standard Specification for Ferromanganese[1]

This standard is issued under the fixed designation A 99; 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. This specification replaces Federal Specification QQ-F-145.

1. Scope

1.1 This specification covers ten grades of ferromanganese, designated as follows:

Standard ferromanganese	Grade A
	Grade B
	Grade C
Medium-carbon ferromanganese	Grades A,B,C, and D
	Nitrided
Low-carbon ferromanganese	Grade A
	Grade B

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 1025 Specification for Ferroalloys, General Requirements[2]

E 11 Specification for Wire Cloth and Sieves for Testing Purposes[3]

E 29 Practice for Using Significant Digits in Test Data to Determine Conformance with Specifications[3]

E 32 Practices for Sampling Ferroalloys and Steel Additives for Determination of Chemical Composition[4]

3. General Conditions for Delivery

3.1 Materials furnished to this specification shall conform to the requirements of Specification A 1025, including any supplementary requirements that are indicated in the purchase order. Failure to comply with the general requirements of Specification A 1025 constitutes nonconformance with this specification. In case of conflict between the requirements of this specification and Specification A 1025, this specification shall prevail.

4. Chemical Composition

4.1 The material shall conform to the requirements as to chemical composition specified in Table 1.

4.2 The manufacturer shall furnish an analysis of each shipment showing the percentage of each element specified..

5. Size

5.1 The various grades are available in sizes as listed in Table 2.

5.2 The sizes and friability ratings listed in Table 2 are typical as shipped from the manufacturer's plant. These alloys exhibit varying degrees of friability; therefore, some attrition may be expected in transit, storage, and handling. A code system has been developed. Therefore, for this purpose, a number rating for each product type is shown in the last column of Table 2. Definitions applicable to these code numbers are given in Specification A 1025.

6. Keywords

6.1 ferroalloy; ferromanganese

[1] This specification is under the jurisdiction of ASTM Committee A01 on Steel, Stainless Steel, and Related Alloys and is the direct responsibility of Subcommittee A01.18 on Castings.

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[2] *Annual Book of ASTM Standards*, Vol 01.02.

[3] *Annual Book of ASTM Standards*, Vol 14.02.

[4] *Annual Book of ASTM Standards*, Vol 03.05.

TABLE 1 Chemical Requirements

	Standard Ferromanganese			Medium Carbon Ferromanganese				Nitrided Medium Carbon Ferromanganese	Low Carbon Ferromanganese	
	Grade A	Grade B	Grade C	Grade A	Grade B	Grade C	Grade D		Grade A	Grade B
Manganese, %	78.0 to 82.0	76.0 to 78.0	74.0 to 76.0	80.0 to 85.0	80.0 to 85.0	80.0 to 85.0	80.0 to 85.0	75 to 80[A]	85.0 to 90.0	80.0 to 85.0
Carbon, max, %	7.5	7.5	7.5	1.5	1.5	1.5	1.5	1.5[A]	As specified	0.75
Silicon, max, %	1.2	1.2	1.2	1.5	1.0	0.70	0.35	1.5[A]	2.0	5.0 to 7.0
Phosphorus, max, %	0.35	0.35	0.35	0.30	0.30	0.30	0.30	0.3	0.20	0.30
Sulfur, max, %	0.050	0.050	0.050	0.020	0.020	0.020	0.020	0.020	0.020	0.020
Nitrogen, %								4% min		

[A] Based on metallic content.

TABLE 2 Standard Sizes and Tolerances

Product	Standard Sizes	Tolerances[A]		Friability Rating
Standard ferromanganese Grades A, B, C	8 × 4 in. (200 × 100 mm) 5 x 2 in. (125 × 50 mm) 4 × 1 in. (100 × 25 mm) 2 × ¼ in. (50 × 6.3 mm) ⅜ in. × 12 mesh (9.5 × 1.4 mm) ¼ in. × down (6.3 mm × down) 8 mesh × down (2.36 mm × down) 20 mesh × down (0.85 mm × down)	90 lb (40.8-kg) lump, max 10 % max retained on 5-in. (125-mm) sieve 10 % max retained on 4-in. (100-mm) sieve 10 % max retained on 2-in. (50-mm) sieve 5 % max retained on ⅜-in. (9.5-mm) sieve 5 % max retained on ¼-in. (6.3-mm) sieve 5 % max retained on No. 8 (2.36-mm) sieve 5 % max retained on No. 20 (0.85 mm) sieve	10 % max passing 4-in. (100-mm) sieve 10 % max passing 2-in. (50-mm) sieve 10 % max passing 1-in. (25-mm) sieve 10 % max passing ¼-in. (6.3-mm) sieve 5 % max passing No. 14 (1.4-mm) sieve	4
Medium-carbon ferromanganese Grades A, B, C, and D	8 × 4 in. (200 × 100 mm) 5 × 2 in. (125 × 50 mm) 4 in. × down (100 mm × down) 2 in. × down (50 mm × down) 8 mesh × down (2.36 mm × down)	90-lb (40.8-kg) lump, max 10 % max retained on 5-in. (125-mm) sieve 10 % max retained on 4-in. (100-mm) sieve 10 % max retained on 2-in. (50-mm) sieve 5 % max retained on No. 8 (2.36-mm) sieve	10 % max passing 4-in. (100-mm) sieve 10 % max passing 2-in. (50-mm) sieve 12 % max passing ¼-in. (6.3-mm) sieve 15 % max passing No. 8 (2.36-mm) sieve	4½
Medium-carbon ferromanganese Nitrided grade	Briquetted only			4
Low-carbon ferromanganese Grades A and B	6 × 2 in. (150 × 50 mm) 4 × ¼ in. (100 × 6.3 mm) 8 mesh × down (2.36 mm × down) 20 mesh × down (0.85 mm × down)	10 % max retained on 6-in. (150-mm) sieve 10 % max retained on 4-in. (100-mm) sieve 5 % max retained on No. 8 (2.36-mm) sieve 5 % max retained on No. 20 (0.85-mm) sieve	10 % max passing 2-in. (50-mm) sieve 5 % max passing ¼-in. (6.3-mm) sieve	5

[A] Specifications of sieve sizes used to define tolerances herein are as listed in Specification E 11.

SUPPLEMENTARY REQUIREMENTS

The following supplementary requirements shall apply only when specified by the purchaser in the purchase order or contract.

TABLE S1 Supplemental Chemical Requirements

	Composition, max, %		
	Standard Ferromanganese, All Grades	Medium-Carbon Ferromanganese, All Grades	Low-Carbon Ferromanganese, All Grades
Arsenic	0.30	0.15	0.10
Tin	0.020	0.010	0.010
Lead	0.050	0.050	0.020
Chromium	0.50	0.50	0.50
Carbon	0.10 or 0.50 or 0.70 for Grade A only		

S1. Chemical Requirements

The composition shall be further limited to the requirements of Table S1 in addition to those of Table 1. The manufacturer shall furnish an analysis of each shipment showing the percentage of the elements specified.

Designation: A 100 – 04

Standard Specification for Ferrosilicon[1]

This standard is issued under the fixed designation A 100; 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 grades of ferrosilicon for steelmaking and foundry uses.

1.2 The values stated in inch-pound units are to be regarded as the standard. The metric equivalents of inch-pound units (SI units) given in parentheses may be approximate.

2. Referenced Documents

2.1 *ASTM Standards:* [2]

A 1025 Specification for Ferroalloys, General Requirements

E 11 Specification for Wire Cloth and Sieves for Testing Purposes

E 29 Practice for Using Significant Digits in Test Data to Determine Conformance with Specifications

E 32 Practices for Sampling Ferroalloys and Steel Additives for Determination of Chemical Composition

E 360 Test Methods for Chemical Analysis of Silicon and Ferrosilicon

3. General Conditions of Delivery

3.1 Materials furnished to this specification shall conform to the requirements of Specification A 1025, including any supplementary requirements that are indicated in the purchase order. Failure to comply with the general requirements of Specification A 1025 constitutes nonconformance with this specification. In case of conflict between the requirements of this specification and Specification A 1025, this specification shall prevail.

4. Chemical Composition

4.1 The various grades shall conform to the requirements as to chemical composition prescribed in Table 1.

4.2 The manufacturer shall furnish an analysis of each shipment showing the silicon content and when required, such of the other elements specified in Table 1.

5. Size

5.1 The various grades are available in sizes as listed in Table 2.

5.2 The sizes listed in Table 2 are typical as shipped from the manufacturer's plant. These alloys exhibit varying degrees of friability; therefore, some attrition may be expected in transit, storage, and handling. A quantitative test is not available for rating relative friability of ferroalloys. A code system has been developed, therefore, for this purpose, and a number rating for each product type is shown in the last column of Table 2. Definitions applicable to these code numbers are given in Specification A 1025.

6. Chemical Analysis

6.1 Unless otherwise agreed upon, the chemical analysis of the material shall be made in accordance with Test Methods E 360.

6.2 If alternative methods of analysis are used, Methods E 360 shall be used for referee.

6.3 Where a method is not given in Methods E 360 for the analysis for a particular element, the analysis shall be made in accordance with a procedure agreed upon between the manufacturer and the purchaser.

7. Keywords

7.1 ferroalloy; ferrosilicon

[1] This specification is under the jurisdiction of ASTM Committee A01 on Steel, Stainless Steel, and Related Alloys and is the direct responsibility of Subcommittee A01.18 on Castings.

Current edition approved May 1, 2004. Published May 2004. Originally approved in 1925. Last previous edition approved in 1993 as A 100 – 93 (2000).

[2] 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.**

TABLE 1 Chemical Requirements

Element	Grade																	
	C	CA	CB	C1	C2	D	DA	E	EA	E1	E1A	F	F1	F1A	G	GA	G1	G1A
	Composition, %[A,B]																	
Silicon	74.0–79.0	74.0–79.0	74.0–79.0	74.0–79.0	74.0–79.0	65.0–67.0	65.0–67.0	47.0–51.0	47.0–51.0	47.0–51.0	47.0–51.0	20.0–24.0	20.0–24.0	20.0–24.0	14.0–17.0	14.0–17.0	14.0–17.0	14.0–17.0
Carbon	0.10	0.10	0.10	0.10	0.10	0.10	0.10	.010	.010	0.10	0.10	0.50	0.50	0.50	0.70	0.70	0.70	0.70
Sulfur	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025
Phosphorous	0.035	0.035	0.035	0.035	0.035	0.035	0.035	0.040	0.040	0.040	0.040	0.120	0.120	0.120	0.120	0.120	0.120	0.120
Aluminum	1.50	0.50	0.10	1.00–1.50	1.00–1.50	1.25	0.10	1.25	0.40	1.25	1.25	1.00	1.00	1.00	0.75	0.75	0.75	0.75
Manganese	0.40	0.40	0.40	0.40	0.40	0.50	0.50	0.75	0.75	0.75	0.75	1.00	1.00	1.00	1.25	—	1.25	—
Calcium	—	—	—	0.50	0.50	—	—	—	—	—	—	—	—	—	—	—	—	—
Boron	—	—	—	—	—	—	—	—	—	0.04–0.10	0.04–0.10	—	0.04–0.10	0.04–0.10	—	—	0.04–0.10	0.04–0.10

[A] A single value indicates a maximum.
[B] When shipped in 3000 lb containers, the average boron content of a container shall not vary from the average reported for the entire shipment by more than 0.010 %.

TABLE 2 Standard Sizes and Tolerances

Grades	Standard Sizes	Tolerances and Sieve Sizes Defined by ASTM Specification E 11		Friability Rating[A]
C,D,E	8-in. (203-mm) by 4-in. (102-mm)	90-lb (40.8-kg) lump, max	10 %, max, passing 4-in. (102-mm) sieve	
	8-in. (203-mm) by 2-in. (50.8-mm)	90-lb (40.8-kg) lump, max	10 %, max, passing 2-in. (50.8-mm) sieve	
	5-in. (127-mm) by 2-in. (50.8-mm)	10 %, max, retained on 5-in. (127-mm) sieve	10 %, max, passing 2-in. (50.8-mm) sieve	
	4-in. (102-mm) by ½-in. (12.7-mm)	10 %, max, retained on 4-in. (102-mm) sieve	10 %, max, passing ½-in. (12.7-mm) sieve	
	4-in. (102-mm) by down	10 %, max, retained on 4-in. (102-mm) sieve	12 %, max, passing ¼-in. (6.35-mm) sieve	
	3-in. (76.2-mm) by ½-in. (12.7-mm)	10 %, max, retained on 3-in. (76.2-mm) sieve	15 %, max, passing ½-in. (12.7-mm) sieve	
	3-in. (76.2-mm) by down	10 %, max, retained on 3-in. (76.2-mm) sieve	15 %, max, passing No. 8 (2.38-mm) sieve	
	2-in. (50.8-mm) by ½ in. (12.7-mm)	10 %, max, retained on 2-in. (50.8-mm) sieve	15 %, max, passing ½-in. (12.7-mm) sieve	
	2-in. (50.8-mm) by down	10 %, max, retained on 2-in. (50.8-mm) sieve	15 %, max, passing No. 8 (2.38-mm) sieve	
	1-in. (25.4-mm) by No. 8 (2.38-mm)	5 %, max, retained on 1-in. (25.4-mm) sieve	10 %, max, passing No. 8 (2.38-mm) sieve	
	1-in. (25.4-mm) by down	5 %, max, retained on 1-in. (25.4-mm) sieve	20 %, max, passing No. 8 (2.38-mm) sieve	
C,D,F	Lump or Pig	90-lb (40.8-kg) lump or pig, max		
C,D,E	½-in. (12.7-mm) by No. 8 (2.38-mm)	5 %, max, retained on ½-in. (12.7-mm) sieve	10 %, max, passing No. 8 (2.38-mm) sieve	
	⅜-in. (9.51-mm) by No. 6 (3.36-mm)	5 %, max, retained on ⅜-in. (9.51-mm) sieve	10 %, max, passing No. 6 (3.36-mm) sieve	
	⅜-in. (9.51-mm) by No. 12 (1.68-mm)	5 %, max, retained on ⅜-in. (9.51-mm) sieve	10 %, max, passing No. 14 (1.41-mm) sieve	
	⅜-in. (9.51-mm) by down	5 %, max, retained on ⅜-in. (9.51-mm) sieve	15 %, max, passing No. 70 (0.21-mm) sieve	
	¼-in. (6.35-mm) by down	5 %, max, retained on ¼-in. (6.35-mm) sieve		
	No. 8 (2.38-mm) by down	5 %, max, retained on No. 8 (2.38-mm) sieve		
	No. 28 (841-ϵm) by down	5 %, max, retained on No. 20 (841-ϵm) sieve		
G	pig	90-lb (40.8-kg) pig, max.		

[A] See Appendixes.

SUPPLEMENTARY REQUIREMENTS

The composition shall be further limited to the requirements of Table S1.1. Upon request of the purchaser, the manufacturer shall furnish an analysis of these elements on a schedule agreed between the manufacturer and purchaser.

TABLE S1.1 Supplementary Chemical Requirements

Element	Grade																
	C	CA	CB	C1	C2	D	DA	E	EA	E1	E1A	F	F1	F1A	G	GA	G1	G1A
	Composition, % maximum																	
Chromium 0.30	0.30	0.30	—	—	0.50	0.50	0.50	0.50	0.15	0.15	0.25	0.25	0.25	—	—	0.25	0.25	—
Nickel	0.10	0.10	0.10	—	—	0.20	0.20	0.30	0.30	—	—	—	—	—	—	—	—	—
Copper	0.10	0.10	0.10	—	—	0.20	0.20	0.30	0.30	—	—	—	—	—	—	—	—	—
Titanium	0.20	0.20	0.20	—	—	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20	—	—	0.20	0.20

APPENDIX

(Nonmandatory Information)

X1. FRIABILITY RATINGS

X1.1 Proposed friability ratings are shown in Table X1.1 as follows:

TABLE X1.1 Proposed Friability Ratings for Ferrosilicon

Product Grade	Proposed Friability Rating
C	4
D	4
E	5
F	4
G	2

SUMMARY OF CHANGES

Committee A01 has identified the location of selected changes to this standard since the last issue (A 100 – 93 (2000)) that may impact the use of this standard.

(1) Revised 1.1, 3, 4.1, 5, and 6.
(2) Added Specification A1025 to 2.
(3) Removed sections on Sampling, Inspection, Rejection, and Packaging.
(4) Added keywords.
(5) Added Supplementary Requirements section.
(6) Added Appendix X1.
(7) Removed original Tables 1 through 3 and replaced with new Tables 1 and 2.

Standard Specification for Ferrochromium[1]

This standard is issued under the fixed designation A 101; 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 two types of ferrochromium designated as high carbon and low carbon, the latter including nitrogen-bearing and vacuum grades.

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

2. Referenced Documents

2.1 *ASTM Standards:* [2]

A 1025 Specification for Ferroalloys, Common Requirements

E 363 Test Methods for Chemical Analysis of Chromium and Ferrochromium

3. General Conditions for Delivery

3.1 Materials furnished to this specification shall conform to the requirements of Specification A 1025, including any supplementary requirements that are indicated in the purchase order. Failure to comply with the general requirements of Specification A 1025 constitutes nonconformance with this specification. In case of conflict between the requirements of this specification and Specification A 1025, this specification shall prevail.

4. Chemical Composition

4.1 The grades shall conform to the requirements as to chemical composition specified in Table 1. The manufacturer shall furnish an analysis of each shipment showing the elements specified in Table 1.

5. Size

5.1 The various grades are available in sizes as listed in Table 2.

5.2 The sizes listed in Table 2 are typical, as shipped from the manufacturer's plant. These alloys exhibit varying degrees of friability; therefore, some attrition may be expected in transit, storage, and handling. A quantitative test is not available for rating relative friability of ferroalloys. A code system has been developed, therefore, for this purpose, and a number rating for each product type is shown in the last column of Table 2. Definitions applicable to these code numbers are given in Specification A 1025.

6. Chemical Analysis

6.1 The chemical analysis method shall be agreed upon by the purchaser and supplier.

6.2 In cases of discrepancy, Test Methods E 363 shall be used for referee purposes.

7. Keywords

7.1 ferroalloys; ferrochromium; high carbon; low carbon; nitrogen-bearing; vacuum low carbon

[1] This specification is under the jurisdiction of ASTM Committee A01 on Steel, Stainless Steel, and Related Alloys and is the direct responsibility of Subcommittee A01.18 on Castings.

Current edition approved May 1, 2004. Published May 2004. Originally approved in 1925. Last previous edition approved in 1993 as A 101 – 93 (2000).

[2] 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.**

TABLE 1 Chemical Requirements

Type Ferrochromium	Composition, %						
	Grade	Chromium	Carbon	Silicon	Sulfur, max	Phosphorus, max	Nitrogen
High carbon	A	51.0–56.0	6.0–8.0	6.0 max	0.040	0.030	. . .
	B	56.0–62.0	6.0–8.0	8.0–14.0	0.050	0.030	. . .
	C	62.0 min	6.0–8.0	3.0 max	0.050	0.030	. . .
Low carbon	A	60.0–67.0	0.025 max	1.0–8.0	0.025	0.030	. . .
	B	67.0–75.0	0.025 max	1.0 max	0.025	0.030	. . .
	C	67.0–75.0	0.050 max	1.0 max	0.025	0.030	. . .
	D	67.0–75.0	0.75 max	1.0 max	0.025	0.030	. . .
Vacuum low carbon	E	66.0–70.0	0.015 max	2.0 max	0.030	0.030	. . .
	G	63.0–68.0	0.050 max	2.0 max	0.030	0.030	5.0–6.5
Nitrogen bearing		62.0–70.0	0.10 max	1.0 max	0.025	0.030	1.0–5.0

TABLE 2 Standard Sizes and Tolerances

Product	Standard Sizes	Tolerances		Friability Ratings
Ferrochromium:				
High-carbon	8 in. (200 mm) by 4 in. (100 mm)	10 in. (250 mm), max	10 %, max, passing 4-in. (100-mm) sieve	4
	6 in. (150 mm) by down	10 %, max, retained on 6-in. (150-mm) sieve		
	5 in. (125 mm) by 2 in. (50 mm)	10 %, max, retained on 5-in. (125-mm) sieve	10 %, max, passing 2-in. (50-mm) sieve	
	4 in. (100 mm) by in. (12.5 mm)	10 %, max, retained on 4-in. (100-mm) sieve	10 %, max, passing ½-in. (12.5-mm) sieve	
	3 in. (75 mm) by 1 in. (25 mm)	10 %, max, retained on 3-in. (75-mm) sieve	10 %, max, passing 1-in. (25-mm) sieve	
	3 in. (75 mm) by ¼ in. (6.3 mm)	10 %, max, retained on 3-in. (75-mm) sieve	10 %, max, passing ¼-in. (6.3-mm) sieve	
	¼ in. (6.3 mm) by down	5 %, max, retained on ¼-in. (6.3-mm) sieve		
	8 mesh (2.36 mm) by down	5 %, max, retained on U.S. No. 8 (2.36-mm) sieve		
Low-carbon	8 in. (200 mm) by down	10 in. (250 mm), max		1
	8 in. (200 mm) by 4 in. (100 mm)	10 %, max, retained on 8-in. (200-mm) sieve	5 %, max, passing 4-in. (100-mm) sieve	
	4 in. (100 mm) by down	10 %, max, retained on 4-in. (100-mm) sieve		
	3 in. (75 mm) by 1 in. (25 mm)	10 %, max, retained on 3-in. (75-mm) sieve	10 %, max, passing 1-in. (25-mm) sieve	
	8 mesh (2.36 mm) by down	5 %, max, retained on U.S. No. 8 (2.36-mm) sieve		
	brick or pellet	designated by manufacturer		
Vacuum low carbon				

SUPPLEMENTARY REQUIREMENTS

The composition shall be limited to the requirements of Table S1.1 in addition to those in Table 1. Upon request of the purchaser, the manufacturer shall furnish an analysis for any of these elements on a cumulative basis over a period mutually agreed upon by the manufacturer and the purchaser.

TABLE S1.1 Supplementary Chemical Requirements

Type	Composition, max, %					
	High Carbon		Low Carbon	Vacuum Low Carbon[A]		Nitrogen Bearing
Grade	A, B	C	All Grades	E	G	—
Nitrogen	0.050	0.050	0.12	0.050		
Manganese	0.75	0.75	0.75	0.75	0.75	0.75
Nickel	0.50	0.50	0.50	0.50	0.50	0.50
Vanadium	0.50	0.50	0.50	0.50	0.50	0.50
Copper	0.050	0.050	0.050	0.050	0.050	0.050
Molybdenum	0.050	0.050	0.050	0.050	0.050	0.050
Columbium	0.050	0.050	0.050	0.050	0.050	0.050
Tantalum	0.050	0.050	0.050	0.050	0.050	0.050
Cobalt	0.10	0.10	0.10	0.10	0.10	0.10
Aluminum	0.25	0.25	0.10	0.10	0.10	0.10
Titanium	0.50	0.30	0.050	0.050	0.050	0.050
Zirconium	0.050	0.050	0.01	0.01	0.01	0.01
Antimony	0.01	0.01	0.01	0.01	0.01	0.01
Arsenic	0.005	0.005	0.005	0.005	0.005	0.005
Lead	0.005	0.005	0.005	0.005	0.005	0.005
Tin	0.005	0.005	0.005	0.005	0.005	0.005
Zinc	0.005	0.005	0.005	0.005	0.005	0.005
Boron	0.005	0.005	0.005	0.005	0.005	0.005
Silver	0.005	0.005	0.005	0.005	0.005	0.005
Bismuth	0.005	0.005	0.005	0.005	0.005	0.005

[A] The inert oxide (SiO_2 + CaO + MgO + Al_2O_3) content of vacuum low-carbon ferrochromium shall be specified as 3.50 % max.

SUMMARY OF CHANGES

Committee A01 has identified the location of selected changes to this standard since the last version (A 101 – 93 (2000)) that may impact the use of this standard.

(1) Practice E 29, Test Methods E 31, and Practices E 32 were removed from 2.
(2) Specification A 1025 was added to 2.
(3) Changed Ordering Information to General Conditions for Delivery.
(4) Revised 4 and 5.
(5) Removed sections on Sampling, Inspection, Rejection, and Packaging.
(6) Added Supplementary Requirements.
(7) Moved Table S1.1 into the Supplementary Requirements section and renumbered other tables appropriately.

Standard Specification for Ferrovanadium[1]

This standard is issued under the fixed designation A 102; 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 one grade of ferrovanadium.

1.2 The values given 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:* [2]

A 1025 Specification for Ferroalloys, General Requirements

E 365 Test Methods for Determination of Vanadium in Ferrovanadium and Vanadium Alloying Additives

3. General Conditions for Delivery

3.1 Materials furnished to this specification shall conform to the requirements of Specification A 1025, including any supplementary requirements that are indicated in the purchase order. Failure to comply with the general requirements of Specification A 1025 constitutes nonconformance with this specification. In case of conflict between the requirements of this specification and Specification A 1025, this specification shall prevail.

3.2 Although ferrovanadium is ordered by total net weight, the customary basis of payment is per pound of contained vanadium.

4. Chemical Composition

4.1 The material shall conform to the requirements as to chemical composition specified in Table 1.

4.2 The manufacturer shall furnish an analysis of each shipment showing the percentage of each element specified.

TABLE 1 Chemical Requirements[A]

Element	Composition, %
Vanadium,[B]	75-85
Carbon, max	0.75
Silicon, max	1.5
Aluminum, max	2.0
Sulfur, max	0.08
Phosphorus, max	0.08

[A] For the purposes of determining conformance with this specification, the reported analysis shall be rounded to the nearest unit in the last right-hand place of figures used in expressing the limiting value, in accordance with the rounding method of Practice E 29.

[B] For the purposes of determining the vanadium content of any shipment, vanadium shall be reported to the nearest 0.1 %, applying the same rounding procedure as prescribed in Footnote *A*.

5. Size

5.1 The grade is available in sizes as listed in Table 2.

NOTE 1—The sizes listed in Table 2 are typical as shipped from the manufacturer's plant. Ferrovanadium has a friability code number of "1". It is a tough material, susceptible to little, if any, breakage during shipment or handling.

6. Chemical Analysis

6.1 The chemical analysis of the material shall be made in accordance with the procedure for ferrovanadium as described in Test Methods E 365 or alternative methods which will yield equivalent results. For elements other than vanadium the chemical analysis shall be agreed upon by the purchaser and supplier.

6.2 If alternative methods of analysis are used, in case of discrepancy, Test Methods E 365 shall be used for referee.

6.3 Where no method is given for the analysis for a particular element, the analysis shall be made in accordance with a procedure agreed upon by the manufacturer and the purchaser.

[1] This specification is under the jurisdiction of ASTM Committee A01 on Steel, Stainless Steel, and Related Alloys and is the direct responsibility of Subcommittee A01.18 on Castings.

Current edition approved May 1, 2004. Published May 2004. Originally approved in 1925. Last previous edition approved in 1993 as A 102 – 93 (2000).

[2] 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.**

TABLE 2 Sizing Requirements

Size Requirements
2 in. (50 mm) by down
1 in. (25 mm) by down
½ in. (12.5 mm) by down
No. 8 (2.36 mm) by down

SUPPLEMENTARY REQUIREMENTS

The composition shall be further limited to the requirements of Table S1.1 in addition to those in Table 1. An analysis of each lot is not required. The manufacturer shall supply, upon request, the results of an analysis for these elements on a cumulative basis over a period mutually agreed upon by the manufacturer and the purchaser.

TABLE S1.1 Supplementary Chemical Requirements

Element	Maximum Limits Allowable, %
Chromium	0.50
Copper	0.15
Nickel	0.10
Lead	0.020
Tin	0.050
Zinc	0.020
Molybdenum	0.75
Titanium	0.15
Nitrogen	0.20

SUMMARY OF CHANGES

Committee A01 has identified the location of selected changes to this standard since the last version (A 102 – 93 (2000)) that may impact the use of this standard.

(1) Practice E 29, Test Methods E 31, and Practices E 32 were removed from 2.
(2) Specification A 1025 was added to 2.
(3) Changed Ordering Information to General Conditions for Delivery.
(4) Revised 4 and 5.
(5) Removed sections on Sampling, Inspection, Rejection, and Packaging.
(6) Added Supplementary Requirements section.
(7) Added Table S1.1.

Designation: A 126 – 04

Standard Specification for Gray Iron Castings for Valves, Flanges, and Pipe Fittings[1]

This standard is issued under the fixed designation A 126; 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 three classes of gray iron for castings intended for use as valve pressure retaining parts, pipe fittings, and flanges.

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.

NOTE 1—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.

2. Referenced Documents

2.1 *ASTM Standards:* [2]

A 48 Specification for Gray Iron Castings

A 644 Terminology Relating to Iron Castings

E 8 Test Methods for Tension Testing of Metallic Materials

3. Terminology

3.1 Definitions of many terms common to gray iron castings are found in Terminology A 644.

4. Classification

4.1 Castings produced to this specification are classified based upon the minimum tensile strength of the iron (see Table 1).

5. Ordering Information

5.1 Orders for material in this specification should include the following information:

5.1.1 ASTM designation and year date,

5.1.2 Class of iron required,

5.1.3 Quantity, and

5.1.4 Certification, if required (see Section 17).

TABLE 1 Tensile Requirements

	Class A	Class B	Class C
Tensile strength, min, ksi (MPa)	21 (145)	31 (214)	41 (283)

6. Workmanship, Finish, and Appearance

6.1 The castings shall be made in a workmanlike manner and the surface shall be free of adhering sand, scale, cracks, and hot tears as determined by visual examination.

7. Chemical Requirements

7.1 A chemical analysis shall be performed on each lot and shall conform to the following requirements for phosphorus and sulfur:

Phosphorus, max, %	0.75
Sulfur, max, %	0.15

7.2 The chemical analysis shall be performed on a sample obtained during the pouring of the lot.

8. Tensile Properties

8.1 One tension test shall be performed on each lot and shall conform to the mechanical properties specified in Table 1.

9. Cast Test Bars

9.1 Separately cast 1⅛ in. (28.6 mm) diameter test bars shown in Fig. 1 shall be poured in sand molds from the same lot as the castings represented.

NOTE 2—The numbering on the test specimens shown in Fig. 1 and Fig. 2 is intended simply to illustrate a method of designation. In the particular method shown[12] refers to December 8, B 1 is the cupola number, and the numeral 1 which follows shows the hour cast (1 p.m.).

9.2 Test bars that are intended to represent castings which are cooled in the mold to less than 900°F (480°C) before shakeout, shall be cooled in their molds to a temperature less than 900°F, and then may be cooled in still air to room temperature.

9.3 Test bars that are intended to represent castings which are hotter than 900°F when shaken out of their molds, shall be

[1] This specification is under the jurisdiction of ASTM Committee A04 on Iron Castings and is the direct responsibility of Subcommittee A04.01 on Gray and White Iron Castings.

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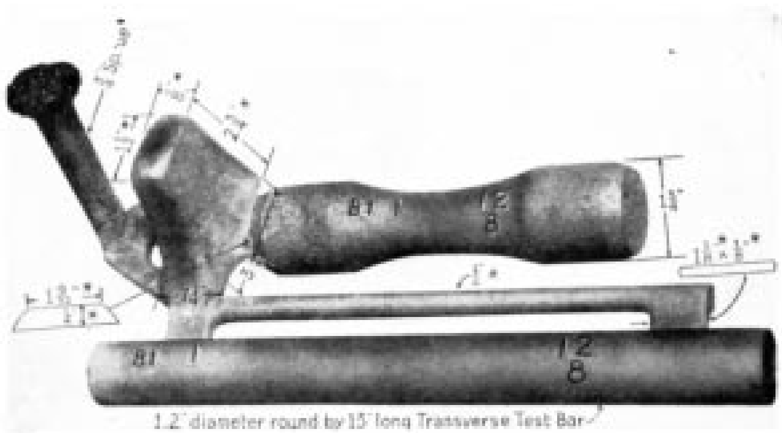
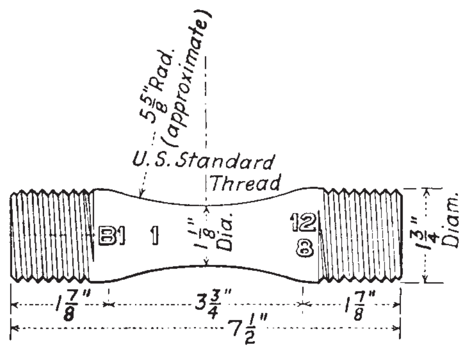
[2] For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.



Metric Equivalents												
in.	1/8	1/4	1/2	3/4	7/8	1 1/8	1.2	1 9/32	1 1/2	1 3/4	2 3/4	13
mm	3.2	6.4	12.7	19.0	22.2	28.6	30.5	32.5	38.1	44.4	69.8	1330

NOTE—These dimensions are suggested as satisfactory for average conditions, but may be varied to best suit individual pouring.

FIG. 1 Mold of Tension and Transverse Test Specimens



Metric Equivalents			
in.	mm	in.	mm
1 1/8	28.6	3 3/4	95.2
1 3/4	44.4	5 5/8	142.9
1 7/8	47.6	7 1/2	290.5

NOTE—Modification may be made to the grip-ends of the tension test specimen to allow alternative means of gripping as required by testing procedures and equipment. Should alternative grip-ends be disputed, the threaded grip-ends shall be used.

FIG. 2 Tension Test Specimen

cooled as described in 9.2 or (by agreement between the manufacturer and the purchaser) may be shaken out of their molds at approximately the same temperature as the castings they represent.

10. Tension Test Apparatus

10.1 Ball and socket specimen holders or spherical-seated bearings or other device which will ensure that the specimen, when under load, will be as nearly as possible in pure axial tension without transverse stress shall be used in making the tension test.

NOTE 3—Suitable socket specimens holders and spherical-seated bearing device are shown in Fig. 4 and described in 5.2.3 of Test Methods E 8.

10.2 After reaching a stress of 15 000 psi (103 MPa), the speed of the crosshead of the testing machine shall not exceed ⅛ in. (3.2 mm)/min.

11. Sampling

11.1 A lot shall consist of one of the following:

11.1.1 All the metal poured from a single heating in a batch type melting furnace,

11.1.2 All the metal from two or more batch type melting furnaces poured into a single ladle or single casting, or

11.1.3 All the metal poured from a continuous melting furnace for a given period of time between changes in charge, processing conditions, or aim-for chemistry or 4 h, whichever is the shorter period.

11.1.3.1 The purchaser may agree to extend the 4-h time period to 8 h if the manufacturer can demonstrate sufficient process control to warrant such an extension.

12. Test Specimens

12.1 Tension test specimens shall have threaded ends and conform to the dimensions shown in Fig. 2. The cross-sectional area of the reduced section shall be 1 in.^{2}(645 mm^2) $\pm$5 %. The actual cross-sectional area shall be used in calculating the tensile strength.

13. Alternate Test Bars

13.1 Alternate test bars poured in accordance with Specification A 48 to the equivalent classes shown in Table 2 may be substituted for the Specification A 126 test bars. When the alternate bars are used, they shall be machined and tested in accordance with Specification A 48 and shall meet the requirements of Specification A 48.

14. Inspection

14.1 All tests and inspections required by this specification shall be performed by the manufacturer or other reliable sources whose services have been contracted for by the manufacturer. Complete records of all tests and inspections shall be maintained by the manufacturer and shall be available for review by the purchaser.

TABLE 2 Equivalent Classes (Specification A 48)

Specification A 126 Class	Under 0.50 in. (12.7 mm)	0.51 to 1.00 in. (13.0 to 25.4 mm)	Over 1 in. (25.4 mm)
A	25 A	20 B	20 C
B	35 A	30 B	30 C
C	45 A	40 B	40 C

15. Rejection and Rehearing

15.1 Castings which fail to conform to the requirements specified when inspected or tested by the purchaser or his agent may be rejected. Rejection shall be reported to the manufacturer or supplier promptly and in writing. In case of dissatisfaction with the test results, the manufacturer or supplier may make claim for a rehearing.

16. Certification

16.1 When requested by the purchaser, the manufacturer shall furnish the certification stating that the material was manufactured, sampled, tested, and inspected in accordance with Specification A 126, including the year date. The certification shall also include the results of all tests performed including chemical analysis.

16.2 A signature is not required on the certification. However, the document shall clearly identify the organization submitting the certification and the authorized agent of the manufacturer who certified the test results. Notwithstanding the absence of a signature, the organization submitting the certification is responsible for its content.

17. Keywords

17.1 gray iron castings; pressure retaining parts

Designation: A 128/A 128M – 93 (Reapproved 2003)

Standard Specification for Steel Castings, Austenitic Manganese[1]

This standard is issued under the fixed designation A 128/A 128M; 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 Hadfield austenitic manganese steel castings and alloy modifications.

1.2 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 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 781/A 781M Specification for Castings, Steel and Alloy, Common Requirements for General Industrial Use[2]

3. General Conditions for Delivery

3.1 Material furnished to this specification shall conform to the requirements of Specification A 781/A 781M, including any supplementary requirements that are indicated in the purchase order. Failure to comply with the general requirements of Specification A 781/A 781M constitutes nonconformance with this specification. In case of conflict between the requirements of this specification and Specification A 781/A 781M, this specification shall prevail.

4. Ordering Information

4.1 Orders for material under this specification should include the following information in proper sequence.

4.1.1 Quantity,

4.1.2 Specification, grade,

4.1.3 Whether any portion of the casting is to be chilled, and whether this is to be spot or full-face chilling,

4.1.4 Special heat-treatment requirements, and

4.1.5 Supplementary requirements.

5. Heat Treatment

5.1 The castings shall be suitably heat treated to achieve toughness and ductility. This heat treatment shall consist of uniformly heating the castings to a temperature applicable for grade of steel produced, at least 1800°F [1000°C], and holding until the temperature is uniform throughout and quenching in an applicable medium, normally water.

5.2 By agreement between the purchaser and the manufacturer, castings may be furnished in a condition other than described in 5.1.

6. Chemical Composition

6.1 The steel shall conform to the requirements as to chemical composition prescribed in Table 1.

6.2 Contamination of the drillings by drill chips must be avoided. Flat drills of the best highspeed steels, or drills of some of the newer tool materials, will generally be satisfactory for drilling manganese steel. Manganese steel may be drilled best after it has been annealed for several hours at from 900 to 1100°F [500 to 600°C].

7. Repair by Welding

7.1 Defects shall be welded using a procedure and welders capable of producing sound welds. The weld deposit shall be austenitic steel in general, but welds on wearing surfaces shall consist of austenitic-manganese steel.

7.2 Weld repairs shall be inspected to the same quality standards as are used to inspect the castings.

8. Keywords

8.1 austenitic manganese steel; manganese steel; steel castings

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[1] This specification is under the jurisdiction of ASTM Committee A01 on Steel, Stainless Steel and Related Alloys, and is the direct responsibility of Subcommittee A01.18 on Castings.

Current edition approved April 10, 2003. Published April 2003. Originally approved in 1930. Last previous edition approved in 1998 as A 128/A 128M – 93 (1998).

[2] *Annual Book of ASTM Standards*, Vol 01.02.

TABLE 1 Chemical Requirements

Grade[A]	Composition, %						
	Carbon	Manganese	Chromium	Molybdenum	Nickel	Silicon	Phosphorus
A[B]	1.05–1.35	11.0 min	...	...	...	1.00 max	0.07 max
B-1	0.9 –1.05	11.5–14.0	...	...	...	1.00 max	0.07 max
B-2	1.05–1.2	11.5–14.0	...	...	...	1.00 max	0.07 max
B-3	1.12–1.28	11.5–14.0	...	...	...	1.00 max	0.07 max
B-4	1.2 –1.35	11.5–14.0	...	...	...	1.00 max	0.07 max
C	1.05–1.35	11.5–14.0	1.5–2.5	...	...	1.00 max	0.07 max
D	0.7 –1.3	11.5–14.0	...	...	3.0–4.0	1.00 max	0.07 max
E-1	0.7 –1.3	11.5–14.0	...	0.9–1.2	...	1.00 max	0.07 max
E-2	1.05–1.45	11.5–14.0	...	1.8–2.1	...	1.00 max	0.07 max
F (J91340)	1.05–1.35	6.0–8.0	...	0.9–1.2	...	1.00 max	0.07 max

[A] Section size precludes the use of all grades and the producer should be consulted as to grades practically obtainable for a particular design required. Final selection shall be by mutual agreement between manufacturer and purchaser.
[B] Unless otherwise specified, Grade A will be supplied.

SUPPLEMENTARY REQUIREMENTS

A list of standardized supplementary requirements for use at the option of the purchaser is described in Specification A 781/A 781M. Those which are considered suitable for use with this specification are listed below by title only. Additional supplementary requirements suitable for use with this specification at the option of the purchaser are described below. One or more of the supplementary requirements indicated below may be included in the purchaser's order or contract. When so included, a supplementary the same force as if it were in the body of the specification. Supplementary requirements details not fully described shall be agreed upon between the purchaser and the supplier, but shall not negate any of the requirements in the body of the specification.

S6. Certification

S8. Marking

S50. Bend Test

S50.1 The test specimen shall withstand cold bending through 150° around a pin 1 in. [25.4 mm] in diameter without breaking into two pieces. (Surface cracks after bending are not considered as failure if the sample remains in one piece.) The specimen may be bent by any method preferred by the manufacturer. When the bend test is specified, one such test shall be made from each heat of steel.

NOTE —The bend test has become essentially obsolete as a result of improved technology. Furthermore, it is not recommended as a suitable test for the special alloy grades.

S50.2 The bend specimen shall be poured in separatemolds from the same heat of steel as the castings. They shall be ½ by ¾in. [13 by 19 mm] in cross section and 12 in. [300 mm] in length, and shall be heat treated and tested without being machined or ground, except when necessary to remove surface irregularities or decarburization.

S50.3 Bend specimens shall be heat treated in the same manner as the castings they represent, with due regard for the metal section. At the discretion of the manufacturer and unless otherwise specified by the purchaser, specimens may be heat treated separately or with the castings they represent.

S50.4 If any specimen fails as the result of flaws, it may be discarded and another specimen tested from the same heat. If the results of the bend tests for any heat do not conform to the requirements specified, the manufacturer may reheat treat and retest additional specimens from the same heat, but not more than twice. In the case of reheat treating and retesting, two bend tests from each heat shall be required.

Standard Specification for Ferromolybdenum[1]

This standard is issued under the fixed designation A 132; 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 two grades of ferromolybdenum.

1.2 The values stated in inch-pound units are to be regarded as the standard.

2. Referenced Documents

2.1 *ASTM Standards:* [2]

A 1025 Specification for Ferroalloys, General Requirements

E 11 Specification for Wire-Cloth Sieves for Testing Purposes

3. General Conditions for Delivery

3.1 Materials furnished to this specification shall conform to the requirements of Specification A 1025, including any supplementary requirements that are indicated in the purchase order. Failure to comply with the general requirements of Specification A 1025 constitutes nonconformance with this specification. In case of conflict between the requirements of this specification and Specification A 1025, this specification shall prevail.

4. Chemical Requirements

4.1 The material shall conform to the requirements as to chemical composition specified in Table 1. The manufacturer shall furnish an analysis of each shipment showing the percentage of each element specified.

5. Size

5.1 The grades are available in sizes as listed in Table 2.

5.2 The sizes listed in Table 2 are typical as shipped from the manufacturer's plant. These alloys exhibit varying degrees of friability; therefore, some attrition may be expected in transit, storage, and handling.

6. Keywords

6.1 ferromolybdenum; molybdenum

[1] This specification is under the jurisdiction of ASTM Committee A01 on Steel, Stainless Steel, and Related Alloys and is the direct responsibility of Subcommittee A01.18 on Castings.

Current edition approved May 1, 2004. Published May 2004. Originally approved in 1963. Last previous edition approved in 1989 as A 132 – 89 (2000).

[2] 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.**

TABLE 1 Chemical Requirements (maximum unless otherwise indicated)

Grade	A1	A2
Molybdenum, min	60.0	60.0
Carbon	0.10	0.10
Phosphorous	0.050	0.050
Sulfur	0.15	0.15
Silicon	1.0	1.0
Copper	1.0	0.20

TABLE 2 Ferromolybdenum Size Requirements

Product	Size Requirements	Tolerance[A]
Ferromolybdenum	2 in. and under	10 % max retained on 2-in. (50-mm) sieve 10 % max passing ¼-in. (6.3-mm) sieve
	1½ in. and under	10 % max retained on 1½-in. (37.5-mm) sieve 10 % max passing ¼-in. (6.3-mm) sieve
	¾ in. and under	10 % max retained on ¾-in. (19.0-mm) sieve 10 % max passing No. 20 (850-µm) sieve
	4 mesh and under	10 % max retained on No. 4 (4.75-mm) sieve 10 % max passing No. 80 (180-µm) sieve
	20 mesh and under	10 % max retained on No. 20 (850-µm) sieve
	80 mesh and under	10 % max retained on No. 80 (180-µm) sieve

[A] Specification of sieves sizes used to define tolerances herein are as listed in Specification E 11.

SUPPLEMENTARY REQUIREMENTS

The composition shall be further limited to the requirements of Table S1.1 in addition to those in Table 1. The manufacturer shall furnish an analysis of each shipment showing the percentage of each element specified.

TABLE S1.1 Supplementary Chemical Requirements

Element	Composition, max, %
	Ferromolybdenum
Lead	0.010
Tin	0.010

SUMMARY OF CHANGES

Committee A01 has identified the location of selected changes to this standard since the last version (A 132 – 89 (2000)) that may impact the use of this standard.

(1) Specification A1025 added to 2.
(2) Practice E29, Test Methods E31, and Practices E32 were removed from 2.
(3) The section on Ordering Information was changed to General Conditions for Delivery.
(4) Section 4 was revised and moved.
(5) Section 5 was revised.
(6) Sections on Sampling, Chemical Analysis, Rejection, Product Marking, and Packing were removed.
(7) Supplementary Requirements section was added.
(8) A new Table 1 was added.
(9) The previous Table 1 was renumbered as Table 2.
(10) The previous Table 2 was removed.
(11) The previous Table 3 was renumbered as Table S1.1.

Designation: A 144 – 02

Standard Specification for Ferrotungsten[1]

This standard is issued under the fixed designation A 144; 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 four grades of ferrotungsten.

2. Referenced Documents

2.1 *ASTM Standards:*

E 29 Practice for Using Significant Digits in Test Data to Determine Conformance with Specifications[2]

E 31 Methods for Chemical Analysis of Ferroalloys[3]

E 32 Practices for Sampling Ferroalloys and Steel Additives for Determination of Chemical Composition[3]

3. Ordering Information

3.1 Orders for material under this specification shall include the following information:

3.1.1 Quantity,

3.1.2 Name of material,

3.1.3 ASTM designation and year of issue,

3.1.4 Grade,

3.1.5 Sizing, and

3.1.6 Requirements for packaging, analysis reports, and so forth, as appropriate.

3.2 Although ferrotungsten is ordered by total net weight, the customary basis of payment is per pound of contained tungsten.

4. Chemical Composition

4.1 The various grades shall conform to the requirements as to chemical composition specified in Table 1 and Table 2.

4.2 The manufacturer shall furnish an analysis of each shipment showing the elements specified in Table 1.

4.3 The values shown in Table 2 are expected maximums. Upon the request of the purchaser, the manufacturer shall furnish an analysis for any of these elements on a cumulative basis over a period mutually agreed upon between the manufacturer and the purchaser.

5. Chemical Analysis

5.1 The chemical analysis of the material shall be made in accordance with the procedure for ferrotungsten as described in Methods E 31 or alternative methods which will yield equivalent results.

5.2 If alternative methods of analysis are used, in case of discrepancy, Methods E 31 shall be used for referee.

5.3 Where no method is given in Methods E 31 for the analysis for a particular element, the analysis shall be made in accordance with a procedure agreed upon between the manufacturer and the purchaser.

6. Size

6.1 The various grades are available in the sizes listed in Table 3.

6.2 The ferrotungsten is available in various sizes such as ¼ by down (5 % maximum over ¼ in., 20 % maximum under 70 mesh), or ⅜ by down (5 % maximum over ⅜ in., 20 % maximum under 70 mesh). The size shall be specified on the order.

7. Sampling

7.1 The material shall be sampled in accordance with Practices E 32.

7.2 Other methods of sampling mutually agreed upon by the manufacturer and the purchaser may be used; however, in case of discrepancy, Practices E 32 shall be used for referee.

8. Inspection

8.1 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.

9. Rejection

9.1 Any claims or rejections shall be made to the manufacturer within 45 days from receipt of material by the purchaser.

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[1] This specification is under the jurisdiction of ASTM Committee A01 on Steel, Stainless Steel, and Related Alloys and is the direct responsibility of Subcommittee A01.18 on Castings.

Current edition approved Mar. 10, 2002. Published May 2002. Originally published as A 144 – 32 T. Discontinued 2000 and reinstated as A 144 - 02.

[2] *Annual Book of ASTM Standards*, Vol 14.02.

[3] *Annual Book of ASTM Standards*, Vol 03.05.

TABLE 1 Chemical Requirements[A,B]

Grade	Primary Compositions, max, %, Unless Otherwise Shown						
	Tungsten	Carbon	Phosphorus	Sulfur	Silicon	Molybdenum	Aluminum
A	85.0–95.0	0.050	0.010	0.020	0.10	0.20	0.10
B	75.0–85.0	0.10	0.020	0.020	0.50	0.35	0.10
C	75.0–85.0	0.60	0.060	0.050	1.0	1.0	...
D	75.0–85.0	0.60	0.060	0.050	1.0	3.0	...

[A] For the purposes of determining conformance with this specification, the reported analysis shall be rounded to the nearest unit in the last right-hand place of figures used in expressing the limiting value, in accordance with the rounding method of Practice E 29.
[B] For purposes of determining the tungsten content of any shipment, tungsten shall be reported to the nearest 0.1 %, applying the same rounding procedure as prescribed in Footnote *A*.

TABLE 2 Supplementary Chemical Requirements[A,B]

	Manganese	Copper	Nickel	Arsenic	Antimony	Tin	Bismuth	Total: Arsenic, Antimony, Tin	Total: Arsenic Antimony, Tin, Bismuth
A	0.10	0.50	0.05	0.010	0.010	0.010	0.010	...	0.040
B	0.30	0.07	0.05	0.020	0.020	0.020	0.030	...	0.090
C	0.75	0.10	...	0.10	0.080	0.10	...	0.20	...
D	0.75	0.10	...	0.10	0.080	0.10	...	0.20	...

[A] See Footnote *A* of Table 1.
[B] The composition of the ferrotungsten shall be within these limits; however, an analysis of each lot is not required. The manufacturer shall supply upon request the results of an analysis for these elements on a cumulative basis over a period mutually agreed upon between the manufacturer and the purchaser.

TABLE 3 Size Tolerance

Size	Tolerance
¼ in. (6.3 mm) by down	5 % max retained on 6.3 mm (1¼ in.) sieve

10. Product Marking

10.1 When the shipment is made in bulk it shall be accompanied by appropriate identification showing the material, the grade designation, the ASTM designation, the size, the lot number, and the name, brand, or trademark of the manufacturer.

10.2 When the shipment is made in containers, each shall be marked on the container or on a label or tag attached thereto. The marking shall show the material, the grade designation, the ASTM designation, the size, the lot number, gross, tare, and net weight, and the name, brand, or trademark of the manufacturer.

11. Packaging and Package Marking

11.1 The ferrotungsten shall be packaged in sound containers, or shipped in bulk, in such a manner that none of the product is lost or contaminated in shipment.

Standard Specification for Molybdenum Oxide Products[1]

This standard is issued under the fixed designation A 146; 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 four grades of molybdenum oxide, designated as A, B1, B2, and molybdic oxide briquets.

1.2 The values stated in inch-pound units are to be regarded as the standard.

2. Referenced Documents

2.1 *ASTM Standards:* [2]

A 1025 Specification for Ferroalloys, General Requirements

3. General Conditions for Delivery

3.1 Materials furnished to this specification shall conform to the requirements of Specification A 1025, including any supplementary requirements that are indicated in the purchase order. Failure to comply with the general requirements of Specification A 1025 constitutes nonconformance with this specification. In case of conflict between the requirements of this specification and Specification A 1025, this specification shall prevail.

4. Chemical Requirements

4.1 The various grades shall conform to the requirements as to chemical composition specified in Table 1.

4.2 The manufacturer shall furnish an analysis of each shipment showing the percentage of each element specified.

TABLE 1 Chemical Requirements

	Molybdenum Oxide			Molybdic Oxide Briquets
	Grade A	Grade B1	Grade B2	
Molybdenum, min	55.0	57.0	57.0	51.6
Sulfur, max	0.25	0.10	0.10	0.15
Copper, max	1.0	1.0	0.15	0.15

5. Sampling

5.1 *Sampling Small Bags*—When packed in the standardized small packages, each holding contained molybdenum, the material shall be sampled by selecting at random one twentieth of the bags that may bear the same manufacturing lot number, and the combined content of these bags shall be reduced and analyzed as a separate sample. When a shipment cannot be divided by lot numbers, one twentieth of the total number of bags constituting the shipment shall be selected and treated as one sample. The material forming a sample shall be crushed if necessary, and in any event passed through a No. 10 (2.00-mm) sieve. The sample after sieving shall be thoroughly mixed by coning and then reduced to about 2 lb (0.9 kg) by quartering or by means of a riffle sampler. The reduced sample shall then be crushed and passed through a No. 60 (250-µm) sieve. The sample after sieving shall again be mixed by coning and then divided through a riffle, preferably a Jones divider, into the required number of analytical samples.

5.2 *Sampling Large Containers*—When packed in drums or large bags or cartons, the material shall be sampled by selecting about one twentieth of the content of each package that may bear the same manufacturing lot number, and the combined material selected shall be reduced and analyzed as a separate sample. When a shipment cannot be divided by lot numbers, about one twentieth of the content of each package in the shipment shall be selected, and the combined material selected shall be treated as one sample. The material comprising a sample shall be thoroughly mixed by coning and reduced by half-shoveling, alternating the operations until the residual weight reaches about 40 lb (18.1 kg). Segregation of sizes shall be carefully avoided. The sample thus reduced shall be crushed, if necessary, to pass through a No. 10 (2.00-mm) sieve, and the subsequent sampling procedure shall be as prescribed in 5.1 .

5.3 *Correcting Sample to Dry Net Weight*—Absorption of moisture by the material would depress the analytical percentages with respect to the dry basis, on which the product was analyzed when packaged. Accordingly, any analytical sample shall be dried at 110°C, before analysis, and the sampler's moist net weight of the shipment, of a manufacturing lot, or of any constituent package shall be appropriately corrected to the corresponding dry weight, thus leading to the proper weight of contained molybdenum.

[1] This specification is under the jurisdiction of ASTM Committee A01 on Steel, Stainless Steel, and Related Alloys and is the direct responsibility of Subcommittee A01.18 on Castings.

Current edition approved May 1, 2004. Published May 2004. Originally approved in 1932. Last previous edition approved in 1964 as A 146 – 64 (2000). Replaces A 146 – 63 T.

[2] 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.**

6. Keywords

6.1 molybdenum; molybdenum oxide

SUPPLEMENTARY REQUIREMENTS

S1. The composition shall be further limited by the requirements of Table S1.1 in addition to those in Table 1.

TABLE S1.1 Supplementary Chemical Requirements

	Composition, %[A]		
	Molybdenum Oxide		Molybdic Oxide Briquets
	Grade A	Grade B1 and B2	
Carbon	trace	trace	12.0 (approx)
Phosphorus, max	0.050	0.050	0.050

[A]The values shown are maxima. Upon request of the purchaser, the manufacturer shall furnish an analysis for any of these elements on a cumulative basis over a period mutually agreed upon by the manufacturer and the purchaser. An analysis of each lot is not required.

SUMMARY OF CHANGES

Committee A01 has identified the location of selected changes to this standard since the last version (A 146 – 64 (2000)) that may impact the use of this standard.

(1) Practice E 29, and Test Methods E 31 were removed from 2.
(2) Specification A 1025 was added to 2.
(3) Changed Ordering Information to General Conditions for Delivery.
(4) Revised Section 4.
(5) Removed sections on Size, Chemical Analysis, Inspection, Rejection, Marking, and Packaging.
(6) Changed Grade B to Grade B1 and added Grade B2 to Table 1.
(7) Added Supplementary Requirements section.
(8) Changed Table 2 to Table S1.1.

Standard Specification for Steel Castings, High Strength, for Structural Purposes[1]

This standard is issued under the fixed designation A 148/A 148M; 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 carbon steel, alloy steel, and martensitic stainless steel castings that are to be subjected to higher mechanical stresses than those covered in Specification A 27/A 27M.

1.2 Several grades of steel castings are covered, having the chemical composition and mechanical properties prescribed in Table 1 and Table 2.

1.3 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. Combining values from the two systems may result in nonconformance with the specification.

2. Referenced Documents

2.1 *ASTM Standards:*

A 27/A 27M Specification for Steel Castings, Carbon, for General Application[2]

A 370 Test Methods and Definitions for Mechanical Testing of Steel Products[3]

A 781/A 781M Specification for Castings, Steel and Alloy, Common Requirements for General Industrial Use[2]

E 29 Practice for Using Significant Digits in Test Data to Determine Conformance with Specifications[4]

3. General Conditions for Delivery

3.1 Material furnished to this specification shall conform to the requirements of Specification A 781/A 781M, including any supplementary requirements that are indicated in the purchase order. Failure to comply with the general requirements of Specification A 781/A 781M constitutes nonconformance with this specification. In case of conflict between the requirements of this specification and Specification A 781/ A 781M, this specification shall prevail.

TABLE 1 Chemical Requirements

Grade (UNS No.)	Composition, %	
	Sulfur, max	Phosphorus, max
80-40 [550-275] (D50400)	0.06	0.05
80-50 [550-345] (D50500)	0.06	0.05
90-60 [620-415] (D50600)	0.06	0.05
105-85 [725-585] (D50850)	0.06	0.05
115-95 [795-655] (D50950)	0.06	0.05
130-115 [895-795] (D51150)	0.06	0.05
135-125 [930-860] (D51250)	0.06	0.05
150-135 [1035-930] (D51350)	0.06	0.05
160-145 [1105-1000] (D51450)	0.06	0.05
165-150 [1140-1035] (D51500)	0.020	0.020
165-150L [1140-1035L] (D51501)	0.020	0.020
210-180 [1450-1240] (D51800)	0.020	0.020
210-180L [1450-1240L] (D51801)	0.020	0.020
260-210 [1795-1450] (D52100)	0.020	0.020
260-210L [1795-1450L] (D52101)	0.020	0.020

4. Ordering Information

4.1 The inquiry and order should include or indicate the following:

4.1.1 A description of the casting by pattern number or drawing (dimensional tolerances shall be included on the casting drawing),

4.1.2 Grade of steel,

4.1.3 Options in the specification, and

4.1.4 The supplementary requirements desired, including the standards of acceptance.

5. Heat Treatment

5.1 All castings shall be heat treated either by full annealing, normalizing, normalizing and tempering, or quenching and tempering. Unless otherwise specified in the inquiry, contract, or order, the castings may be heat treated by any of these heat treatments or combination of these heat treatments at the option of the manufacturer.

5.2 Heat treatment shall be performed after the castings have been allowed to cool below the transformation range.

6. Temperature Control

6.1 Furnace temperatures for heat-treating shall be regulated by the use of pyrometers.

[1] This specification is under the jurisdiction of ASTM Committee A01 on Steel, Stainless Steel and Related Alloysand is the direct responsibility of Subcommittee A01.18on Castings.

Current edition approved April 10, 2003. Published April 2003. Originally approved in 1955. Last previous edition approved in 2002 as A 148/A 148M – 02.

[2] *Annual Book of ASTM Standards*, Vol 01.02.

[3] *Annual Book of ASTM Standards*, Vol 01.03.

[4] *Annual Book of ASTM Standards*, Vol 14.02.

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

TABLE 2 Tensile Requirements

Grade	Tensile strength min, ksi [MPa]	Yield point min, ksi [MPa]	Elongation in 2 in. or 50 mm, min, %[A]	Reduction of Area, min, %
80-40 [550-275]	80 [550]	40 [275]	18	30
80-50 [550-345]	80 [550]	50 [345]	22	35
90-60 [620-415]	90 [620]	60 [415]	20	40
105-85 [725-585]	105 [725]	85 [585]	17	35
115-95 [795-655]	115 [795]	95 [655]	14	30
130-115 [895-795]	130 [895]	115 [795]	11	25
135-125 [930-860]	135 [930]	125 [860]	9	22
150-135 [1035-930]	150 [1035]	135 [930]	7	18
160-145 [1105-1000]	160 [1105]	145 [1000]	6	12
165-150 [1140-1035]	165 [1140]	150 [1035]	5	20
165-150L [1140-1035L][B]	165 [1140]	150 [1035]	5	20
210-180 [1450-1240]	210 [1450]	180 [1240]	4	15
210-180L [1450-1240L][B]	210 [1450]	180 [1240]	4	15
260-210 [1795-1450]	260 [1795]	210 [1450]	3	6
260-210L [1795-1450L][B]	260 [1795]	210 [1450]	3	6

[A] When ICI test bars are used in tensile testing as provided for in this specification, the gage length to reduced section diameter ratio shall be 4 to 1.
[B] These grades must be charpy impact tested as prescribed in Section 9, and with minimum values as shown in Table 3.

7. Chemical Composition

7.1 The steel shall conform to sulfur and phosphorus requirements as prescribed in Table 1.

7.2 The content of carbon, manganese, silicon, and alloying elements may, by agreement, be prescribed by the purchaser. If not specified, the content may be selected by the manufacturer to obtain the required mechanical properties.

7.3 When the analysis of carbon, manganese, silicon, or any intentionally added alloying element is specifically requested in the contract or order, it shall be made by the manufacturer and reported to the purchaser. The results of these analyses shall not be used as a basis for rejection except by prior agreement.

8. Tensile Requirements

8.1 One tension test shall be made from each heat and shall conform to the tensile requirements specified in Table 2.

8.2 The test coupons and specimens shall conform to requirements specified in Section 11.

8.3 Tension test coupons shall be machined to the form and dimension shown in Fig. 5 of Test Methods and Definitions A 370 and tested in accordance with those test methods.

8.4 To determine conformance with the tension test requirements, an observed value or calculated value shall be rounded off in accordance with Practice E 29 to the nearest 500 psi [5 MPa] for yield point and tensile strength and to the nearest 1 % for elongation and reduction of area.

9. Charpy Impact Requirements

9.1 This section is applicable only to grades 165-150L [1140-1035L], 210-180L [1450-1240L], and 260-210L [1795-1450L].

NOTE 1—Other grades may be ordered to charpy impact test requirements in accordance with Supplementary Requirement S9 of Specification A 781/A 781M.

9.2 The notched bar impact properties of each heat shall be determined by testing one set of three Charpy V-notch impact specimens at −40° ± 2°F [−40° ± 1°C]. The energy value of the three specimens shall not be less than shown in Table 3.

TABLE 3 Impact Requirements

Grade	165-150L [1140-1035L]	210-180L [1450-1240L]	260-210L [1795-1450L]
Impact Requirements Charpy V-notch Energy value, ft·lbf [J], min value for two specimens and minimum average of three specimens	20 [27]	15 [20]	6 [8]
Energy value, ft·lbf [J], min for single specimen	16 [22]	12 [16]	4 [5]

9.3 Test coupons and specimens shall conform to the requirements specified in Section11.

9.4 Impact test specimens shall be machined to the form and dimensions shown in Test Methods and Definitions A 370, Type A, Charpy V-notch specimen, Fig. 11, and tested in accordance with those test methods.

10. Retests

10.1 If the results of the tensile or charpy tests do not conform to the requirements specified, heat-treated castings may, at the manufacturer's option, be reheat treated. Testing after reheat treatment shall consist of the full number of specimens complying with the specification or order.

11. Test Coupons and Specimens

11.1 Test bars shall be poured from the same heat as the castings represented. Test coupons may be cast integrally with the castings or as separate blocks similar to those shown in Fig. 1 of Specification A 781/A 781M.

11.1.1 In the case of quenched and tempered castings where the ruling section of the casting exceeds three inches, supplementary requirement S 15 of Specification A 781/A 781M shall apply.

11.2 The bar from which the test piece is taken shall be heat treated in production furnaces with the castings or to the same procedure as the castings it represents.

11.2.1 When the bar from which the test piece is taken is not heat treated as part of the same heat treatment load as the casting(s) it qualifies, the austenitizing (or solution, if applicable) temperatures for the bar shall be within 25°F of those for the casting(s). The tempering temperature for the bar shall be no higher than 25°F above that of the casting(s) and no higher than permitted by the heat treatment procedure for the material. The cycle time at each temperature shall not exceed that for the casting(s).

11.3 Test specimens may be cut from heat-treated castings, at the producer's option, instead of from test bars.

11.4 If any specimen shows defective machining, or exhibits flaws, it may be discarded and another substituted from the same heat.

12. Repair by Welding

12.1 Weld repairs shall be inspected to the same quality standards that are used to inspect the castings. When castings are produced with Supplementary Requirement S1 specified, weld repairs shall be inspected by magnetic particle examination to the same standards that are used to inspect the castings. When castings are produced with Supplementary Requirement S2 specified, weld repairs in which the depth of the cavity prepared for repair welding exceeds 20 % of the wall thickness or 1 in. [25 mm], whichever is smaller, or in which the cavity prepared for welding is greater than approximately 10 in.^{2}[65 cm^2], shall be radiographed to the same standards that are used to inspect the castings.

12.2 Welds exceeding 20 % of the wall thickness or 1 in. [25 mm], whichever is smaller, or exceeding approximately 10 in.^{2} [65 cm^2] in area, shall be given a suitable stress relief or heat treatment.

13. Rehearing

13.1 Tested samples representing rejected material shall be held for two weeks from the date of the test report. In case of dissatisfaction with the results of the tests, the manufacturer may make claim for a rehearing within that time.

14. Keywords

14.1 alloy steel; carbon steel; castings; high strength steel; martensitic stainless steel; steel castings; structural castings

SUPPLEMENTARY REQUIREMENTS

The following supplementary requirements shall not apply unless specified in the purchase order. A list of standardized supplementary requirements for use at the option of the purchaser is included in Specification A 781/A 781M. Those which are ordinarily considered suitable for use with this specification are given below together with additional supplementary requirements that are applicable only to this specification. Other supplementary requirements enumerated in Specification A 781/A 781M may be used with this specification upon agreement between the manufacturer and purchaser.

S1. Magnetic Particle Examination.

S2. Radiographic Examination.

S6. Certification.

S8. Marking.

S9. Charpy Impact Test

S9.1 Charpy impact test properties shall be determined on each heat from a set of three Charpy V-notch specimens made from a test coupon in accordance with Test Methods and Definitions A 370 and tested at a test temperature agreed upon between the manufacturer and purchaser. The acceptance requirements shall be either energy absorbed, lateral expansion, or percent shear area, or all three, and shall be that agreed upon by the manufacturer and purchaser. Test specimens shall be prepared as Type A and tested in accordance with Test Methods and Definitions A 370.

S9.2 *Absorbed Energy*—Average energy value of three specimens shall be not less than specified, with not more than one value permitted to fall below the minimum specified and no value permitted below the minimum specified for a single specimen.

S9.3 *Lateral Expansion*—Lateral expansion value shall be agreed upon between the manufacturer and purchaser.

S9.4 *Percent Shear Area*—Percent shear area shall be agreed upon between the manufacturer and purchaser.

S15. Alternate Tension Test Coupons and Specimen Locations for Castings (in lieu of Test Bars Poured from Special Blocks).

SUMMARY OF CHANGES

Committee A01 has identified the location of selected changes to this standard since the last issue (A 148/A 148M – 02) that may impact the use of this standard).

(*1*) Added the UNS Numbers to the grades inTable 1.

Designation: A 159 – 83 (Reapproved 2001)

Standard Specification for Automotive Gray Iron Castings[1]

This standard is issued under the fixed designation A 159; 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. This specification replaces Federal specification AA-I-653A.

1. Scope

1.1 This specification applies to gray iron castings, cast in sand molds, used in the products of the automobile, truck, tractor, and allied industries.

1.2 The values stated in inch-pound units are to be regarded as the standard.

2. Referenced Documents

2.1 The following documents of the issue in effect on the date of material procurement form a part of this specification to the extent referenced herein:

2.2 *ASTM Standards:*

A 247 Test Method for Evaluating the Microstructure of Graphite in Iron Castings[2]

E 10 Test Method for Brinell Hardness of Metallic Materials[3]

2.3 *Military Standard:*

MIL-STD-129 Marking for Shipment and Storage[4]

2.4 *Federal Standard:*

Fed. Std. No. 123 Marking for Shipment (Civil Agencies)[4]

3. Grades

3.1 The specified grades, hardness ranges, and metallurgical description are shown in Table 1 and Table 2 and in Section 9.

4. Ordering Information

4.1 Orders for materials under this specification shall include the following information:

4.1.1 ASTM designation,

4.1.2 Grade designation of gray iron required (3.1),

4.1.3 If special heat treatment is required (see Section 6),

4.1.4 If special microstructure requirements are needed (see Section 7),

4.1.5 Surface where hardness test is to be performed (see 9.4),

4.1.6 Depth and surface hardness of case required (see 9.6),

4.1.7 Inspection lot and sampling plan required (see Section 10),

4.1.8 If additional requirements are needed (see 11.3), and

4.1.9 Whether special packaging and marking is required (see Section 12).

TABLE 1 Grades of Gray Iron

Grade	Casting Hardness Range	Description
G1800	HB 187 max 4.4 BID min or as agreed[A]	ferritic-pearlitic
G2500	HB 170-229 4.6–4.0 BID or as agreed[A]	pearlitic-ferritic
G3000	HB 187-241 4.4–3.9 BID or as agreed[A]	pearlitic
G3500	HB 207-255 4.2–3.8 BID or as agreed[A]	pearlitic
G4000	HB 217-269 4.1–3.7 BID or as agreed[A]	pearlitic

[A] Brinell impression diameter (BID) is the diameter in millimetres of the impression of a 10 mm ball at 3000-kg load.

5. Hardness

5.1 The foundry shall exercise the necessary controls and inspection techniques to ensure compliance with the specified hardness range, Brinell hardness shall be determined in accordance with Test Method E 10, after sufficient material has been removed from the casting surface to ensure representative hardness readings. The 10-mm ball and 3000-kg load shall be used unless otherwise agreed upon. The area or areas on the casting where hardness is to be checked shall be established by agreement between supplier and purchaser and shall be shown on the drawing.

6. Heat Treatment

6.1 Unless otherwise specified, castings of Grades G1800 and G2500 may be annealed in order to meet the desired hardness range.

6.2 Appropriate heat treatment for removal of residual stresses, or to improve machinability or wear resistance may be specified by agreement between supplier and purchaser.

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[1] This specification is under the jurisdiction of ASTM Committee A04 on Iron Castings and is the direct responsibility of Subcommittee A04.01 on Gray and White Iron Castings.

Current edition approved July 29, 1983. Published September 1983. Originally published as A 159 – 35 T. Last previous edition A 159 – 77.

[2] *Annual Book of ASTM Standards*, Vol 01.02.

[3] *Annual Book of ASTM Standards*, Vol 03.01.

[4] Available from Standardization Documents Order Desk, Bldg. 4 Section D, 700 Robbins Ave., Philadelphia, PA 19111-5094, Attn: NPODS.

TABLE 2 Brake Drums and Clutch Plates for Special Service

Grade	Carbon min, %[A]	Casting Hardness	Microstructure	
			Graphite	Matrix
G2500a	3.40	HB 170-229 4.6–4.0 BID or as agreed	Type VII, size 2–4[B] A distribution	lamellar pearlite ferrite if present not to exceed 15%
G3500b	3.40[C]	HB 207-255 4.2–3.8 BID or as agreed	Type VII, size 3–5[B] A distribution	lamellar pearlite ferrite or carbide if present not to exceed 5%
G3500c	3.50[C]	HB 207-255 4.2–3.8 BID or as agreed	Type VII, size 3–5[B] A distribution	lamellar pearlite ferrite or carbide, if present not to exceed 5%

[A]The chemical analysis for total carbon shall be made on chilled pencil-type specimens or from thin wafers approximately 1/32 in. (0.8 mm) thick cut from test coupons. Drillings are not reliable because of the probable loss of graphite.
[B]See Method A 247.
[C]Grades G 3500b and G 3500c normally require alloying to obtain the specified hardness at the high carbon levels specified.

7. Microstructure

7.1 The microstructure shall consist of flake graphite in a matrix of ferrite or pearlite or mixtures thereof.

7.2 As graphite size and shape somewhat affect hardness-strength ratio and other properties, the type size and distribution of the graphite flakes at a designated location on the casting may be specified by agreement between supplier and purchaser in accordance with Method A 247.

7.3 Unless otherwise specified, the matrix microstructure of castings covered by this specification shall be substantially free of primary cementite. Castings in Grades G1800 and G2500 may have a matrix of ferrite or pearlite or both. Grades G3000, G3500, and G4000 shall be substantially pearlite in matrix structure.

8. Heavy-Duty Brake Drums and Clutch Plates

8.1 These castings are considered as special cases and are covered in Table 2.

9. Alloy Gray Iron Automotive Camshafts

9.1 These castings are considered as special cases.

9.2 *Grade Designation*—G4000d.

9.3 *Chemistry*—Alloy gray iron camshafts shall contain alloys within the following range or as agreed upon between supplier and purchaser.

Chromium	0.85–1.25 %
Molybdenum	0.40–0.60 %
Nickel	as agreed

9.4 *Casting Hardness*—HB 241-321 determined on a bearing surface as agreed by supplier and purchaser.

9.5 *Microstructure*—Extending 45° on both sides of the centerline of the cam nose and to a minimum depth of 1/8 in. (3.2 mm), the surface shall consist of primary carbides (of acicular or cellular form or a mixture thereof) and graphite in a fine pearlitic matrix. The graphite shall be Type VII A and E distribution, 4 to 7 flake size in accordance with Method A 247. The amount of primary carbides and location at which the structure is checked shall be a matter of agreement between the supplier and the purchaser.

9.6 *Selective Hardening*—The cam areas of camshaft casting are usually selectively hardened by flame or induction hardening by the supplier. The depth and surface hardness of the hardened case shall be as agreed upon between supplier and purchaser.

10. Quality Assurance Provisions

10.1 *Responsibility for Inspection*—Unless otherwise specified in the contract or purchase order, the producer is responsible for the performance of all inspection and tests requirements specified in 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 specified herein, unless disapproved by the purchaser. The purchaser shall have the right to perform any of the inspection and tests set for in this specification where such inspections are deemed necessary to assure that material conform to prescribed requirements.

10.2 *Lot*—For the purpose of inspection, lot and sampling plans shall be agreed upon between the purchaser and the producer.

11. General

11.1 Castings furnished to this specification shall be representative of good foundry practice and shall conform to dimensions and tolerances specified on the casting drawing.

11.2 Minor imperfections usually not associated with the structural function may occur in castings. These are often repairable but repairs shall be made only where allowed by the purchaser and only by approved methods.

11.3 Additional casting requirements may be agreed upon by purchaser and supplier. These should appear as product specifications on the casting or part drawing.

12. Preparation for Delivery

12.1 Unless otherwise specified in the contract or purchase order, castings shall be cleaned, preserved, and packaged in accordance with supplier's standard commercial practice.

12.2 *Government Procurement*—When specified for Government procurement, castings shall be marked for shipment in accordance with MIL-STD-129 for military procurement and Fed. Std. No. 123 for civil agency procurement.

APPENDIX

(Nonmandatory Information)

X1. GRAY IRON

X1.1 Definition

X1.1.1 *gray iron*—a cast iron in which the graphite is present as flakes instead of temper carbon nodules as in malleable iron or small spherulites as in ductile iron.

X1.2 Chemical Composition

X1.2.1 The ranges in composition generally employed in producing the various grades of most automotive gray iron castings are shown in Table X1.1. The composition ranges for such special applications as heavy duty brake drums and clutch plates and camshafts are shown in Table X1.2 and Table X1.3, respectively. The contents of certain elements for these applications are critical in terms of service requirements and the ranges are specified in the standard.

X1.2.2 The specific composition range for a given grade may vary according to the prevailing or governing section of the castings being produced.

X1.2.3 Alloying elements such as chromium, copper, nickel, tin, molybdenum, or other elements may be employed to meet the specified hardness or microstructural requirements or to provide the properties needed for particular service conditions.

TABLE X1.2 Usual Composition of Brake Drums and Clutch Plates for Special Service

Chemical Composition, %	Grade G2500a	Grade G3500b	Grade G3500c
Carbon, total (mandatory)	3.40 min	3.40 min	3.50 min
Silicon (as required)	1.60–2.10	1.30–1.80	1.30–1.80
Manganese (as required)	0.60–0.90	0.60–0.90	0.60–0.90
Sulfur, max	0.12	0.12	0.12
Phosphorus, max	0.15	0.15	0.15
Alloys	as required	as required	as required

TABLE X1.3 Usual Chemical Composition of Alloy Gray Iron Automotive Camshafts

	Grade G4000d, %
Total carbon	3.10–3.60
Silicon	1.95–2.40
Manganese	0.60–0.90
Phosphorus	0.10 max
Sulfur	0.15 max
Chromium	0.85–1.25
Molybdenum	0.40–0.60
Nickel	0.20–0.45 optional
Copper	residual

X1.3 Microstructure

X1.3.1 The microstructure of the various grades of gray iron are generally a mixture of flake graphite in a matrix of ferrite, pearlite, or tempered pearlite. The relative amounts of each of these constituents depends on the analysis of the iron, casting design, and foundry techniques as they affect solidification and subsequent cooling rate and heat treatments if any.

X1.3.2 The distribution and size of graphite flakes like the matrix structure of gray iron depends greatly on the solidification rate and cooling rate of the casting. If a section solidifies very rapidly an appreciable amount of carbide causing a mottled fracture or chilled corners can be present. If a section cools slowly, as in a massive heavy-section casting, an appreciable amount of ferrite may be present. In like manner, light sections will contain small graphite flakes while graphite will form in much larger flakes if the same iron is poured into a heavy casting.

X1.3.3 For these reasons the strength and hardness of gray iron are greatly influenced by the rate of cooling during and after solidification, the design and nature of the mold and the casting, and by other factors such as inoculation practice in addition to the composition of the iron.

X1.3.4 Alloying with nickel, chromium, molybdenum, tin, copper or other alloys usually promotes a more stable pearlitic structure and is often done to obtain increased hardness, strength, and wear resistance especially in heavy sections subjected to severe service.

X1.3.5 Alloying is sometimes used to obtain structures containing a controlled percentage of carbides as in camshaft or valve lifter castings.

X1.3.6 Primary carbides or pearlite or both, can be decomposed by appropriate heat treatment. Gray irons of suitable composition and structure can be hardened by liquid quenching or by flame or induction selective hardening.

X1.4 Mechanical Properties

X1.4.1 The mechanical properties listed in Table X1.4 can

TABLE X1.1 Typical Base Compositions, %

Grade	Carbon	Silicon	Manganese	Sulfur, max	Phosphorus, max	Approximate Carbon Equivalent
G1800	3.40–3.70	2.30–2.80	0.50–0.80	0.15	0.25	4.25–4.5
G2500	3.20–3.50	2.00–2.40	0.60–0.90	0.15	0.20	4.0–4.25
G3000	3.10–3.40	1.90–2.30	0.60–0.90	0.15	0.15	3.9–4.15
G3500	3.00–3.30	1.80–2.20	0.60–0.90	0.15	0.12	3.7–3.9
G4000	3.00–3.30	1.80–2.10	0.70–1.00	0.15	0.10	3.7–3.9 (usually alloyed)

TABLE X1.4 Mechanical Properties for Design Purposes

Grade	Hardness Range[A]	Tensile Strength, min, psi (kgf/mm^2)	Transverse Strength, min, lb (kg)[B]	Deflection, min, in. (mm)[B]
G1800	HB 143-187 5.0–4.4 BID	18 000 (14)	1720 (780)	0.14 (3.6)
G2500	HB 170-229 4.6–4.0 BID	25 000 (17.5)	2000 (910)	0.17 (4.3)
G3000	HB 187-241 4.4–3.9 BID	30 000 (21)	2200 (1000)	0.20 (5.1)
G3500	HB 207-255 4.2–3.8 BID	35 000 (24.5)	2450 (1090)	0.24 (6.1)
G4000	HB 217-269 4.1–3.7 BID	40 000 (28)	2600 (1180)	0.27 (6.9)

[A]Brinell impression diameter (BID) is the diameter in millimetres of the impression of a 10-mm ball at 3000-kg load.
[B]See Method A 438 for information concerning the B transverse test bar and the transverse test.

be used for design purposes. However, the suitability of a particular grade for an intended application is best determined by laboratory or service tests. Typical mechanical properties for such specialized applications as heavy-duty brake drums and clutch plates are shown in Table X1.5.

X1.5 Application of Gray Iron in Automotive Castings *(see* Table X1.6*)*

X1.5.1 The graphite flakes in gray iron give this metal many desirable properties. These include excellent machinability, high thermal conductivity, vibration dampening properties, and resistance to wear or scuffing. Due to its low freezing temperature for a ferrous alloy, high fluidity, and low shrinkage properties it is more readily cast in complex shapes than other ferrous metals.

X1.5.2 Gray iron castings of the lower-strength Grades G1800 and G2500 are characterized by excellent machinability, high damping capacity, low modulus of elasticity, and comparative ease of manufacture. When higher strength is obtained by a reduction in the carbon or carbon equivalent, castings are more difficult to machine, have lower damping capacity, higher modulus of elasticity, and may be more difficult to manufacture.

X1.6 Special Applications of Gray Iron

X1.6.1 *Heavy-Duty Brake Drums and Clutch Plates*

Automotive brake drums and clutch plates for heavy-duty service are considered as special cases. Typical chemical analyses and mechanical properties are listed in Table X1.2 and

TABLE X1.5 Typical Mechanical Properties

Mechanical Properties	Grade G2500a	Grade G3500b	Grade G3500c
Tensile strength, min:			
psi	25 000	35 000	35 000
kgf/mm^2	17.5	24.5	24.5
Transverse strength, min:			
lb	2000	2400	2400
kg	910	1090	1090
Deflection, min:			
in.	0.17	0.24	0.24
mm	4.3	6.1	6.1
Hardness, HB	170–229	207–255	207–255
Brinell indention diameter, mm	4.6–4.0	4.2–3.8	4.2–3.8

TABLE X1.6 Typical Applications of Gray Iron for Automotive Castings

Grade	General Data
G1800	Miscellaneous soft iron castings (as cast or annealed) in which strength is not of primary consideration. Exhaust manifolds may be made of this grade of iron, alloyed or unalloyed. These may be annealed castings for exhaust manifolds in order to avoid growth and cracking due to heat.
G2500	Small cylinder blocks, cylinder heads, air cooled cylinders, pistons, clutch plates, oil pump bodies, transmission cases, gear boxes, clutch housings, and light-duty brake drums.
G3000	Automobile and diesel cylinder blocks, cylinder heads, flywheels, differential carries castings, pistons, medium-duty brake drums, and clutch plates.
G3500	Diesel engine blocks, truck and tractor cylinder blocks and heads, heavy flywheels, tractor transmission cases, and heavy gear boxes.
G4000	Diesel engine castings, liners, cylinders, and pistons.

Table X1.5. Heavy-duty irons for such service require high carbon contents for resistance to thermal shock and to minimize heat checking. To maintain strength levels specified for Grades G3500b and G3500c normally requires alloying due to their high carbon contents.

X1.6.2 *Microstructure*

See Table 2 for microstructure requirements.

X1.6.3 *Suggested Usage*

Following are suggested grades for brake drums and clutch plates according to types of service:

Grade	Suggested Usage
G2500a	Brake drums and clutch plates for moderate service requirements, where high carbon iron is desired to minimize heat checking (see Section 8).
G3500b	Brake drums and clutch plates for heavy-duty service where both resistance to heat checking and higher strength are definite requirements (see Section 8).
G3500c	Extra-heavy-duty service brake drums (see Section 8).

X1.7 Automotive Camshafts

X1.7.1 Alloy gray iron automotive camshafts are also considered as special cases. The chemical composition of such castings is usually within the range given in Table X1.3 but may be modified by mutual agreement.

X1.7.2 In casting hardenable iron from camshafts, the aim is to obtain a suitable microstructure in critical locations of the casting and balance the composition to obtain response to induction or flame-hardening treatment. These depend not only on the chemistry of the iron but even more on the cross section of the casting and details of melting practice. In making a given casting, it is recognized that the foundry will find it necessary to adjust the chemistry to narrower limits within the range of analysis in Table X1.3.

X1.7.3 As the performance of an automotive camshaft is determined by the microstructure and hardness, producers do not normally use tensile or transverse tests for quality control purposes. Camshaft iron with chemistry as given in Table X1.3 would be expected to have the following minimum mechanical properties.

Tensile strength, min:	
psi	40 000
kgf/mm^2	28
Transverse strength, min:	
lb	2600
kg	1180
Deflection, min:	
in.	0.27
mm	6.9
Hardness, HB	241–321
BID	3.9–3.4

X1.7.4 *Microstructure*——See 9.5 for microstructure requirements for Grade G4000d alloy cast iron camshafts.

X1.8 Additional Information

X1.8.1 Additional information concerning gray iron castings, their properties and uses can be obtained from the following sources:

(*1*) *Metals Handbook,* 8th Edition, Vols 1, 2, and 5, published by the American Society for Metals, Metals Park, Ohio.
(*2*) *Cast Metals Handbook* published by the American Foundrymen's Society, Des Plaines, Ill.
(*3*) Gray & Ductile Iron Castings Handbook (1971) published by Gray and Ductile Iron Founders Society, Cleveland, Ohio.
(*4*) *Physical and Engineering Properties of Cast Iron,* Angus, British Cast Iron Research Association (1960), Alvechurch, Birmingham, England.
(*5*) *Engineering Data on Gray Cast Irons,* G. N. J. Gilbert British Cast Iron Research Association (1968), Alvechurch, Birmingham, England.
(*6*) *Gray, Ductile and Malleable, Iron Castings Current Capabilities. ASTM STP 455,* (1969).

Designation: A 197/A 197M – 00

Standard Specification for Cupola Malleable Iron[1]

This standard is issued under the fixed designation A 197/A 197M; 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 malleable irons for castings made by the cupola process.

1.2 Without knowledge of casting geometry and process details, quantitative relationship cannot be stated between the properties of the iron in the various locations of a casting and those of a test bar cast from the same iron.

1.3 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.

2. Referenced Documents

2.1 *ASTM Standards:*

A 197M Specification for Cupola Malleable Iron (Metric)[2]

A 247 Test Method for Evaluating the Microstructure of Graphite in Iron Castings[2]

A 644 Terminology Relating to Iron Castings[2]

E 8 Test Methods for Tension Testing of Metallic Materials[3]

3. Terminology

3.1 *Definitions*—Definitions for many terms common to iron castings are found in Terminology A 644.

4. Classification

4.1 Iron produced for castings ordered under this specification is classified in a single grade and is qualified by tests on separately cast test bars. Separately cast test bars shall be poured from the same lot of iron as the castings they represent and shall be heat treated with those castings.

5. Ordering Information

5.1 The purchase order for castings ordered under this specification shall state the specification designation and the year in which the specification was issued.

5.2 Any options or special additions to the basic requirements of this specification shall be clearly and fully stipulated.

6. Chemical Composition

6.1 The chemical composition of the iron shall be such as to produce the mechanical properties required by this specification.

7. Mechanical Requirements

7.1 Factors influencing the properties of castings and their relationship to those of test specimens and separate test castings are discussed in Appendix X1.

7.2 *Tensile Test*:

7.2.1 *Tensile Test Specimens*:

7.2.1.1 The tensile test specimens shall be cast to the form and dimensions shown in Fig. 1 and Fig. 2 using the same kind of molding material used for the production castings.

7.2.1.2 All test specimens shall be suitably identified with the designation of the pour period.

7.2.1.3 All test specimens shall be heat treated in the same production furnace and for the same cycles as the castings they represent.

7.2.2 *Tensile Test Method*:

7.2.2.1 Perform the tensile test on unmachined specimens.

7.2.2.2 *Gage Length*—The gage length of the standard tensile specimen shall be 2.00 ± 0.01 in. [50.0 ± 0.03 mm].

7.2.2.3 *Cross-Sectional Area*—The diameter used to compute the cross-sectional area shall be the average between the largest and smallest diameters in that section of the 2-in. [50 mm] gage length having the smallest diameter and shall be measured to the nearest 0.001 in. [0.02 mm]. No cast bar having a mean diameter less than 0.590 in. [15 mm] shall be accepted for test.

7.2.2.4 *Speed of Testing*—After reaching a stress equivalent to approximately half of the anticipated yield stress, the speed of the moving head of the testing machine shall not exceed 0.50 in./min [12.5 mm/min] through the breaking load.

7.2.2.5 *Yield Strength*—While the values for yield point and yield strength are not identical, they are sufficiently close for most applications to be used interchangeably. They shall be determined by an approved techniques described in Test Methods E 8 or by an equivalent method. If determined as yield strength, that stress producing an extension under load of

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[1] This specification is under the jurisdiction of ASTM Committee A-4 on Iron Castings and is the direct responsibility of Subcommittee A04.02 on Malleable Iron Castings.

Current edition approved May. 10, 2000. Published May 2000. Originally published as A 197 – 36 T. Last previous edition A 197 – 98.

[2] *Annual Book of ASTM Standards*, Vol 01.02.

[3] *Annual Book of ASTM Standards*, Vol 03.01.

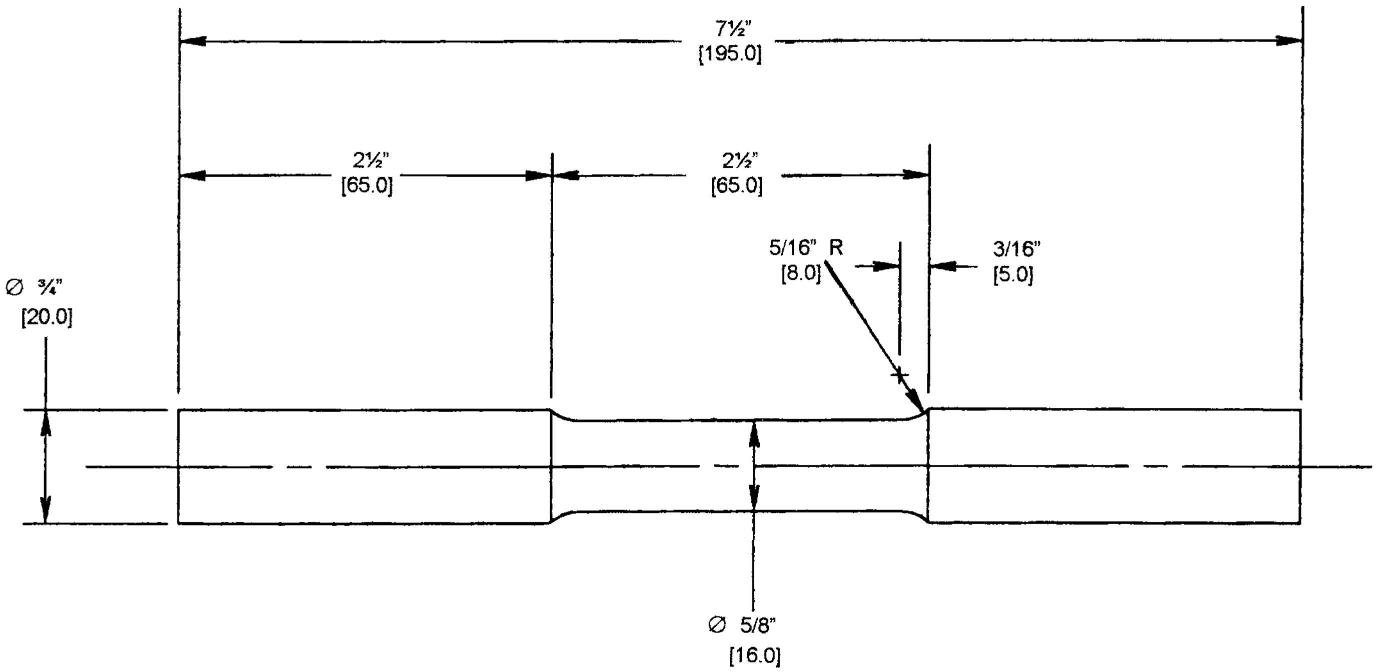
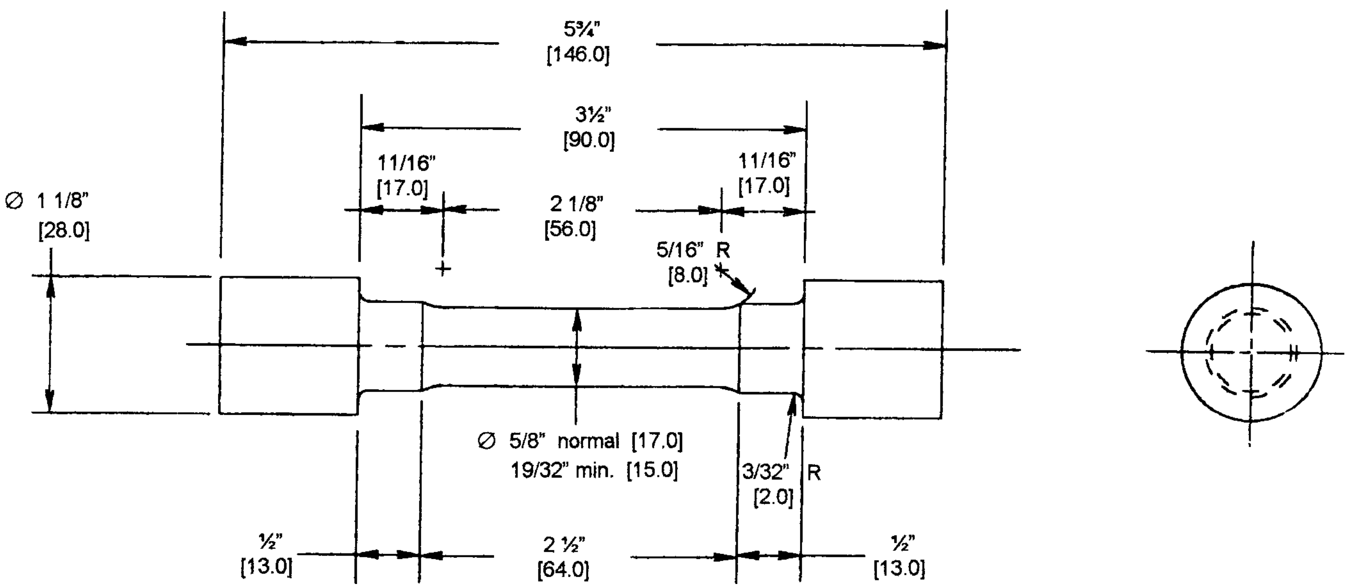


FIG. 1 Tension Test Specimen



NOTE 1—Modifications may be made in the dimensions indicated above for those details of the specimen outside of the gage length as required by testing procedure and equipment.

FIG. 2 Alternative Unmachined Tension Test Specimen

0.01 in. [0.25 mm] over the 2-in. [50 mm] gage length (for example, 0.5 % extension) or an offset of 0.2 % shall be taken as the yield stress, which shall be converted to yield strength by dividing by the original cross-sectional area of the gage length found in accordance with 7.2.2.3. It shall be reported to the nearest 100 psi [1 MPa]. In referee work, yield strength shall be determined at an offset of 0.2 % from the stress strain curve.

7.2.2.6 *Tensile Strength*—The tensile strength shall be the maximum load carried by the specimen during the test divided by the original cross-sectional area of the gage length, as found in accordance with 7.2.2.3. It shall be reported to the nearest 100 psi [1 MPa].

7.2.2.7 *Elongation*—The elongation is the increase in gage length after fracture of a tensile specimen, measured to the nearest 0.01 in. [0.25 mm] expressed as a percentage of the original gage length. It shall be reported to the nearest 0.5 %.

7.2.3 *Number of Tests and Retests*:

7.2.3.1 At least three tensile test specimens shall be cast from a representative ladle of iron from each 4-h pour period during which the purchaser's castings were poured.

7.2.3.2 Only one test specimen need be tested to qualify each pour period and heat treatment batch provided the requirements of this specification are met by that test specimen.

7.2.3.3 If after testing, a specimen shows evidence of a defect, another tensile test may be made on a companion specimen. Also, a retest shall be permitted whenever fracture occurs outside the central 50 % of the gage length.

7.2.3.4 If the result of a valid test fails to conform to the requirements of this specification, two retests shall be made. If either of the retest fails to meet the specification, all the castings from the pour period and the heat treat batch represented by these test specimens shall be rejected.

7.2.3.5 If the first test results indicate that a reheat treatment is needed to meet the test requirements, the entire lot of castings and the representative test specimens shall be reheat treated together. Testing shall then be repeated in accordance with 7.2.3.1 through 7.2.3.4.

7.2.4 The results of all tests, including retests, shall be posted in permanent records, that shall state any abnormalities observed during the test and in the fractured ends. Such records shall be kept for at least one year after production of the castings and shall be available for examination by the purchaser or by his authorized representative.

7.2.5 Tensile test results, obtained in accordance with this section, must conform to the requirements of Table 1.

7.2.6 When agreed upon between the manufacturer and the purchaser, tested specimens or unbroken test bars, or both, shall be saved by the manufacturer for a period of three months after the date of the test report.

8. Microstructural Requirements

8.1 The microstructure of the malleable iron shall consist of temper carbon nodules uniformly distributed in a ferritic matrix and shall be free from excessive pearlite, massive carbides, and primary graphite.

8.2 In referee work the metallographic practice recommended in Test Method A 247 shall be followed.

9. Soundness Requirements

9.1 All castings, on visual examination shall be sound and free from obvious shrinkage and porosity.

9.2 If the purchaser requires soundness tests to be performed, it shall be so stated in the purchase agreement and the method and soundness requirements shall be detailed.

10. Dimensional Requirements

10.1 The castings shall conform to the dimensions given on drawings furnished by the purchaser, or to the dimensions established by the pattern equipment supplied by the purchaser.

11. Workmanship, Finish, and Appearance

11.1 The surface of the casting shall be clean, free from sand, and have a workmanlike finish.

12. Identification Marking

12.1 When the size of the casting permits, each casting shall bear the identifying mark of the manufacturer and the part or pattern number at a location shown on the covering drawing and if not shown on the drawing, at such a location at the discretion of the producer that the identification will not interfere with subsequent processing and service of the casting.

12.2 For steam service pressures in excess of 150 psi [1000 KPa], the castings shall be marked with the manufacturer's name or trademark, numerals to indicate the steam service intended, and any other marks that will clearly indicate the maximum service for which the casting is intended. These identifying marks shall be located where they will not interfere with service of the casting.

TABLE 1 Tensile Test Requirements

Tensile strength, min, psi [MPa]	40 000 [275]
Yield strength, min, psi [MPa]	30 000 [200]
Elongation in 2 in. [50 mm], min, %	5 [5]

13. Responsibility for Inspection

13.1 Unless otherwise specified in the contract or purchase order, the manufacturer shall be responsible for carrying out all the tests and inspections required by this specification, using his own or other reliable facilities. The manufacturer shall maintain complete records of all such test and inspections. Such records shall be available for review by the purchaser.

13.2 The manufacturer shall afford the purchaser's inspector all reasonable facilities necessary to satisfy that the material is being produced and furnished in accordance with the applicable specification. Foundary inspection by the purchaser shall not interfere unnecessarily with the manufacturer's operations.

13.3 The purchaser reserves the right to perform any tests and inspections set forth in the specification where such tests and inspections are deemed necessary to assure that compliance with this specification is being met.

14. Rejection and Rehearing

14.1 Any casting or lot of castings failing to comply with the requirements of this specification may, where possible, be reprocessed, retested, and reinspected. If the tests and inspections on the reprocessed casting(s) show compliance with this specification, the castings shall be acceptable; if they do not, they shall be rejected.

14.2 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.

15. Certification

15.1 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 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.

16. Packaging and Package Marking

16.1 Unless otherwise stated in the contract or order, the cleaning, preservation, and packing of casting for shipment shall be in accordance with the manufacturer's commercial practice. Packaging and package marking shall also be adequate to identify the contents and to ensure acceptance and safe delivery by the carrier for the mode of transportation employed.

APPENDIX

(Nonmandatory Information)

X1. MECHANICAL PROPERTIES OF CASTINGS

X1.1 The mechanical properties of malleable iron castings are influenced by a number of factors, that include the cooling rate during solidification, chemical composition, the heat treatment, the design of the casting, section thickness, and the location and effectiveness of gates, risers, and chills.

X1.2 Because of the complexity of these factors in influencing the properties of the final product, no precise quantitative relationship can be stated between the properties of the iron in various locations of a given casting or between the properties of a casting and those of a test specimen cast from the same iron. When such a relationship is important and must be known for a specific application, it may be determined by appropriate experimentation.

X1.3 The specimen specified in 7.2.1.1 as the standard tensile test bar for malleable iron has a ⅝-in. [16 mm] diameter test section that reasonably represents a typical section of the general run of malleable iron castings. Furthermore, the initial freezing and malleable irons as homogeneous white iron, together with the heat treatment that is inherent in the manufacture of malleable iron, tends to reduce the section-sensitivity effect. Therefore, where experimentation into precise properties within a given casting would be unfeasible, this standard test bar, made like any typical casting, should provide a practical approximation of the properties that can be expected in any average sound malleable iron castings. When the number of standard test bars to determine specification compliance is insufficient, the manufacturer may wish to seek purchaser approval by comparing tension test results from the casting in question with those of two other castings having the same design and test bar location and from which acceptable standard bar results were obtained.

X1.4 If malleable iron castings are welded, the microstructure of the iron is markedly affected, particularly in the heat-affected zone. Since this may adversely affect the properties of the casting, the welding of malleable iron castings should be done under strict metallurgical control, followed by appropriate post-weld heat treatment, to minimize the substantial reductions in ductility, impact resistance, and machinability that could result, particularly in the vicinity of the weldment. Nevertheless, it is generally considered inadvisable to join castings to similar castings or to other materials, by fusion welding out in the field, or in manufactured assemblies, without fully testing the entire completed part.

Endorsed by Manufacturers Standardization Society
of the Valve and Fittings Industry
Endorsed by American Foundrymen's Society
Used in USDOE-NE Standards

Standard Specification for Steel Castings, Carbon, Suitable for Fusion Welding, for High-Temperature Service[1]

This standard is issued under the fixed designation A 216/A 216M; 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[2] covers carbon steel castings for valves, flanges, fittings, or other pressure-containing parts for high-temperature service and of quality suitable for assembly with other castings or wrought-steel parts by fusion welding.

1.2 Three grades, WCA, WCB, and WCC, are covered in this specification. Selection will depend upon design and service conditions, mechanical properties, and the high temperature characteristics.

1.3 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 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 488/A 488M Practice for Steel Castings, Welding, Qualifications of Procedures and Personnel[3]

A 703/A 703M Specification for Steel Castings, General Requirements, for Pressure-Containing Parts[3]

E 165 Test Method for Liquid Penetrant Examination[4]

E 709 Guide for Magnetic Particle Examination[4]

2.2 *Manufacturers' Standardization Society of the Valve and Fittings Industry Standard:*

SP 55 Steel Castings for Valve, Flanges, and Fittings, and Other Components (Visual Method)[5]

3. General Conditions for Delivery

3.1 Material furnished to this specification shall conform to the requirements of Specification A 703/A 703M, including any supplementary requirements that are indicated in the purchase order. Failure to comply with the general requirements of Specification A 703/A 703M constitutes nonconformance with this specification. In case of conflict between the requirements of this specification and Specification A 703/A 703M, this specification shall prevail.

4. Ordering Information

4.1 The inquiry and order should include or indicate the following:

4.1.1 A description of the casting by pattern number or drawing (dimensional tolerances shall be included on the casting drawing),

4.1.2 Grade of steel,

4.1.3 Options in the specification, and

4.1.4 The supplementary requirements desired including the standards of acceptance.

5. Heat Treatment

5.1 All castings shall receive a heat treatment proper to their design and chemical composition.

5.2 Castings shall be furnished in the annealed, or normalized, or normalized and tempered condition unless Supplementary Requirement S15 is specified.

5.3 Heat treatment shall be performed after castings have been allowed to cool below the transformation range.

6. Temperature Control

6.1 Furnace temperatures for heat treating shall be effectively controlled by pyrometer.

7. Chemical Composition

7.1 The steel shall conform to the requirements as to chemical composition prescribed in Table 1.

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[1] This specification is under the jurisdiction of ASTM Committee A01 on Steel, Stainless Steel, and Related Alloys and is the direct responsibility of Subcommittee A01.18 on Castings.

Current edition approved April 10, 2003. Published April 2003. Originally approved in 1939. Last previous edition approved in 1998 as A 216/A 216M – 93 (1998).

[2] For ASME Boiler and Pressure Vessel Code applications, see related Specification SA-216/SA-216M in Section II of that code.

[3] *Annual Book of ASTM Standards*, Vol 01.02.

[4] *Annual Book of ASTM Standards*, Vol 03.03.

[5] Available from Manufacturers' Standardization Society of the Valve and Fittings Industry, 127 Park St., N.E. Vienna, VA 22180.

TABLE 1 Chemical Requirements

Element	Composition, %		
	Grade WCA	Grade WCB	Grade WCC
Carbon, max	0.25[A]	0.30[B]	0.25[C]
Manganese, max	0.70[A]	1.00[B]	1.20[C]
Phosphorus, max	0.04	0.04	0.04
Sulfur, max	0.045	0.045	0.045
Silicon, max	0.60	0.60	0.60
Specified residual elements:			
Copper, max	0.30	0.30	0.30
Nickel, max	0.50	0.50	0.50
Chromium, max	0.50	0.50	0.50
Molybdenum, max	0.20	0.20	0.20
Vanadium, max	0.03	0.03	0.03
Total of these specified residual elements, max[D]	1.00	1.00	1.00

[A] For each reduction of 0.01 % below the specified maximum carbon content, an increase of 0.04 % manganese above the specified maximum will be permitted up to a maximum of 1.10 %.

[B] For each reduction of 0.01 % below the specified maximum carbon content, an increase of 0.04 % Mn above the specified maximum will be permitted up to a maximum of 1.28 %.

[C] For each reduction of 0.01 % below the specified maximum carbon content, an increase of 0.04 % manganese above the specified maximum will be permitted to a maximum of 1.40 %.

[D] Not applicable when Supplementary Requirement S11 is specified.

8. Tensile Requirements

8.1 Steel used for the castings shall conform to the requirements as to tensile properties prescribed in Table 2.

TABLE 2 Tensile Requirements

	Grade WCA	Grade WCB	Grade WCC
Tensile strength, ksi [MPa]	60 to 85 [415 to 585]	70 to 95 [485 to 655]	70 to 95 [485 to 655]
Yield strength,[A] min, ksi [MPa]	30 [205]	36 [250]	40 [275]
Elongation in 2 in. [50 mm], min, %[B]	24	22	22
Reduction of area, min, %	35	35	35

[A] Determine by either 0.2 % offset method or 0.5 % extension-under-load method.

[B] When ICI test bars are used in tensile testing as provided for in Specification A 703/A 703M, the gage length to reduced section diameter ratio shall be 4 to 1.

9. Quality

9.1 The surface of the casting shall be examined visually and shall be free of adhering sand, scale, cracks, and hot tears. Other surface discontinuities shall meet the visual acceptance standards specified in the order. Visual Method SP-55 or other visual standards may be used to define acceptable surface discontinuities and finish. Unacceptable visual surface discontinuities shall be removed and their removal verified by visual examination of the resultant cavities.

9.2 When additional inspection is desired, Supplementary Requirements S4, S5, and S10 may be ordered.

9.3 The castings shall not be peened, plugged, or impregnated to stop leaks.

10. Repair by Welding

10.1 Repairs shall be made using procedures and welders qualified under Practice A 488/A 488M.

10.2 Weld repairs shall be inspected to the same quality standards that are used to inspect the castings. When castings are produced with Supplementary Requirement S4 specified, weld repairs shall be inspected by magnetic particle examination to the same standards that are used to inspect the castings. When castings are produced with Supplementary Requirement S5 specified, weld repairs on castings that have leaked on hydrostatic test, or on castings in which the depth of any cavity prepared for repair welding exceeds 20 % of the wall thickness or 1 in. [25 mm], whichever is smaller, or on castings in which any cavity prepared for welding is greater than approximately 10 in.^{2} [65 cm^2], shall be radiographed to the same standards that are used to inspect the castings.

10.3 Castings containing any repair weld that exceeds 20 % of the wall thickness or 1 in. [25 mm], whichever is smaller, or that exceeds approximately 10 in.^{2} [65 cm^2] in area, or that was made to correct hydrostatic test defects, shall be stress relieved or heat-treated after welding. This mandatory stress relief or heat-treatment shall be in accordance with the procedure qualification used.

11. Keywords

11.1 carbon steel; high temperature; pressure containing parts; steel castings

SUPPLEMENTARY REQUIREMENTS

The following supplementary requirements shall not apply unless specified in the purchase order. A list of standardized supplementary requirements for use at the option of the purchaser is included in Specification A 703/A 703M. Those which are ordinarily considered suitable for use with this specification are given below. Others enumerated in A 703/A 703M may be used with this specification upon agreement between the manufacturer and purchaser.

S1. Unspecified Elements

S2. Destruction Tests

S3. Bend Test

S4. Magnetic Particle Inspection

S5. Radiographic Inspection

S10. Examination of Weld Preparation

S10.1 The method of performing the magnetic particle or liquid penetrant test shall be in accordance with Practice E 709 or Practice E 165.

S11. Carbon Equivalent

S11.1 When specified on the order, the maximum carbon equivalent shall be:

Grade	Carbon Equivalent, max
WCA	0.50
WCB	0.50
WCC	0.55

S11.2 Carbon equivalent (CE) shall be determined as follows:

$$CE = C + \frac{Mn}{6} + \frac{Cr + Mo + V}{5} + \frac{Ni + Cu}{15}$$

S15. Quench and Temper Heat-Treatment

Endorsed by Manufacturers Standardization Society
of the Valve and Fittings Industry

Endorsed by American Foundrymen's Society
Used in USDOE-NE Standards

Standard Specification for Steel Castings, Martensitic Stainless and Alloy, for Pressure-Containing Parts, Suitable for High-Temperature Service[1]

This standard is issued under the fixed designation A 217/A 217M; 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[2] covers martensitic stainless steel and alloy steel castings for valves, flanges, fittings, and other pressure-containing parts (Note 1) intended primarily for high-temperature and corrosive service (Note 2).

1.2 One grade of martensitic stainless steel and nine grades of ferritic alloy steel are covered. Selection will depend on design and service conditions, mechanical properties, and the high-temperature and corrosion-resistant characteristics (Note 3).

NOTE 1—Carbon steel castings for pressure-containing parts are covered by Specification A 216/A 216M. Low alloy quench-and-tempered grades equivalent to Specification A 217/A 217M grades may be found in both Specifications A 352/A 352M and A 487/A 487M.

NOTE 2—The grades covered by this specification represent materials that are generally suitable for assembly with other castings or wrought steel parts by fusion welding. It is not intended to imply that these grades possess equal degrees of weldability; therefore, it is the responsibility of the purchaser to establish for himself a suitable welding technique. Since these grades possess varying degrees of suitability for high-temperature and corrosion-resistant service, it is also the responsibility of the purchaser to determine which grade shall be furnished, due consideration being given to the requirements of the applicable construction codes.

NOTE 3—The committee formulating this specification has included nine grades of materials that are considered to represent basic types of ferritic alloy steels suitable for valves, flanges, fittings, and other pressure-containing parts. Additional alloy steels that may better fulfill certain types of service will be considered for inclusion in this specification by the committee as the need becomes apparent.

1.3 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 must be used independently of the other. Combining values from the two systems may result in nonconformance with the specification. Inch-pound units are applicable for material ordered to Specification A 217 and SI units for materials ordered to Specification A 217M.

2. Referenced Documents

2.1 *ASTM Standards:*

A 216/A 216M Specification for Steel Castings, Carbon, Suitable for Fusion Welding, for High-Temperature Service[3]

A 352/A 352M Specification for Steel Castings, Ferritic and Martensitic, for Pressure-Containing Parts, Suitable for Low-Temperature Service[3]

A 487/A 487M Specification for Steel Castings Suitable for Pressure Service[3]

A 488/A 488M Practice for Steel Castings, Welding, Qualifications of Procedures and Personnel[3]

A 703/A 703M Specification for Steel Castings, General Requirements, for Pressure-Containing Parts[3]

A 802/A 802M Practice for Steel Castings, Surface Acceptance Standards, Visual Examination[3]

E 165 Test Method for Liquid Penetrant Examination[4]

E 709 Guide for Magnetic Particle Examination[4]

3. General Conditions for Delivery

3.1 Material furnished to this specification shall conform to the requirements of Specification A 703/A 703M including any supplementary requirements that are indicated in the purchase order. Failure to comply with the general requirements of Specification A 703/A 703M constitutes nonconformance with this specification. In case of conflict between the requirements of this specification and Specification A 703/A 703M, this specification shall prevail.

4. Ordering Information

4.1 The inquiry and order should include or indicate the following:

[1] This specification is under the jurisdiction of ASTM Committee A01 on Steel, Stainless Steel, and Related Alloys and is the direct responsibility of Subcommittee A01.18 on Castings.

Current edition approved Mar. 10, 2002. Published May 2002. Originally published as A 217 – 39 T. Last previous edition A 217/A 217M – 01.

[2] For ASME Boiler and Pressure Vessel Code applications, see related Specification SA-217/SA 217M in Section II of that code.

[3] *Annual Book of ASTM Standards*, Vol 01.02.

[4] *Annual Book of ASTM Standards*, Vol 03.03.

4.1.1 A description of the casting by pattern number or drawing (dimensional tolerances shall be included on the casting drawing),

4.1.2 Grade of steel,

4.1.3 Options in the specification, and

4.1.4 The supplementary requirements desired including the standards of acceptance.

5. Heat Treatment

5.1 All castings shall receive a heat treatment proper to their design and chemical composition.

5.2 Castings shall be furnished in the normalized and tempered conditions; Grades WC1, WC4, WC5, WC6, and CA15 shall be tempered at 1100°F [595°C] min; Grades WC9, C5, C12, and WC11 shall be tempered at 1250°F [675°C] min; Grade C12A shall be tempered at 1350°F [730°C] min.

5.3 Heat treatment shall be performed after castings have been allowed to cool below the transformation range.

6. Chemical Composition

6.1 The steel shall conform to the requirements as to chemical composition prescribed in Table 1 (Note 4).

NOTE 4—The role of alloying elements in the development of Grade C12A has been extensively investigated. V and Cb contribute to precipitation strengthening by forming fine and coherent precipitation of M(C,N)X carbo-nitrides in the ferrite matrix. V also precipitates as VN during tempering or during creep. The two elements are more effective in combination. Therefore, the addition of strong nitride forming elements, those with a stronger affinity for nitrogen than Cb and V, as deoxidation agents, interferes with these high-temperature strengthening mechanisms.[5]

7. Tensile Requirements

7.1 Steel used for the castings shall conform to the requirements as to tensile properties prescribed in Table 2.

8. Quality

8.1 The surface of the casting shall be examined visually and shall be free of adhering sand, scale, cracks, and hot tears. Other surface discontinuities shall meet the visual acceptance standards specified in the order. Practice A 802/A 802M or other visual standards may be used to define acceptable surface discontinuities and finish. Unacceptable visual surface discontinuities shall be removed and their removal verified by visual examination of the resultant cavities. When methods involving high temperature are used in the removal of discontinuities, castings shall be preheated to at least the minimum temperatures in Table 3.

8.2 When additional inspection is desired, Supplementary Requirements S4, S5, and S10 may be ordered.

8.3 The castings shall not be peened, plugged, or impregnated to stop leaks.

9. Repair by Welding

9.1 Repairs shall be made using procedures and welders qualified under Practice A 488/A 488M.

[5] Viswanathan, R. and Bakker, W. T., *Materials for Ultra Supercritical Fossil Power Plants*, EPRI, Palo Alto, CA: 2000. TR-114750.

TABLE 1 Chemical Requirements

NOTE—All values are maximum unless otherwise indicated.

	Composition, %									
	Carbon Molybdenum	Nickel Chromium Molybdenum	Nickel Chromium Molybdenum	Chromium Molybdenum	Chromium Molybdenum	Chromium Molybdenum	Chromium Molybdenum	Chromium Molybdenum	Chromium Molybdenum Vanadium	Chromium
Grade Identification Symbol	WC1	WC4	WC5	WC6	WC9	WC11	C5	C12	C12A (J84090)	CA15
Carbon	0.25	0.05–0.20	0.05–0.20	0.05–0.20	0.05–0.18	0.15–0.21	0.20	0.20	0.08-0.12	0.15
Manganese	0.50–0.80	0.50–0.80	0.40–0.70	0.50–0.80	0.40–0.70	0.50–0.80	0.40–0.70	0.35–0.65	0.30–0.60	1.00
Phosphorus	0.04	0.04	0.04	0.04	0.04	0.020	0.04	0.04	0.030	0.040
Sulfur	0.045	0.045	0.045	0.045	0.045	0.015	0.045	0.045	0.010	0.040
Silicon	0.60	0.60	0.60	0.60	0.60	0.30–0.60	0.75	1.00	0.20–0.50	1.50
Nickel	. . .	0.70–1.10	0.60–1.00	. . .	. . .	. . .	. . .	. . .	0.40	1.00
Chromium	. . .	0.50–0.80	0.50–0.90	1.00–1.50	2.00–2.75	1.00–1.50	4.00–6.50	8.00–10.00	8.0–9.5	11.5–14.0
Molybdenum	0.45–0.65	0.45–0.65	0.90–1.20	0.45–0.65	0.90–1.20	0.45–0.65	0.45–0.65	0.90–1.20	0.85–1.05	0.50
Columbium	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	0.060–0.10	. . .
Nitrogen	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	0.030–0.070	. . .
Specified Residual Elements										
Aluminum	. . .	. . .	. . .	. . .	. . .	0.01	. . .	. . .	0.040	. . .
Copper	0.50	0.50	0.50	0.50	0.50	0.35	0.50	0.50	. . .	. . .
Nickel	0.50	. . .	. . .	0.50	0.50	0.50	0.50	0.50	. . .	. . .
Chromium	0.35	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .
Tungsten	0.10	0.10	0.10	0.10	0.10	. . .	0.10	0.10	. . .	. . .
Vanadium	. . .	. . .	. . .	. . .	. . .	0.03	. . .	. . .	0.18–0.25	. . .
Total content of these residual elements	1.00	0.60	0.60	1.00	1.00	1.00	1.00	1.00		

TABLE 2 Tensile Requirements

Grade	Tensile Strength, ksi [MPa]	Yield Strength,[A] min, ksi [MPa]	Elongation in 2 in. [50 mm] min, %[B]	Reduction of Area, min, %
WC1	65 [450] to 90 [620]	35 [240]	24	35
WC4, WC5, WC6, WC9	70 [485] to 95 [655]	40 [275]	20	35
WC11	80 [550] to 105 [725]	50 [345]	18	45
C5, C12	90 [620] to 115 [795]	60 [415]	18	35
C12A (J84090)	85 [585] to 110 [760]	60 [415]	18	45
CA15	90 [620] to 115 [795]	65 [450]	18	30

[A] Determine by either 0.2 % offset method or 0.5 % extension-under-load method.
[B] When ICI test bars are used in tensile testing as provided for in Specification A 703/A 703M, the gage length to reduced section diameter ratio shall be 4 to 1.

TABLE 3 Minimum Preheat Temperatures

Grade	Thickness, in. [mm]	Minimum Preheat Temperature, °F [°C]
WC1	⅝ and under	50 [10]
	Over ⅝ [15.9]	250 [120]
WC4	All	300 [150]
WC5	All	300 [150]
WC6	All	300 [150]
WC9	All	400 [200]
WC11	All	300 [150]
C5	All	400 [200]
C12	All	400 [200]
C12A (J84090)	All	400 [200]
CA15	All	400 [200]

9.2 Weld repairs shall be inspected to the same quality standards that are used to inspect the castings. When castings are produced with Supplementary Requirement S4 specified, weld repairs shall be inspected by magnetic particle examination to the same standards that are used to inspect the castings. When castings are produced with Supplementary Requirement S5 specified, weld repairs on castings that have leaked on hydrostatic test, or on castings in which the depth of any cavity prepared for repair welding exceeds 20 % of the wall thickness or 1 in. [25 mm], whichever is smaller, or on castings in which any cavity prepared for welding is greater than approximately 10 in.^{2} [65 cm^2], shall be radiographed to the same standards that are used to inspect the castings.

9.3 Weld repairs shall be considered major in the case of a casting that has leaked on hydrostatic test, or when the depth of the cavity prepared for welding exceeds 20 % of the wall thickness or 1 in. [25 mm], whichever is smaller, or when the extent of the cavity exceeds approximately 10 in.^{2} [65 cm^2]. All castings with major repair welds shall be thermally stress relieved or completely reheat-treated. This mandatory stress relief or reheat-treatment shall be in accordance with the qualified procedure used. Major repairs shall be inspected to the same quality standards that are used to inspect the castings.

10. Keywords

10.1 alloy steel; high-temperature; martensitic stainless steel; pressure-containing; steel castings

SUPPLEMENTARY REQUIREMENTS

The following supplementary requirements shall not apply unless specified in the purchase order. A list of standardized supplementary requirements for use at the option of the purchaser is included in Specification A 703/A 703M. Those which are ordinarily considered suitable for use with this specification are given below. Others enumerated in Specification A 703/A 703M may be used with this specification upon agreement between the manufacturer and purchaser.

S1. Unspecified Elements
S2. Destruction Tests
S3. Bend Tests
S4. Magnetic Particle Inspection
S5. Radiographic Inspection

S10. Examination of Weld Preparation

S10.1 The method of performing the magnetic particle or liquid penetrant test shall be in accordance with Test Method E 165 or Guide E 709.

S13. Hardness Test
S21. Heat Treatment Furnace Record
S22. Heat Treatment

S51. Mandatory Postweld Heat Treatment

S51.1 All castings with repair welds shall receive a mandatory thermal stress relief or complete reheat treatment in accordance with the qualified procedure after all weld repairs.

Designation: A 220/A 220M – 99

Standard Specification for Pearlitic Malleable Iron[1]

This standard is issued under the fixed designation A 220/A 220M; 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 pearlitic malleable iron castings for general engineering usage at temperatures from normal ambient to approximately 750°F [400°C].

1.1.1 For continuous service at temperatures up to 1200°F [650°C] design factors should be incorporated to compensate for possible property changes, as demonstrated by Marshall and Sommer[2] and by Pearson.[3]

1.2 Without knowledge of casting geometry and process details, no quantitative relationship can be stated between the properties of the iron in the various locations of a casting and those of a test bar cast from the same iron.

1.3 The values stated in either inch-pound units or SI units are to be regarded separately as standard. Within the Test, 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.

2. Referenced Documents

2.1 *ASTM Standards:*

A 220M Specification for Pearlitic Malleable Iron (Metric)[4]
A 247 Test Method for Evaluating the Microstructure of Graphite in Iron Castings[4]
A 644 Terminology Relating to Iron Castings[4]
E 8 Test Methods for Tension Testing of Metallic Materials[5]
E 10 Test Method for Brinell Hardness of Metallic Materials[5]
E 18 Test Methods for Rockwell Hardness and Rockwell Superficial Hardness of Metallic Materials[5]
E 140 Hardness Conversion Tables for Metals[5]

2.2 *Military Standard:*

MIL-STD-129 Marking for Shipment and Storage[6]

2.3 *Federal Standard:*

Fed. Std. No. 123 Marking for Shipment (Civil Agencies)[6]

3. Terminology

3.1 *Definitions*:

3.1.1 Definitions for many terms common to iron castings are found in Terminology A 644.

4. Classification

4.1 Iron produced for castings ordered under this specification is classified in a number of grades as shown in Table 1 and is qualified by tests on separately cast test bars. Separately cast test bars shall be poured from the same lot of iron as the castings they represent and shall be heat treated with those castings.

5. Ordering Information

5.1 The purchase order for castings ordered under this specification shall state the specification designation, the year in which the specification was issued, and the grade of pearlitic malleable iron to be supplied.

5.2 Any options or special additions to the basic requirements of this specification shall be clearly and fully stipulated.

6. Chemical Composition

6.1 The chemical composition of the iron shall be such as to produce the mechanical properties required by this specification.

7. Mechanical Requirements

7.1 Factors influencing the properties of castings and their relationship to those of test specimens and separate test castings are discussed in Appendix X1.

7.2 *Tensile Test*:

7.2.1 *Tensile Test Specimens*:

7.2.1.1 The tensile test specimens shall be cast to the form and dimensions shown in Fig. 1 or Fig. 2 using the same kind of molding material used for the production castings.

7.2.1.2 All test specimens shall be suitably identified with the designation of the pour period.

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[1] This specification is under the jurisdiction of ASTM Committee A-4 on Iron Castings and is the direct responsibility of Subcommittee A04.02 on Malleable Iron Castings.

Current edition approved July 10, 1999. Published September 1999. Originally published as A 220 – 68. Last previous edition A 220 – 88 (1993)$^{\epsilon 1}$.

[2] Marshall, L. C., and Sommer, G. F., "Stress-Rupture Properties of Malleable Iron at Elevated Temperatures," *Proceedings,* American Society of Testing and Materials, Vol 58, pp. 752–773.

[3] Pearson, D. A., "Stress-Rupture and Elongation Properties of Malleable Iron at Elevated Temperatures," *Transactions,* 70th Castings Congress and Exposition, May 9, 1966.

[4] *Annual Book of ASTM Standards*, Vol 01.02.

[5] *Annual Book of ASTM Standards*, Vol 03.01.

[6] Available from Standardization Documents Order Desk, Bldg. 4 Section D, 700 Robbins Ave., Philadelphia, PA 19111-5094, Attn: NPODS.

TABLE 1 Tensile Test Requirements

Inch-Pound Grades			
English Grade	Tensile Strength, min	Yield Strength, min	Elongation, mn
	psi	psi	2 in., %
40010	60 000	40 000	10
45008	65 000	45 000	8
45006	65 000	45 000	6
50006	70 000	50 000	5
60004	80 000	60 000	4
70003	85 000	70 000	3
80002	95 000	80 000	2
90001	105 000	90 000	1
Metric Grades			
Metric Grade	Tensile Strength, min	Yield Strength, min	Elongation, min
	MPa	MPa	50 mm, %
280M10	400	280	10
310M8	450	310	8
310M6	450	310	6
340M5	480	340	5
410M4	550	410	4
480M3	590	480	3
550M2	650	550	2
620M1	720	620	1

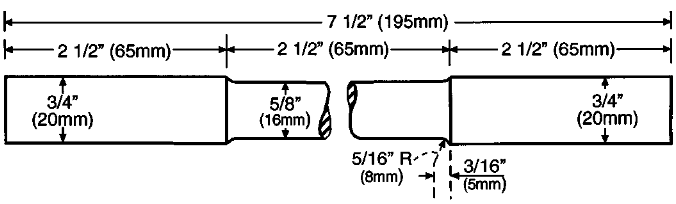
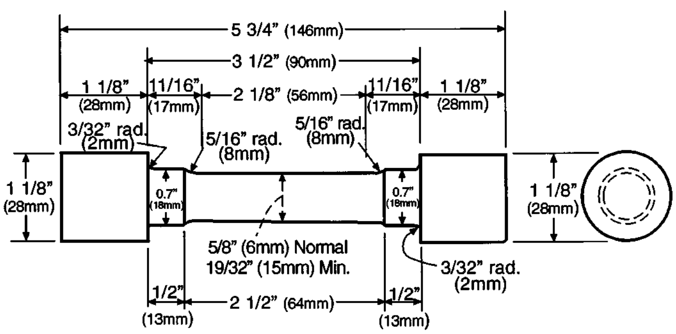


FIG. 1 Unmachined Tension Test Specimen



NOTE 1—Modification may be made in the dimensions indicated above for those details of the specimen outside of the gage length as required by testing procedure and equipment.

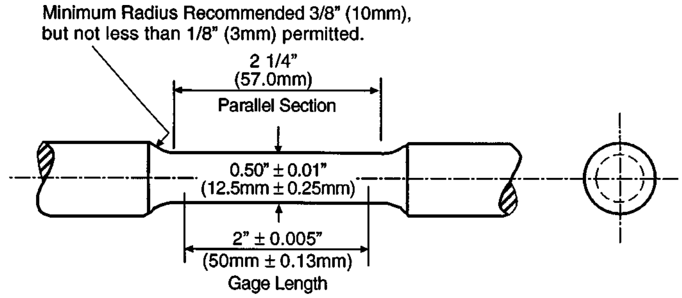
FIG. 2 Alternative Unmachined Tension Test Specimen

7.2.1.3 All test specimens shall be heat treated in the same production furnace and for the same cycles as the castings they represent.

7.2.2 *Tensile Test Method*:

7.2.2.1 The tensile test is usually performed on unmachined specimens. However, for referee work the specimen may be machined from the standard cast bar to the dimensions shown in Fig. 3.

7.2.2.2 *Gage Length*—The gage length of the standard tensile specimen shall be 2.00 ± 0.01 in. [50.0 ± 0.3 mm].



NOTE 1—The gage length and filets shall be as shown, but the ends may be of any shape to fit the holders of the testing machine in such a way that the load shall be axial. The reduced section shall have a gradual taper from the ends toward the center, with the ends 0.003 to 0.005 in. [0.08 to 0.13 mm] larger in diameter than the center.

FIG. 3 Machined Tension Test Specimen

7.2.2.3 *Cross-Sectional Area*—The diameter used to compute the cross-sectional area shall be the average between the largest and smallest diameter in that section of the 2-in. [50-mm] gage length having the smallest diameter and shall be measured to the nearest 0.001 in. [0.02 mm]. No cast bar having a mean diameter less than 19⁄32 in. [15 mm] shall be accepted for test.

7.2.2.4 *Speed of Testing*—After reaching a stress equivalent to approximately half of the anticipated yield stress, the speed of the moving head of the testing machine shall not exceed 0.50 in./mm [12.5 mm/min] through the breaking load.

7.2.2.5 *Yield Strength*—Yield strength may be determined by any of the approved techniques described in Test Methods E 8. In referee work it shall be determined at an offset of 0.2 % from the stress-strain curve. Yield strength shall be reported to the nearest 100 psi [megapascal].

7.2.2.6 *Tensile Strength*—The tensile strength shall be the maximum load carried by the specimen during the test divided by the original cross-sectional area of the gage length, as found in accordance with 7.2.2.3. It shall be reported to the nearest 100 psi [megapascal].

7.2.2.7 *Elongation*—The increase in gage length after fracture of a tensile specimen, measured to the nearest 0.01 in. [0.25 mm] expressed as a percentage of the original gage length. It shall be reported to the nearest 0.5 %.

7.2.3 *Number of Tests and Retests*:

7.2.3.1 At least three tensile test specimens shall be cast from a representative ladle of iron from each 4-h pour period during which the purchaser's castings were poured.

7.2.3.2 Only one test specimen need be tested to qualify each pour period and heat treatment batch provided the requirements of this specification are met by that test specimen.

7.2.3.3 If after testing a specimen shows evidence of a defect, another tensile test may be made on a companion specimen. Also, a retest shall be permitted whenever fracture occurs outside the central 50 % of the gage length.

7.2.3.4 If the result of a valid test fails to conform to the requirements of this specification, two retests shall be made. If either of the retest fails to meet specification, the castings represented by these test specimens shall be rejected. A valid test is one wherein the test specimen has been properly prepared and appears to be sound and on which the approved test procedure has been followed.

7.2.3.5 If the first test results indicate that a reheat treatment is needed to meet the test requirements, the entire lot of castings and the representative test specimens shall be reheat treated together. Testing shall then be repeated in accordance with 7.2.3.1-7.2.3.4.

7.2.4 The results of all tests, including retests, shall be posted in permanent records, that shall state any abnormalities observed during the test and in the fractured ends. Such records shall be kept for at least one year after production of the castings and shall be available for examination by the purchaser or by an authorized representative.

7.2.5 Tensile test results, obtained in accordance with this section, must conform to the requirements of Table 1.

7.2.6 When agreed upon between the manufacturer and the purchaser, tested specimens or unbroken test bars, or both, shall be saved by the manufacturer for a period of three months after the date of the test report.

7.3 *Hardness Test*:

7.3.1 If the purchase agreement requires hardness testing, the acceptable hardness range shall be stated and a location shall be clearly shown on the covering drawing(s).

7.3.2 *Hardness Test Method*:

7.3.2.1 The Brinell method of hardness testing in accordance with Test Method E 10, shall be employed whenever possible.

7.3.2.2 For castings of such size or shape that do not permit Brinell testing with the standard 3000-kgf load, the 500-kgf load may be employed; the hardness number being reported as HB 10/500/15. In very unusual cases where it is impossible to use the Brinell method, the Rockwell test may be substituted, using Test Methods E 18 with an appropriate Rockwell scale. Conversions of hardness values from one method to another according to Tables E 140, that does not specifically cover cast irons, are approximate only and are generally inadvisable.

7.3.2.3 Sufficient material shall be removed from the cast surface to ensure that the measured hardness is representative.

7.3.3 Sampling procedures and the frequency of hardness testing shall be fully detailed on the purchase agreement. Otherwise hardness tests shall be performed at the discretion of the producer.

7.3.4 Castings failing to conform to the required hardness range may be reheat treated and retested. If after reheat treating they still fail the hardness requirements, they shall be rejected.

7.3.5 Typical hardness ranges for the various grades of pearlitic malleable iron are listed in Table 2.

TABLE 2 Typical Hardness Ranges[A]

Inch-Pound Grade [Metric Grade}	Typical Hardness, HB	Typical Indentation Diameters, mm
40010 [280M10]	149–197	4.3–4.9
45008 [310M8]	156–197	4.3–4.8
45006 [310M6]	156–207	4.2–4.8
50005 [340M5]	179–229	4.0–4.5
60004 [410M4]	197–241	3.9–4.3
70003 [480M3]	217–269	3.7–4.1
80002 [550M2]	241–285	3.6–3.9
90001 [620M1]	269–321	3.4–3.7

[A]Hardness test in accordance with Test Method E 10 using a 0.39-in. [10-mm] ball and 6600–lbf [3000-kgf] load.

8. Microstructure Requirements

8.1 The microstructure of the pearlitic malleable iron shall consist of temper carbon nodules uniformly distributed in a matrix of ferrite, pearlite, and tempered transformation products of austenite.

8.2 When agreed upon between the purchaser and the producer, the maximum decarburization at any as-cast surface after heat treatment may be stipulated in writing as measured by visual depletion of combined carbon after polishing, etching in nital, and viewing at 100×.

8.3 If the castings are to be subsequently hardened, the selected grade designation should be preceded by the letter *L*. Such castings shall contain sufficient combined carbon in the matrix to respond satisfactorily to any of the common hardening processes properly applied. A minimum hardness of 197 HB is recommended. Free ferrite shall be as low as is consistent with other properties.

8.4 In referee work, the metallographic practice recommended in Test Method A 247 shall be followed.

9. Soundness Requirements

9.1 All castings on visual examination, shall be sound and free from obvious shrinkage and porosity.

9.2 If the purchaser requires soundness tests to be performed, it shall be so stated in the purchase agreement and the method and soundness requirements shall be detailed.

10. Dimensional Requirements

10.1 The castings shall conform to the dimensions given on drawings furnished by the purchaser, or to the dimensions established by the patterns supplied by the purchaser.

10.1.1 Variations of solid casting dimensions as shown in Table 3 will be permitted unless otherwise agreed upon between the purchaser and the producer.

11. Workmanship, Finish and Appearance

11.1 The surface of the castings shall be clean, free from sand, and have a workmanlike finish.

11.2 No repairing by plugging or welding of any kind shall be permitted unless written permission is granted by the purchaser.

12. Identification Marking

12.1 When the size of the casting permits, each casting shall bear the identifying mark of the manufacturer and the part or pattern number at a location shown on the covering drawing and, if not shown on the drawing, at such a location at the discretion of the producer that the identification will not interfere with subsequent processing and service of the casting.

TABLE 3 Permissible Variations in Any Solid Dimension

Solid Casting Dimension, in. [mm]	Permissible Variation,± in. [mm]
Up to 1 [up to 25]	1⁄32 [0.8]
1–6 [25–150]	1⁄16[1.6]
6–12 [150–300]	1⁄8[3.2]
12–18 [300–450]	5⁄32[4.0]
18–24 [450–600]	3⁄16[4.8]
24–38 [600–900]	7⁄32[5.6]

13. Responsibility for Inspection

13.1 Unless otherwise specified in the contract or purchase order, the manufacturer shall be responsible for carrying out all the tests and inspections required by this specification, using his own or other reliable facilities. The manufacturer shall maintain complete records of all such tests and inspections. Such records shall be available for review by the purchaser.

13.2 The manufacturer shall afford the purchaser's inspector all reasonable facilities necessary to satisfy that the material is being produced and furnished in accordance with the applicable specification. Foundry inspection by the purchaser shall not interfere unnecessarily with the manufacturer's operations.

13.3 The purchaser reserves the right to perform any of the tests and inspections set forth in this specification where such tests and inspections are deemed necessary to assure that compliance with this specification is being met.

14. Rejection and Rehearing

14.1 Any casting or lot of castings failing to comply with the requirements of this specification may, where possible, be reprocessed, retested, and reinspected. If the tests and inspections on the reprocessed casting(s) show compliance with the specification, the casting(s) shall be acceptable; if they do not, they shall be rejected.

14.2 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.

15. Certification

15.1 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 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.

16. Packaging and Package Marking

16.1 Unless otherwise stated in the contract or order, the cleaning, preservation, and packing of castings for shipment shall be in accordance with the manufacturer's commercial practice. Packaging and package marking shall also be adequate to identify the contents and to ensure acceptance and safe delivery by the carrier for the mode of transportation employed.

16.2 *U.S. Government Procurement*—When specified in the contract or purchase order, marking for shipment shall be in accordance with the requirements of Fed. Std. No. 123 for civil agencies and MIL-STD-129 for military activities.

17. Keywords

17.1 casting; malleable iron; mechanical properties; pearlitic; tensile strength; tension test; yield strength

SUPPLEMENTARY REQUIREMENTS

S1. Test Lugs

S1.1 If requested in writing or included on the pattern or pattern drawing, a test lug or lugs may be cast on all castings of sufficient size to permit their incorporation. The size of such lugs shall be proportional to the thickness of the castings. On castings over 24 in. [600 mm] in length, a test lug shall be cast near each end, such as not to interfere with any subsequent processing of the castings. The purchase order shall stipulate whether the foundry's inspector or the purchaser's inspector shall break, inspect, and pass judgement on the fracture quality of these test lugs.

S2. Destructive Tests

S2.1 At the option of the purchaser or his representative, a casting of each design ordered may be tested to destruction, or otherwise broken up, to determine the presence of any manufacturing condition that might be detrimental to the serviceability of the casting.

S3. Special Composition

S3.1 For improved resistance to atmospheric corrosion, the basic chemical composition of the iron may be modified slightly as suggested by research conducted by ASTM Committee A-4[7] and this shall be so stated in the purchase agreement.

[7] Appendix, Report on ASTM Committee A-4 on Iron Castings, "Corrosion Test Results on 15 Ferrous Metals after 12-years Atmospheric Exposure," *Proceedings*, American Society of Testing and Materials, Vol 72, 1972, pp. 42–63.

APPENDIX

(Nonmandatory Information)

X1. MECHANICAL PROPERTIES OF CASTINGS

X1.1 The mechanical properties of pearlitic malleable iron castings are influenced by a number of factors, which include the cooling rate during solidification, chemical composition, heat treatment, design of the casting, section thickness, and location and effectiveness of gates, risers, and chills.

X1.2 Because of the complexity of these factors in influencing the properties of the final product, no precise quantitative relationship can be stated between the properties of the iron in various locations of the same casting or between the properties of a casting and those of a test specimen cast from the same iron. When such a relationship is important and must be known for a specific application, it may be determined by appropriate experimentation.

X1.3 The specimen specified in 7.2.1.1, as the standard tensile test bar for pearlitic malleable iron, has a ⅝-in. [16-mm] diameter test section that reasonably represents a typical section of the general run of pearlitic malleable iron castings. Furthermore, the initial freezing of malleable irons as homogeneous white iron, together with the heat treatment which is inherent in the manufacture of malleable iron, tends to reduce the section-sensitivity effect. Therefore, where experimentation into the precise properties within a given casting would be unfeasible, this standard test bar, made like any typical casting, should provide a practical approximation of the properties that can be expected in any average sound malleable iron castings. When the number of standard test bars to determine specification compliance is insufficient, the manufacturer may wish to seek purchaser approval by comparing tension test results from the casting in question with those of two other castings having the same design and test bar location and from which acceptable standard bar results were obtained.

X1.4 If pearlitic malleable iron castings are welded, the microstructure of the iron is markedly affected, particularly in the heat-affected zone. Since this may adversely affect the properties of the casting, the welding of pearlitic malleable iron castings should be under strict metallurgical control, followed by appropriate post-weld heat treatment, to minimize the substantial reductions in ductility, impact resistance, and machinability that could result, particularly in the vicinity of the weldment. Nevertheless, it is generally considered inadvisable to join castings to similar castings or to other materials, by fusion welding out in the field, or in manufactured assemblies, without fully testing the entire completed part.

Standard Specification for Gray Iron Castings for Pressure-Containing Parts for Temperatures Up to 650°F (350°C)[1]

This standard is issued under the fixed designation A 278/A 278M; 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[2] covers gray iron for castings suitable for pressure-containing parts for use at temperatures up to 650°F (350°C).

1.2 *Classes of Iron*:

1.2.1 Castings of all classes are suitable for use up to 450°F (230°C). For temperatures above 450°F and up to 650°F, only Class 40, 45, 50, 55, and 60 castings are suitable.

1.2.2 Castings of all classes are suitable for use up to 230°C. For temperatures above 230°C and up to 350°C, only Class 275, 300, 325, 350, 380, and 415 castings are suitable.

2. Referenced Documents

2.1 *ASTM Standards:*

A 644 Terminology Relating to Iron Castings[3]

E 8 Test Methods for Tension Testing of Metallic Materials[4]

3. Terminology

3.1 Definitions of many terms common to gray iron castings may be found in Terminology A 644.

4. Classification

4.1 Classification by tensile strength.

4.1.1 Castings ordered to this specification are classified based upon the minimum tensile strength of the iron in ksi, in English units. Class 25 has a minimum specified tensile strength of 25 ksi.

4.1.2 Castings ordered to this specification are classified based upon the minimum tensile strength of the iron in MPa, in Metric units. Class 150 has a minimum specified tensile strength of 150 MPa.

5. Ordering Information

5.1 Orders for material in this specification should include the following information:

5.1.1 ASTM designation and year date,

5.1.2 Class of iron required and service temperature,

5.1.3 Quantity,

5.1.4 *Heat Treatment*:

5.1.4.1 Whether or not heat treatment is required for Class 40, 45, 50, 55, and 60 castings to be used at temperatures at 450°F or less (see 6.2),

5.1.4.2 Whether or not heat treatment is required for Class 275, 300, 325, 350, 380, and 415 castings to be used at temperatures at 230°C or less (see 6.2),

5.1.5 The size of separately cast test bar to be poured (see Section 9 and Table 1),

5.1.6 The size of test specimen to be machined from test bars C or S, and

5.1.7 Special requirements.

6. Materials and Manufacture

6.1 Castings intended for use above 450°F (230°C) shall be stress-relieved by placing them in a suitable furnace at a temperature not exceeding 400°F (200°C) and heating them uniformly to the temperatures and for the times specified in Table 2. The heating and cooling rates shall be uniform and shall not be more than 400°F/h (250°C/h) for castings of 1-in. (25-mm) maximum section. For heavier sections the maximum heating and cooling rates in degrees Fahrenheit per hour shall be 400 divided by the maximum section thickness.

6.2 *Heat Treatment and Cooling Rate*:

6.2.1 Castings of Class Nos. 45, 50, 55, and 60, which are to be used at temperatures below 450°F, may be heat treated in accordance with 6.1 or they shall be cooled in the mold to 500°F at an average rate of not more than 100°F/h for castings up to 1 in. in section. For heavier sections the maximum cooling rate in degrees Fahrenheit per hour shall be 100 divided by the maximum section thickness.

6.2.2 Castings of Class Nos. 275, 300, 325, 350, 380, and 415, which are to be used at temperatures below 230°C, may be heat treated in accordance with 6.1 or they shall be cooled in the mold to 250°C at an average rate of not more than 50°C/h for castings up to 25-mm in section. For heavier sections the maximum cooling rate in degrees Celsius per hour shall be 1250 divided by the maximum section thickness.

7. Chemical Composition

7.1 *Carbon Equivalent*:

7.1.1 Class 40, 45, 50, 55, and 60 castings intended for

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[1] This specification is under the jurisdiction of ASTM Committee A04 on Iron Castings and is the direct responsibility of Subcommittee A04.01 on Gray and White Iron Castings.

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[2] For ASME Boiler and Pressure Vessel Code applications see related Specification SA-278 in Section II of that Code.

[3] *Annual Book of ASTM Standards*, Vol 01.02.

[4] *Annual Book of ASTM Standards*, Vol 03.01.

TABLE 1 Diameters and Lengths of Cast Test Bars

Test Bar	As-Cast Diameter, in. (mm)			Length, in. (mm)	
	Minimum (Bottom)	Maximum (Top)	Minimum (Specified)	Maximum (Recommended)	
A	0.88 (23)	0.85 (22)	0.96 (25)	5.0 (125)	6.0 (1.50)
B	1.20 (33)	1.14 (32)	1.32 (36)	7.0 (150)	9.0 (230)
C	2.00 (54)	1.90 (53)	2.10 (58)	6.0 (175)	10.0 (255)
S[A]					

[A] All dimensions of Test Bar S shall be agreed upon by the manufacturer and the purchaser.

TABLE 2 Stress Relieving Requirements

Class	Metal Temperature, °F (°C)	Holding Time, h[A]	
40, 45, 50, 55, 60 (275, 300, 325, 350, 380, 415)	1050 to 1200 (565 to 650)	2 (2 min)[B]	12 (12 max)[B]

[A] In no case shall the holding time be less than 1 h/in. of maximum metal section, or in excess of 12 h max, dependent upon which governs.

[B] In no case shall the holding time be less than 1 h for every 25-mm metal section, or in excess of 12 h max, depending upon which governs.

service above 450°F (230°C) shall have a maximum carbon equivalent of 3.8 % as calculated from the equation CE = %C + 0.3 (%Si + %P). The maximum phosphorus and sulfur contents shall be 0.25 % and 0.12 %, respectively.

7.1.2 Class 275, 300, 325, 350, 380, and 415 castings intended for service above 230°C shall have a maximum carbon equivalent of 3.8 % as calculated from the equation CE = %C + 0.3 (%Si + %P). The maximum phosphorus and sulfur contents shall be 0.25 % and 0.12 %, respectively.

7.2 The chemical analysis for total carbon shall be made on either chilled cast pencil-type specimens or thin wafers approximately 1⁄32 in. thick cut from test coupons. Drillings shall not be used because of attendant loss of graphite.

8. Tensile Requirements

8.1 Iron used in supplying castings to this specification shall conform to the tensile requirements prescribed in Table 3 and Table 4.

9. Test Bars

9.1 Separately cast test bars having the dimensions shown in Table 1 shall be poured from the same lot as the castings represented. The size of the test bar to be poured shall be selected by the purchaser using Table 5. In the event no choice is made, the selection will be made by the manufacturer.

9.2 Separately cast test bars shall be heat treated in the same furnace together with the castings represented.

TABLE 3 Tensile Requirements

Class	Tensile Strength, min, ksi
No. 20	20
No. 25	25
No. 30	30
No. 35	35
No. 40	40
No. 45	45
No. 50	50
No. 55	55
No. 60	60

TABLE 4 Tensile Requirements (SI)

Class	Tensile Strength, min, MPa
No. 150	150
No. 175	175
No. 200	200
No. 225	225
No. 250	250
No. 275	275
No. 300	300
No. 325	325
No. 350	350
No. 380	380
No. 415	415

TABLE 5 Separately Cast Test Bars for Use When a Specific Correlation Has Not Been Established Between the Test Bar and the Casting

Thickness of the Wall of the Controlling Section of the Casting, in. (mm)	Test Bar
Under 0.25 (6)	S
0.25 to 0.50 (6 to 12)	A
0.51 to 1.00 (13 to 25)	B
1.01 to 2 (26 to 50)	C
Over 2 (50)	S

9.3 At the option of the manufacturer, test coupons may be removed from the casting at a location agreed upon between the manufacturer and purchaser.

9.4 Castings weighing in excess of 2000 lb may be represented either by separately cast test bars (9.1) or by integrally cast test bars having a cooling rate closely approximating that of the controlling section of the casting.

9.5 For castings weighing in excess of 10 000 lb or having a controlling section greater than 2 in., test bars may be removed from the casting or integral projections having a cross section no less than the controlling section. The minimum tensile strength requirement for tension tests performed on either of these test bars shall be 80 % of the specified class.

10. Molding and Pouring Test Bars

10.1 The test bars shall be cast in dried siliceous sand molds maintained at approximately room temperature. A suitable design for a mold is shown in Fig. 1.

11. Workmanship, Finish, and Appearance

11.1 All castings shall be made in a workmanlike manner and shall conform to the dimensions on drawings furnished by the purchaser. If the pattern is supplied by the purchaser without drawings, the dimensions of the casting shall be as predicted by the pattern.

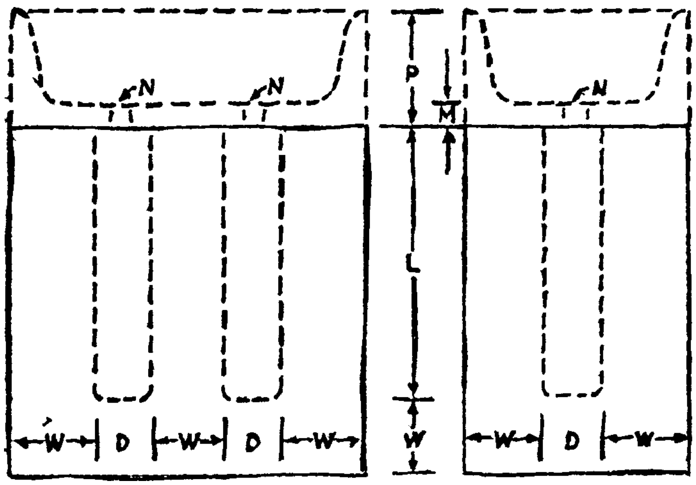
11.2 The surface of the casting shall be free of adhering sand, scale, cracks, and hot tears as determined by visual examination. Other surface discontinuities shall meet the visual acceptance standards specified in the order.

12. Sampling

12.1 A lot shall consist of one of the following:

12.1.1 All the metal poured from a single heating in a batch type melting furnace,

12.1.2 All the metal from two or more batch type melting furnaces poured into a single ladle or single casting, or



Number of test bars in a single mold-2 suggested.
L—see Table 1.
D—see Table 1.
W—not less than diameter, *D*.
P—2 in. (50-mm) suggested
N—5⁄16in. (8-mm) in diameter, suggested
M—1.5 *N*, suggested

FIG. 1 Suitable Design and Dimensions for Mold for Separately Cast Cylindrical Test Bars for Gray Iron

12.1.3 All the metal poured from a continuous melting furnace for a given period of time between changes in charge, processing conditions, or aim-for chemistry or 4 h, whichever is the shorter period.

12.1.3.1 The purchaser may agree to extend the 4-h time period to 8 h if the manufacturer can demonstrate sufficient process control to warrant such an extension.

13. Tension Test Specimens

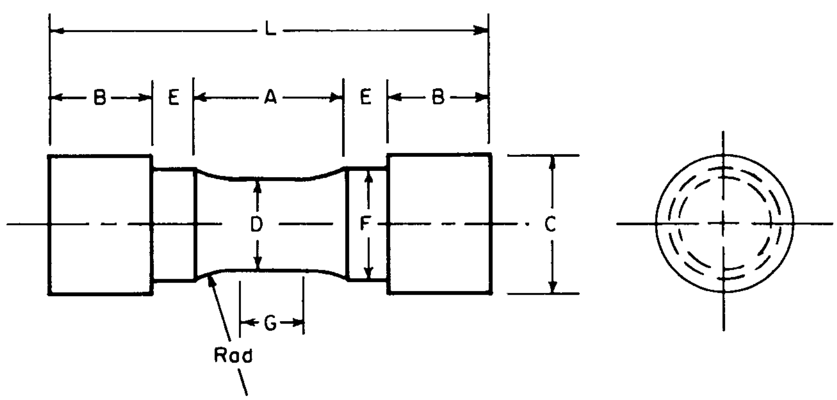
13.1 Tension test specimens A and B in Fig. 2 shall be machined from test bars A and B in Table 1, respectively.

13.2 The purchaser shall specify whether test specimen B or C is to be machined from test bar C. If no choice is made, the manufacturer shall make the selection.

13.3 The size of the test specimen to be machined from test bar S shall be as agreed upon between the manufacturer and purchaser.

14. Number of Tests and Retests

14.1 One tension test shall be performed on each lot in



Dimensions, in. (mm)	Tension Test Specimen A	Tension Test Specimen B	Tension Test Specimen C
G— Length of parallel, min	0.50 (13)	0.75 (20)	1.25 (32)
D— Diameter	0.500 ± 0.010 (13 ± 0.25)	0.750 ± 0.015 (20 ± 0.4)	1.25 ± 0.025 (32 ± 0.5)
R— Radius of fillet, min	1 (25)	1 (25)	2 (50)
A— Length of reduced section, min	1¼ (32)	1½ (38)	2¼ (57)
L— Overall length, min	3¾ (95)	4 (100)	6⅜ (160)
C— Diameter of end section, approximate	⅞ (22)	1¼ (32)	1⅞ (47)
E— Length of shoulder, min	¼ (6)	¼ (6)	5⁄16 (8)
F— Diameter of shoulder	⅝± 1⁄64 (16 ± 0.5)	15⁄16± 1⁄64 (25 ± 0.5)	17⁄16± 1⁄64 (36 ± 0.5)
B— Length of end section	A	A	A

A Optional to fit holders on testing machine. If threaded, root diameter shall not be less than dimension *F*.

FIG. 2 Tension-Test Specimens

accordance with Test Method E 8 and conform to the tensile requirements specified.

14.2 If the results of a valid test fail to conform to the requirements of this specification, two retests shall be made. If either retest fails to meet the specification requirements, the castings represented by these test specimens shall be rejected.

14.3 If, after testing, a test specimen shows evidence of a defect, the results of the test may be invalidated and another made on a specimen from the same lot.

15. Repair

15.1 Any repairs performed on castings produced to this specification shall be agreed upon between the manufacturer and purchaser.

16. Certification

16.1 When requested by the purchaser, the manufacturer shall furnish his certification stating that the material was manufactured, sampled, tested, and inspected in accordance with this specification including the year date. The certification shall also include the results of all tests performed.

16.2 A signature is not required on the certification. However, the document shall clearly identify the organization submitting the certification and the authorized agent of the manufacturer who certified the test results. Notwithstanding the absence of a signature, the organization submitting the certification is responsible for its content.

17. Inspection

17.1 All tests and inspections required by this specification shall be performed by the manufacturer or other reliable sources whose services have been contracted for by the manufacturer. Complete records of all tests and inspections shall be maintained by the manufacturer and shall be available for review by the purchaser.

18. Rejection and Rehearing

18.1 Castings which fail to conform to the requirements specified when inspected or tested by the purchaser or his agent may be rejected. Rejection shall be reported to the manufacturer or supplier promptly and in writing. In case of dissatisfaction with the test results, the manufacturer or supplier may make claim for a rehearing.

19. Product Marking

19.1 Castings shall have the name of the manufacturer, or his recognized trademark, and the class of iron to which it conforms, cast or indelibly stamped on a surface indicated by the purchaser or in such a position as not to injure the usefulness of the casting.

20. Keywords

20.1 elevated temperature service; gray iron castings; pressure containing parts

Standard Specification for Steel Castings, Iron-Chromium and Iron-Chromium-Nickel, Heat Resistant, for General Application[1]

1. Scope

1.1 This specification covers iron-chromium and iron-chromium-nickel alloy castings for heat-resistant service. The grades covered by this specification are general purpose alloys and no attempt has been made to include heat-resisting alloys used for special production application.

NOTE 1—For heat-resisting alloys used for special product application, reference should be made to Specification A 351/A 351M, A 217/A 217M, and A 447/A 447M.

1.2 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 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 217/A 217M Specification for Steel Castings, Martensitic Stainless and Alloy, for Pressure–Containing Parts, Suitable for High-Temperature Service[2]

A 351/A 351M Specification for Castings, Austenitic, Austenitic–Ferritic (Duplex), for Pressure–Containing Parts[2]

A 370 Test Methods and Definitions for Mechanical Testing of Steel Products[3]

A 447/A 447M Specification for Steel Castings, Chromium-Nickel-Iron Alloy (25-12 Class), for High-Temperature Service[2]

A 781/A 781M Specification for Castings, Steel and Alloy, Common Requirements, for General Industrial Use[2]

3. General Conditions for Delivery

3.1 Material furnished to this specification shall conform to the requirements of Specification A 781/A 781M, including any supplementary requirements that are indicated in the purchase order. Failure to comply with the general requirements of Specification A 781/A 781M constitutes nonconformance with this specification. In case of conflict between the requirements of this specification and Specification A 781/A 781M, this specification shall prevail.

4. Ordering Information

4.1 The inquiry and order should include or indicate the following:

4.1.1 A description of the casting by pattern number or drawing (dimensional tolerances shall be included on the casting drawing),

4.1.2 Grade of steel,

4.1.3 Options in the specification, and

4.1.4 The supplementary requirements desired including the standards of acceptance.

5. Process

5.1 Alloys shall be made by the following processes: electric-arc, electric-induction, or other approved processes.

6. Heat Treatment

6.1 Castings for heat-resistant service may be shipped in the as-cast condition without heat treatment. If heat treatment is required, the treatment shall be established by mutual agreement between the manufacturer and the purchaser and shall be so specified in the inquiry, contract, or order.

7. Chemical Composition

7.1 Alloys shall conform to the requirements as to chemical composition prescribed in Table 1.

8. Repair by Welding

8.1 The composition of the deposited weld metal shall be similar to the composition of the casting. All weld repairs shall be subjected to the same inspection standards as the casting.

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[1] This specification is under the jurisdiction of ASTM Committee A01 on Steel, Stainless Steel, and Related Alloys and is the direct responsibility of Subcommittee A01.18 on Castings.

Current edition approved April 10, 2003. Published April 2003. Originally approved in 1946. Last previous edition approved in 1998 as A 297/A 297M – 97 (1998).

[2] *Annual Book of ASTM Standards*, Vol 01.02.

[3] *Annual Book of ASTM Standards*, Vol 01.03.

TABLE 1 Chemical Requirements

Grade	Type	Composition, %							
		Carbon	Manganese, max	Silicon, max	Phosphorus, max	Sulfur, max	Chromium	Nickel	Molybdenum, max[A]
HF	19 Chromium, 9 Nickel	0.20–0.40	2.00	2.00	0.04	0.04	18.0–23.0	8.0–12.0	0.50
HH	25 Chromium, 12 Nickel	0.20–0.50	2.00	2.00	0.04	0.04	24.0–28.0	11.0–14.0	0.50
HI	28 Chromium, 15 Nickel	0.20–0.50	2.00	2.00	0.04	0.04	26.0–30.0	14.0–18.0	0.50
HK	25 Chromium, 20 Nickel	0.20–0.60	2.00	2.00	0.04	0.04	24.0–28.0	18.0–22.0	0.50
HE	29 Chromium, 9 Nickel	0.20–0.50	2.00	2.00	0.04	0.04	26.0–30.0	8.0–11.0	0.50
HT	15 Chromium, 35 Nickel	0.35–0.75	2.00	2.50	0.04	0.04	15.0–19.0	33.0–37.0	0.50
HU	19 Chromium, 39 Nickel	0.35–0.75	2.00	2.50	0.04	0.04	17.0–21.0	37.0–41.0	0.50
HW	12 Chromium, 60 Nickel	0.35–0.75	2.00	2.50	0.04	0.04	10.0–14.0	58.0–62.0	0.50
HX	17 Chromium, 66 Nickel	0.35–0.75	2.00	2.50	0.04	0.04	15.0–19.0	64.0–68.0	0.50
HC	28 Chromium	0.50 max	1.00	2.00	0.04	0.04	26.0–30.0	4.00 max	0.50
HD	28 Chromium, 5 Nickel	0.50 max	1.50	2.00	0.04	0.04	26.0–30.0	4.0–7.0	0.50
HL	29 Chromium, 20 Nickel	0.20–0.60	2.00	2.00	0.04	0.04	28.0–32.0	18.0–22.0	0.50
HN	20 Chromium, 25 Nickel	0.20–0.50	2.00	2.00	0.04	0.04	19.0–23.0	23.0–27.0	0.50
HP	26 Chromium, 35 Nickel	0.35–0.75	2.00	2.50	0.04	0.04	24–28	33–37	0.50

[A] Castings having a specified molybdenum range agreed upon by the manufacturer and the purchaser may also be furnished under these specifications.

8.2 Castings with major weld repairs shall be heat treated in accordance with Section 6.

8.3 Weld repairs shall be considered major when the depth of the cavity after preparation for repair exceeds 20 % of the actual wall thickness, or 1 in. [25 mm], whichever is smaller, or when the extent of the cavity exceeds approximately 10 in.^{2} [65 cm ^{2}].

8.3.1 When Supplementary Requirement S7 is specified on the purchase order, or inquiry, major weld repairs shall be subject to the prior approval of the purchaser.

8.4 All other weld repairs shall be considered minor and may be made at the discretion of the manufacturer without prior approval of the purchaser.

SUPPLEMENTARY REQUIREMENTS

The following supplementary requirements shall not apply unless specified in the purchase order. A list of standardized supplementary requirements for use at the option of the purchaser is included in Specification A 781/A 781M. Those which are ordinarily considered suitable for use with this specification are given below. Others enumerated in A 781/A 781M may be used with this specification upon agreement between the manufacturer and purchaser.

S1. Magnetic Particle Examination
S2. Radiographic Examination
S3. Liquid Penetrant Examination
S4. Ultrasonic Examination
S5. Examination of Weld Preparation
S6. Certification
S7. Prior Approval of Major Weld Repairs
S8. Marking
S9. Tension Test

S9.1 One tension test shall be made from material representing each heat. The bar from which the test specimen is taken shall be heat treated in production furnaces to the same procedure as the castings it represents. The results shall conform to the requirements specified in Table S9.1.

S9.2 Test bars shall be poured in separately cast keel blocks similar to Fig. 3 of Test Methods and Definitions A 370 of Fig.1 of Specification A 447/A 447M.

S9.3 Tension test specimens may be cut from heat-treated castings; or from as-cast castings if no heat treatment is specified for the castings, instead of from test bars when agreed upon between the manufacturer and the purchaser.

S9.4 Test specimens shall be machined to the form and dimensions of the standard round 2-in. [50-mm] gage length specimen shown in Fig. 6 of Test Methods and Definitions A 370 and shall be tested in accordance with Test Methods and Definitions A 370.

S9.5 If the results of the mechanical tests for any heat do not conform to the requirements specified, the castings may be

TABLE S9.1 Tensile Requirements

Grade	Type	Tensile Strength, min		Yield Point, min		Elongation in 2 in. [50 mm], min, %[A]
		ksi	[MPa]	ksi	[MPa]	
HF	19 Chromium, 9 Nickel	70	485	35	240	25
HH	25 Chromium, 12 Nickel	75	515	35	240	10
HI	28 Chromium, 15 Nickel	70	485	35	240	10
HK	25 Chromium, 20 Nickel	65	450	35	240	10
HE	29 Chromium, 9 Nickel	85	585	40	275	9
HT	15 Chromium, 35 Nickel	65	450	...	...	4
HU	19 Chromium, 39 Nickel	65	450	...	...	4
HW	12 Chromium, 60 Nickel	60	415	...	...	...
HX	17 Chromium, 66 Nickel	60	415	...	...	...
HC	28 Chromium	55	380	...	...	...
HD	28 Chromium, 5 Nickel	75	515	35	240	8
HL	29 Chromium, 20 Nickel	65	450	35	240	10
HN	20 Chromium, 25 Nickel	63	435	...	...	8
HP	26 Chromium, 35 Nickel	62.5	430	34	235	4.5

[A] When ICI test bars are used in tensile testing as provided for in this specification, the gage length to reduced section diameter ratio shall be 4 to 1.

re-heat treated and re-tested, but may not be solution treated or re-austenitized more than twice.

S9.6 If any test specimen shows defective machining or develops flaws, it may be discarded and another specimen substituted from the same heat.

Standard Specification for Gray Iron Castings for Elevated Temperatures for Non-Pressure Containing Parts[1]

This standard is issued under the fixed designation A 319; 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 three classes of gray iron suitable for castings exposed to temperatures encountered in such service as grate bars, stoker links, stoker parts, oil still furnace parts, firebox parts, ingot molds, glass molds, caustic pots, and metal melting pots.

NOTE 1—This specification is general, covering cast irons normally used for the above types of service, at temperatures as high as 1400°F (760°C). It is not intended to imply that all three classes are suitable throughout this entire temperature range without regard to actual service stresses. Some are suitable for long service at the lower temperatures only, unless low stresses are involved.

1.2 The three classes of gray iron covered by this specification are as follows:

1.2.1 *Class I*, possessing superior resistance to thermal shock,

1.2.2 *Class II*, possessing average resistance to thermal shock and a moderately good tensile strength (tensile strengths above 30 000 psi (207 MPa) may be expected), and

1.2.3 *Class III*, possessing a higher tensile strength than either Classes I or II (tensile strengths as high as 40 000 psi (276 MPa) may be expected).

1.3 The values stated in inch-pound units are to be regarded as the standard.

2. Referenced Documents

2.1 *ASTM Standards:*

A 48 Specification for Gray Iron Castings[2]

3. Manufacture

3.1 The melting procedure shall be optional with the foundry.

4. Physical Requirements

4.1 Some of the gray cast irons described in this specification are deliberately made of a soft, low-strength iron for resistance to thermal shock, and strength requirements are unnecessary. For applications in which a strength requirement is essential, room temperature tensile strengths may be specified up to those prescribed for Class 40 in Specification A 48.

5. Machinability

5.1 All machinable castings shall be limited in hardness at such locations on the castings as designated by the purchaser. The maximum hardness at the locations on castings that are to be machined shall be a matter of agreement between the manufacturer and the purchaser.

6. Chemical Composition

6.1 It is the intention of this specification to classify these irons in accordance with their carbon content equivalent calculated as follows:

$$\text{Carbon content equivalent} = \text{C} + 0.3\,(\text{Si} + \text{P}) \tag{1}$$

where:

C = carbon content, %,
Si = silicon content, %, and
P = phosphorus content, %,

6.2 The carbon content equivalent and the minimum carbon content for the various classes shall be as prescribed in Table 1. Table 2 prescribes the allowable silicon ranges predicated on the basis of various permissible carbon contents. It is recommended that embrittling impurities be held to the following maximum limits:

Phosphorus, max, %	0.60
Sulfur, max, %	0.15

6.3 The three basic classes may be alloyed with chromium. When chromium is present as an alloying element, each class shall be subdivided into types designated as follows:

Type	Chromium, %
A	0.20–0.40
B	0.41–0.65
C	0.66–0.95
D	0.96–1.20

6.4 All irons may be alloyed to increase the strength and to improve and stabilize the structure for elevated-temperature service. The alloying elements, which, in addition to chromium, are commonly added to improve these properties, are copper, molybdenum, nickel, and vanadium. Any combination of these alloying elements that assists in resisting oxidation or surface deterioration or in stabilizing the structure or retaining strength at elevated temperatures, may be used.

[1] This specification is under the jurisdiction of ASTM Committee A04 on Iron Castings and is the direct responsibility of Subcommittee A04.01 on Gray and White Iron Castings.

Current edition effective Oct. 25, 1971. Originally issued 1948. Replaces A319 – 53.

[2] *Annual Book of ASTM Standards*, Vol 01.02.

TABLE 1 Chemical Requirements

Class	Carbon Content Equivalent	Carbon, min, %
I	3.81–4.40	3.50
II	3.51–4.10	3.20
III	3.20–3.80	2.80

TABLE 2 Variations in Carbon and Silicon Contents

Class	Carbon, %	Silicon, %
I	3.50	0.90–2.70
	3.70	0.90–2.10
	3.90	0.90–1.50
II	3.20	0.90–2.70
	3.40	0.90–2.10
	3.50	1.80 max
III	2.80	1.20–2.70
	3.00	0.60–2.40
	3.20	0.60–1.80

NOTE 2—The provisions of this specification permit the purchaser to select a grade of cast iron suitable for his service and to define the product as, for example:

Castings Class II, Type B, plus |Cz|Cz alloys. All surfaces marked "f" (for finish) with HBN 250, max.

7. Product Analysis

7.1 When alloying elements are agreed upon between the manufacturer and the purchaser, the purchaser may make check analyses from any casting, test bar, or lot of castings delivered under this specification. Results of such analyses shall be in accordance with the limits agreed upon.

8. Workmanship, Finish, and Appearance

8.1 The castings shall conform substantially to the dimensions on drawings furnished by the purchaser or to the dimensions predicated by the pattern supplied by the purchaser, if no drawing has been provided. The castings shall be free from injurious defects. Surfaces of the castings shall be free from burnt-on sand and shall be reasonably smooth. Runners, risers, fins, and other cast-on pieces shall be removed. In other respects the castings shall conform to whatever points may be specially agreed upon between the manufacturer and the purchaser.

9. Inspection

9.1 The inspector representing the purchaser shall have free 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 manufacturer shall afford the inspector, without charge, 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.

10. Rejection

10.1 Failure to meet the requirements of Section 7 or of physical tests, when required, shall be sufficient cause for rejection as defective castings.

11. Certification

11.1 Upon request of the purchaser, the manufacturer shall furnish a statement that the inspection and all of the tests have been made as specified; this statement shall contain the results of all specified tests.

12. Keywords

12.1 chemical composition; elevated temperature; gray iron; iron castings; non-pressure containing; tensile strength

Standard Specification for Ferroboron[1]

This standard is issued under the fixed designation A 323; 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 six grades of ferroboron, designated A1, A2, B1, B2, C1, and C2.

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

2. Referenced Documents

2.1 *ASTM Standards:*

E 29 Practice for Using Significant Digits in Test Data to Determine Conformance with Specifications[2]

E 31 Methods for Chemical Analysis of Ferroalloys[3]

E 32 Practices for Sampling Ferroalloys and Steel Additives for Determination of Chemical Composition[3]

E 371 Test Methods for Chemical Analysis of Ferroboron[4]

3. Ordering Information

3.1 Orders for material to this specification shall include the following information:

3.1.1 Quantity,

3.1.2 Name of material,

3.1.3 ASTM designation,

3.1.4 Grade,

3.1.5 Size (see 4.1), if appropriate, and

3.1.6 Special requirements for packing, inspection, analysis reports, etc., as appropriate.

NOTE 1—A typical ordering description follows: 10 000 lb (4500 kg) ferroboron, ASTM A 323, Grade B1, 2 in. (50.8 mm) by down, packed in sealed containers.

4. Sizing

4.1 Ferroboron is available in various sizes such as: 2 in. (50.8 mm) by down, 1 in. (25.4 mm) by down, ¼ in. (6.35 mm) by down, and 20 mesh (0.841 mm) by down. The size shall be as specified in the order.

5. Chemical Analysis

5.1 The chemical analysis of the material shall be made in accordance with Methods E 31 and Test Methods E 371. Where no method is given in Methods E 31 and Test Methods E 371 for the analysis for a particular element, the analysis shall be made in accordance with a procedure agreed upon by the manufacturer and purchaser.

6. Sampling

6.1 The material shall be sampled in accordance with Practices E 32.

6.2 Other methods of sampling mutually agreed upon by manufacturer and purchaser may be used. For referee purposes, Practices E 32 shall be used.

7. Inspection

7.1 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.

8. Rejection

8.1 Any claims or rejections based upon check analysis shall be made to the manufacturer within 45 days from the purchaser's receipt of the material.

9. Packaging and Marking

9.1 *Packaging*:

9.1.1 Ferroboron shall be packed in such a manner as to be protected from loss or damage during shipment.

9.1.2 When shipment is required to be in containers under the provisions of Section 3, the containers shall be sound and capable of protecting the material from loss or damage during shipment and handling.

9.2 *Marking*:

9.2.1 When the shipment is made in bulk, it shall be accompanied by appropriate identification showing the material, grade, ASTM designation, size, lot number, and the name, brand, or trademark of the manufacturer.

9.2.2 When the shipment is made in containers, each container shall be identified by an attached label or tag. The marking shall show the material, grade, ASTM designation,

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[1] This specification is under the jurisdiction of ASTM Committee A-1 on Steel, Stainless Steel, and Related Alloys and is the direct responsibility of Subcommittee A01.18 on Castings.

Current edition approved Dec. 15, 1993. Published April 1994. Originally issued 1949, Replaces A 323–52T. Last previous edition A 323-76 (1983).

[2] *Annual Book of ASTM Standards*, Vol 14.02.

[3] *Annual Book of ASTM Standards*, Vol 03.05.

[4] *Annual Book of ASTM Standards*, Vol 03.06.

size, lot number, gross, tare and net weight, and name, brand, or trademark of the manufacturer.

10. Chemical Requirements

10.1 The various grades shall conform to the requirements as to chemical composition specified in Table 1.

TABLE 1 Chemical Requirements[A]

NOTE 1— An analysis report on each lot is required.

Grade	Boron[B]		Composition, % Carbon	Silicon	Aluminum
	min	max	max	max	max
A1	12.0	14.0	1.5	2.0	0.5
A2	12.0	14.0	1.5	2.0	4.0
B1	17.5	19.0	1.5	2.0	0.5
B2	17.5	19.0	1.5	2.0	4.0
C1	19.0	24.0	1.5	2.0	0.5
C2	19.0	24.0	1.5	2.0	4.0

[A] To determine conformance with this specification, the reported analysis shall be rounded off to the nearest unit in the last right-hand place of figures used in expressing the limiting value in accordance with Practice E 29.

[B] To determine the boron content of any shipment, boron shall be reported to the nearest 0.1 %, applying the same rounding-off procedure used in Footnote *A*.

Designation: A 324 – 73 (Reapproved 2000)

Standard Specification for Ferrotitanium[1]

This standard is issued under the fixed designation A 324; 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 four grades of ferrotitanium, designated A, B, C, and D.

2. Referenced Documents

2.1 *ASTM Standards:*

E 29 Practice for Using Significant Digits in Test Data to Determine Conformance with Specifications[2]

E 32 Practices for Sampling Ferroalloys and Steel Additives for Determination of Chemical Composition[3]

3. Ordering Information

3.1 The material furnished under this specification shall be crushed to the specified size, and mixed before packaging, so that the quality in each package is uniform with the lot.

3.2 The reported percentage of titanium as obtained by chemical analysis shall be used to determine the billing of the material to the purchaser.

4. Chemical Composition

4.1 The various grades shall conform to the requirements as to chemical composition prescribed in Table 1, Table 2, Table 3, and Table 4.

5. Chemical Analysis

5.1 The chemical analysis of the material shall be made in accordance with a procedure agreed upon between the manufacturer and the purchaser.

6. Sampling

6.1 The material shall be sampled in accordance with Practices E 32.

TABLE 1 Chemical Requirements[A]

Grade	Composition, %			
	Titanium[B]	Carbon, max	Silicon, max	Aluminum, max
A	65.0–75.0	0.15	0.25	0.50
B	65.0–75.0	0.20	0.25	5.0
C	35.0–45.0	0.15	5.0	8.0
D	15.0–25.0	5.0	5.0	8.0

[A] For purposes of determining conformance with these specifications, the reported analysis shall be rounded to the nearest unit in the last right-hand place of figures used in expressing the limiting value, in accordance with the rounding method of Recommended Practice E 29.

[B] For purposes of determining the titanium content of any shipment, titanium shall be reported to the nearest 0.01 %, applying the same rounding procedure as prescribed in Footnote *A*.

7. Inspection

7.1 The inspector representing the purchaser shall have free 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 sampling, packaging, and shipping of material ordered. The manufacturer shall afford the inspector all reasonable facilities, without charge, to satisfy him that the material is being furnished in accordance with this specification.

7.2 If the purchaser so elects, the material may be sampled by him at the destination, in which case at least 10 % of the shipment shall be sampled.

8. Rejection

8.1 Any claims or rejections based on check analysis shall be made to the manufacturer within 45 days from receipt of material by the purchaser.

9. Packaging

9.1 Ferrotitanium shall be packaged in sound containers in such manner that none of the metal is lost in shipment.

[1] This specification is under the jurisdiction of ASTM Committee A-1 on Steel, Stainless Steel, and Related Alloys and is the direct responsibility of Subcommittee A01.18 on Castings.

Current edition approved Aug. 27, 1973. Published October 1973. Originally published as A 324 – 49 T. Last previous edition A 324 – 66 (Reapproved 1972).

[2] *Annual Book of ASTM Standards*, Vol 14.02.

[3] *Annual Book of ASTM Standards*, Vol 03.05.

TABLE 2 Supplementary Chemical Requirements

Grade	Composition, %[A]																
	Manganese	Phosphorus	Sulfur	Chromium	Nickel	Molybdenum	Copper	Cobalt	Vanadium	Lead	Arsenic	Bismuth	Tin	Zinc	Zirconium	Boron	Nitrogen
A	0.50	0.050	0.050	1.0	0.050	0.050	0.15	0.030	0.50	0.010	0.010	0.010	0.050	0.010	0.10	0.010	0.15
B	1.5	0.050	0.050	1.0	0.050	0.25	0.20	0.050	1.5	0.030	0.010	0.010	0.050	0.020	0.50	0.020	0.20
C	1.5	0.10	0.050	1.0	0.050	0.25	0.20	0.050	1.5	0.030	0.010	0.010	0.050	0.020	0.50	0.020	0.20
D	1.5	0.10	0.050	1.0	0.050	0.25	0.20	0.050	1.5	0.050	0.010	0.010	0.050	0.020	0.50	0.020	0.20

[A]Maximum limits allowable unless otherwise stated.

TABLE 3 Size Requirements (All Grades)

Category	Tolerances
2 in. (50 mm) by down	10 %, max retained on USA Standard 2 in. (50 mm) Sieve 10 %, max passing USA Standard No. 20 (850 µm) Sieve
1 in. (25 mm) by down	10 %, max retained on USA Standard 1 in. (25.0 mm) Sieve 10 %, max passing USA Standard No. 20 (850 µm) Sieve
½in. (12.5 mm) by down	10 %, max retained on USA Standard ½in. (12.5 mm) Sieve 15 %, max passing USA Standard No. 30 (600 µm) Sieve
8 M (2.36 mm) by down	10 %, max retained on USA Standard No. 8 (2.36 mm) Sieve 10 %, max passing USA Standard No. 200 (75 µm) Sieve

TABLE 4 Friability Rating

All grades	Number 3

Standard Test Methods for Impact Testing of Cast Irons[1]

This standard is issued under the fixed designation A 327; 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 These test methods for impact testing cover the details of apparatus, test specimens and procedures for cast iron, including gray iron, white iron, malleable iron, ductile iron, and austempered ductile iron, but not including chilled rolls or rolls with white iron skins.

1.2 The values stated in inch-pound units are to be regarded as the standard. A companion standard, A 327M, lists values in 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:*

E 23 Test Methods for Notched Bar Impact Testing of Metallic Materials[2]

METHOD A—ROUND BAR CHARPY-TYPE IMPACT TEST FOR GRAY AND WHITE IRONS

3. Scope

3.1 The Charpy-type impact test shall be employed for testing gray and white irons.

4. Apparatus

4.1 The single-blow Charpy impact test for gray and white irons shall be carried out in a pendulum-type impact machine with a capacity of at least 110 ft · lbf as used for the simple beam test for steel described in Test Methods E 23.

5. Test Specimens

5.1 The test specimens shall have a plain cylindrical form, machined or ground to a smooth finish and shall conform to the following dimensions:

	Type A	Type M
Diameter	1.125 ± 0.002 in.	0.787 ± 0.001 in.
Length	8.0 ± 0.5 in.	4.73 ± 0.08 in.
Span	6.00 ± 0.03 in.	3.937 ± 0.020 in.

6. Procedure

6.1 Test the bars on the spans indicated in the tabular data of 5.1. In all other respects, the test shall conform to the appropriate requirements of Test Methods E 23.

6.2 Make the test at room temperature.

6.3 Characterization of the fracture toughness of any cast iron should be based upon testing at least three specimens.

NOTE 1—Care should be taken to examine broken specimens for indication of anvil interference which will give erroneous results.

7. Report

7.1 The results shall be reported as ____ ft · lbf cast iron Charpy impact with ____ in. diameter bar.

METHOD B—STANDARD CHARPY-TYPE IMPACT TEST FOR MALLEABLE AND DUCTILE IRONS

8. Scope

8.1 Either the standard notched or unnotched Charpy impact test shall be employed in testing of malleable or ductile irons. Selection of the type bar is dependent upon the specific material to be evaluated as defined in Section 9.

8.2 Both types of charpy bars have been designated to characterize the fracture toughness of irons. The unnotched Charpy bar, when tested, will produce substantially higher energy values than the notch bar type. The unnotched bar is therefore specified for testing irons that have low fracture toughness characteristics.

9. Charpy Test Bar Type

9.1 Unless specified otherwise, the notched bar type specimens in Fig. 1 or Fig. 2 (for pipe type products) shall be employed. Exceptions are defined in 9.2 and 9.3.

9.2 The unnotched charpy type specimen in Fig. 3 shall be employed for testing of all grades of austempered ductile iron. These irons are tested after the austempering heat treatment.

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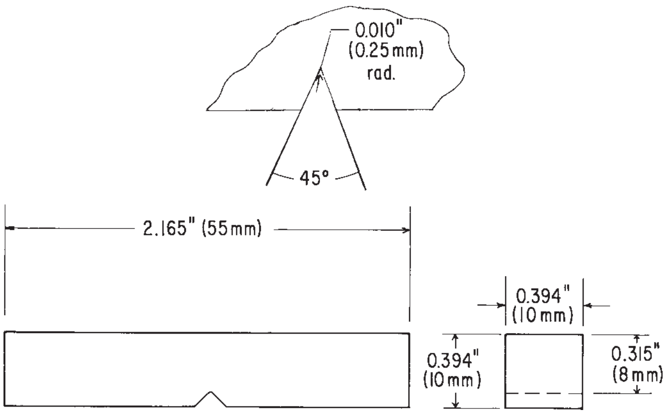
[1] These test methods are under the jurisdiction of ASTM Committee A-4 on Iron Castings and are the direct responsibility of Subcommittee A04.21 on Testing.

Current edition approved April 15, 1991. Published November 1991. Originally published as A 327 – 50 T. Last previous edition A 327 – 72 (1985).

[2] *Annual Book of ASTM Standards*, Vol 03.01.



NOTE—Permissible variations shall be as follows:

Adjacent sides shall be at	90° ± 10 min
Cross section dimensions	±0.001 in.
Length of specimen, *L*	±0, −0.100 in.
Angle of notch	±1°
Radius of notch	±0.001 in.
Dimension to bottom of notch	±0.001 in.
Distance to notch, ½	±0.040 in.

FIG. 1 Standard Vee Notch Charpy Bar Impact Test Specimen

9.3 The unnotched charpy test specimen may be specified for other types of irons or irons that have been heat treated in various ways other than austempering, by specific agreement between producer and purchaser.

10. Apparatus

10.1 The single-blow Charpy test for ductile and malleable iron shall be carried out in a pendulum-type impact machine with a capacity of at least 110 ft · lbf as used for the simple beam test for steel described in Test Methods E 23.

10.2 Standard machines may be modified by using a more sensitive scale, or pendulum machines of a lower capacity may be used where values of less than 25 ft · lbf will be obtained.

11. Test Specimens

11.1 Except for pipe, the test specimen shall have the shape and dimensions as shown in Fig. 1 for notch Charpy bars and Fig. 3 for unnotched Charpy bars. Bars must have a smooth machined or ground surface finish. The notched area of notch type bars shall be free of any burrs or machining marks that could adversely influence test values.

11.2 In the case of malleable or ductile irons that are to be tested after heat treatment, such as austempered ductile irons, final finish grinding of longitudinal faces and cutting of the notch must be performed after completion of all heat treatment operations.

11.3 Test specimens taken from ductile iron pipe shall be 0.500 in. wide, measured from the notched face. The thickness of the notched face shall be equal to the full wall thickness of the pipe (t), except that specimens in which the pipe wall specimen thickness exceeds the maximum height accommodated by the impact test machine shall be machined to a thickness that can be accommodated by the machine. Specimens shall be machined in accordance with Fig. 2.

12. Procedure

12.1 Test the specimen in accordance with the procedures set forth in Test Methods E 23.

12.2 Unless otherwise specified, the test shall be performed at 70 ± 10°F.

12.3 For testing at other than room temperature, accuracy of results is ensured by following the procedure outlined in Test Methods E 23.

12.4 Characterization of the fracture toughness of any cast iron should be based upon testing at least three specimens.

13. Report

13.1 Report the following information:

13.1.1 For malleable or ductile irons, the results shall be reported as ft · lbf at °F, "standard notched Charpy test" or "standard unnotched Charpy test," depending upon which specimen type was employed.

13.1.2 Impact test results for ductile iron pipe shall be corrected by calculation as follows:

Impact value corrected = $[0.40/t] \times$ impact value measured where t is the thickness of the specimen in inches (see Fig. 2 and Note 2).

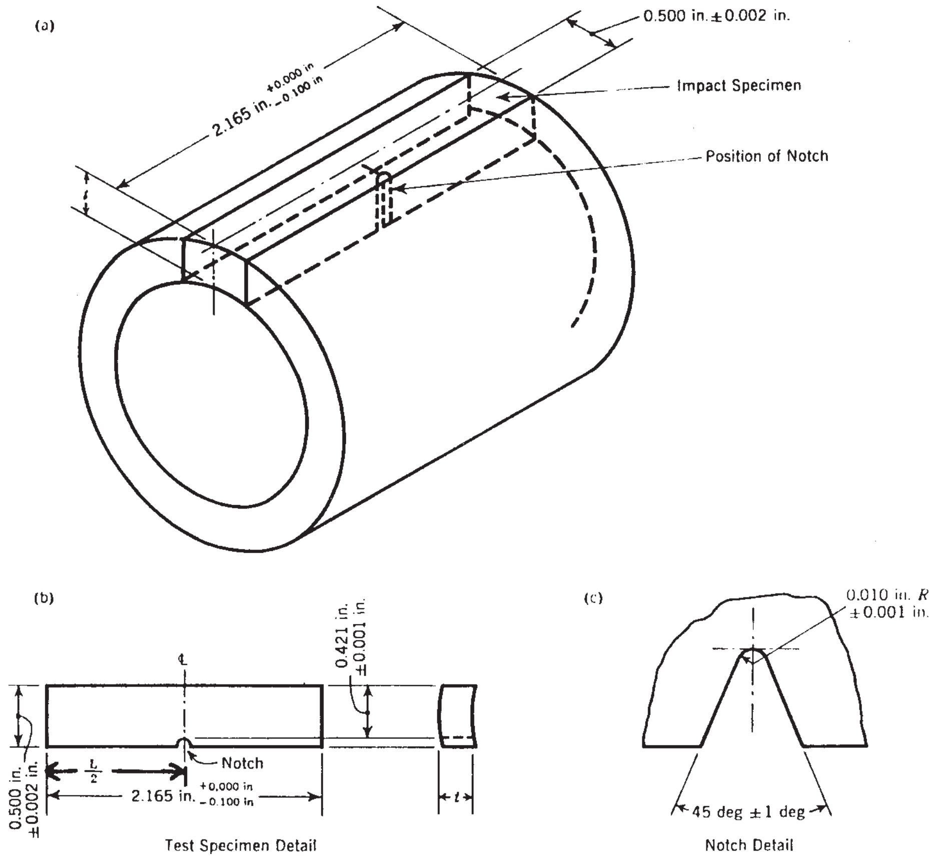
NOTE 2—The ratio $0.40/t$ (where t = pipe wall thickness in inches), when multiplied by the measured energy values, normalizes reported energy values for pipe or tube of different wall thicknesses to a standard 0.40 in. wall dimension.

13.1.3 Where tests are conducted at other than room temperature, as defined in 12.2, actual test temperature in the samples themselves at the time of testing shall be recorded and reported with the determined energy values. These temperatures shall be measured and reported to ±2°F.

14. Precision and Bias

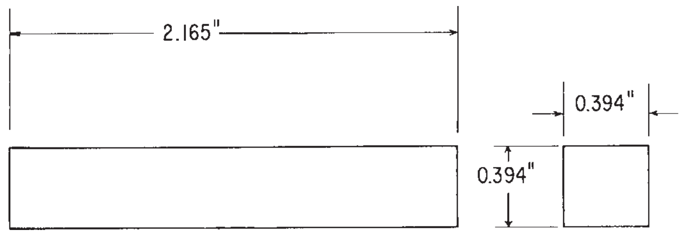
14.1 *Precision*—No statement on precision is currently available. The test methods for impact testing in A 327 and A 327 M are based on referenced Test Methods E 23. Determination of precision for Test Methods E 23 is currently under evaluation in Judicial Committee E-28 on Mechanical Testing.

14.2 *Bias*—Since no acceptable single reference material for determining bias in measuring impact energy for the variety of cast irons covered by these test methods has been identified, bias has not been established.



In Diagrams (*a*) and (*b*) the symbol *t* is for the pipe wall thickness.
Permissible variations for ½ shall be ±0.040 in.

FIG. 2 Impact Test Specimen for Ductile Iron Pipe and Tube



NOTE—Permissible variations shall be as follows:

Adjacent sides shall be at	90° ± 10 min
Cross section dimensions	±0.001 in.
Length of specimen	±0, −0.100 in.

FIG. 3 Unnotched Charpy Bar Impact Test Specimen

Standard Test Methods for Impact Testing of Cast Irons (Metric)[1]

This standard is issued under the fixed designation A 327M; 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 These test methods for impact testing cover the details of apparatus, test specimens and procedures for cast iron, including gray iron, white iron, malleable iron, ductile iron, and austempered ductile iron, but not including chilled rolls or rolls with white iron skins.

1.2 The values stated in SI units are to be regarded as the standard. A companion standard, A 327, lists values in inch-pound 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:*

E 23 Test Methods for Notched Bar Impact Testing of Metallic Materials[2]

METHOD A—ROUND BAR CHARPY-TYPE IMPACT TEST FOR GRAY AND WHITE IRONS

3. Scope

3.1 The Charpy-type impact test shall be employed for testing gray and white irons.

4. Apparatus

4.1 The single-blow Charpy impact test for gray and white irons shall be carried out in a pendulum-type impact machine with a capacity of at least 150 J as used for the simple beam test for steel described in Test Methods E 23.

5. Test Specimens

5.1 The test specimens shall have a plain cylindrical form, machined or ground to a smooth finish and shall conform to the following dimensions:

	Type A	Type M
Diameter	28.575 ± 0.050 mm	20.00 ± 0.03 mm
Length	200 ± 13 mm	120 ± 2 mm
Span	152.0 ± 0.7 mm	100.0 ± 0.5 mm

6. Procedure

6.1 Test the bars on the spans indicated in the tabular data of 5.1. In all other respects, the test shall conform to the appropriate requirements of Test Methods E 23.

6.2 Make the test at room temperature.

6.3 Characterization of the fracture toughness of any cast iron should be based upon testing at least three specimens.

NOTE 1—Care should be taken to examine broken specimens for indication of anvil interference, which will give erroneous results.

7. Report

7.1 The results shall be reported as ____ J cast iron charpy impact with ____ mm diameter bar.

METHOD B—STANDARD CHARPY-TYPE IMPACT TEST FOR MALLEABLE AND DUCTILE IRONS

8. Scope

8.1 Either the standard notched or unnotched charpy impact test shall be employed in testing of malleable or ductile irons. Selection of the type bar is dependent upon the specific material to be evaluated as defined in Section 9.

8.2 Both types of charpy bars have been designated to characterize the fracture toughness of irons. The unnotched charpy bar, when tested, will produce substantially higher energy values than the notch bar type. The unnotched bar is therefore specified for testing irons that have low fracture toughness characteristics.

[1] These test methods are under the jurisdiction of ASTM Committee A-4 on Iron Castings and are the direct responsibility of Subcommittee A04.21 on Testing.

Current edition approved April 15, 1991. Published November 1991.

[2] *Annual Book of ASTM Standards*, Vol 03.01.

9. Charpy Test Bar Type

9.1 Unless specified otherwise, the notched bar type specimens in Figs. 1 and 2 (for pipe type products) shall be employed. Exceptions are defined in 9.2 and 9.3.

9.2 The unnotched charpy type specimen in Fig. 3 shall be employed for testing of all grades of austempered ductile iron. These irons are tested after the austempering heat treatment.

9.3 The unnotched charpy type specimen may be specified for other types of irons or irons that have been heat treated in various ways other than austempering, by specific agreement between producer and purchaser.

10. Apparatus

10.1 The single-blow Charpy test for ductile and malleable iron shall be carried out in a pendulum-type impact machine with a capacity of at least 150 J as used for the simple beam test for steel described in Test Methods E 23.

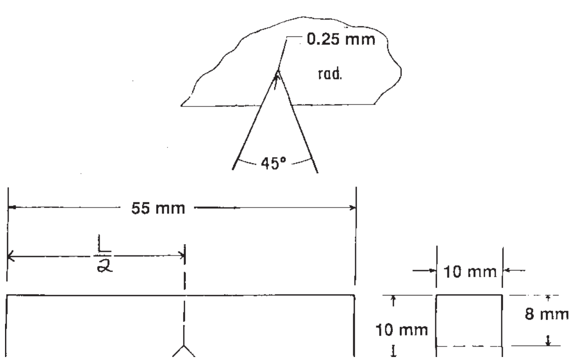
10.2 Standard machines may be modified by using a more sensitive scale, or pendulum machines of a lower capacity may be used where values of less than 34 J will be obtained.

11. Test Specimens

11.1 Except for pipe, the test specimen shall have the shape and dimensions as shown in Fig. 1 for notch charpy bars and Fig. 3 for unnotched charpy bars. Bars must have a smooth machined or ground surface finish. The notched area of notch type bars shall be free of any burrs or machining marks that could be judged to adversely influence test values.

11.2 In the case of malleable or ductile irons that are to be tested after heat treatment, such as austempered ductile irons, final finish grinding of longitudinal faces and cutting of the notch must be performed after completion of all heat treatment operations.

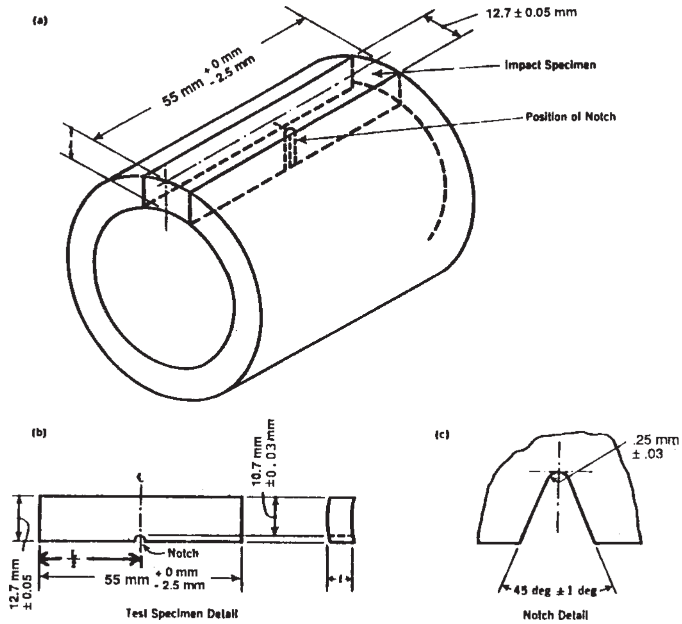
11.3 Test specimens taken from ductile iron pipe shall be 0.500 in. wide, measured from the notched face. The thickness of the notched face shall be equal to the full wall thickness of the pipe, *t*, except that specimens in which the pipe wall specimen thickness exceeds the maximum height accommodated by the impact test machine shall be machined to a thickness that can be accommodated by the machine. Specimens shall be machined in accordance with Fig. 2.



NOTE—Permissible variations shall be as follows:

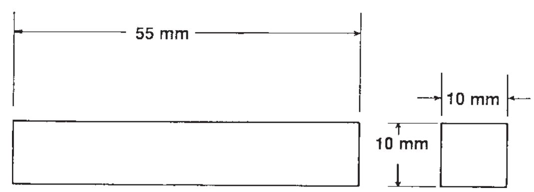
Adjacent sides shall be at	90° ± 10 min
Cross section dimensions	±0.03 mm
Length of specimen	+0, −2.5 mm
Angle of notch	±1°
Radius of notch	±0.03 mm
Dimension to bottom of notch	±0.03 mm
Distance to notch, ½	±1 mm

FIG. 1 Standard Vee Notch Charpy Bar Impact Test Specimen



NOTE 1—The symbol *t* is for the pipe wall thickness.
NOTE 2—Permissible variations for *L*/2 shall be ±1 mm.

FIG. 2 Impact Test Specimen for Ductile Iron Pipe and Tube



NOTE—Permissible variations shall be as follows:

Adjacent sides shall be at	90° ± 10 min
Cross section dimensions	±0.03 mm
Length of specimen	+0, −2.5 mm

FIG. 3 Unnotched Charpy Bar Impact Test Specimen

12. Procedure

12.1 Test the specimen in accordance with the procedures set forth in Test Methods E 23.

12.2 Unless otherwise specified, the test shall be performed at 21 ± 5.5°C.

12.3 For testing at other than room temperature, accuracy of results is ensured by following the procedure outlined in Test Methods E 23.

12.4 Characterization of the fracture toughness of any cast iron should be based upon testing at least three specimens.

13. Report

13.1 For malleable or ductile irons, the results shall be reported as ____ J at ____ °C, "standard notched Charpy test" or "standard unnotched Charpy test," depending upon which specimen type was employed.

13.2 Impact test results for ductile iron pipe shall be corrected by calculation as follows:

$$\text{Impact value corrected} = [10.2/t] \times \text{impact value measured},$$

where t is the thickness of the specimen in millimetres (see Fig. 2 and Note 2).

NOTE 2—The ratio $^{10.2}/_{t}$ (where t = pipe wall thickness, mm), when multiplied by the measured energy values, normalizes reported energy values for pipe or tube of different wall thicknesses to a standard 10.2 mm wall dimension.

13.3 Where tests are conducted at other than room temperature, as defined in 12.2, actual test temperature in the samples themselves at the time of testing shall be recorded and reported with the determined energy values. These temperatures shall be measured and reported to ±1°C.

14. Precision and Bias

14.1 *Precision*—No statement on precision is currently available. The methods of impact testing in A 327 and A 327M are based on Test Methods E 23. Determination of precision for Test Methods E 23 is currently under evaluation in Judicial Committee E 28 on Mechanical Testing.

14.2 *Bias*—Since no acceptable single reference material for determining bias in measuring impact energy for the variety of cast irons covered by these test methods has been identified, bias has not been established.

Designation: A 338 – 84 (Reapproved 2004)

Standard Specification for Malleable Iron Flanges, Pipe Fittings, and Valve Parts for Railroad, Marine, and Other Heavy Duty Service at Temperatures Up to 650°F (345°C)[1]

This standard is issued under the fixed designation A 338; 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 malleable iron flanges, pipe fittings, and valve parts, including parts to be assembled for use in railroad, marine, and other heavy duty service applications where fittings furnished in accordance with American National Standard for Malleable Iron Threaded Fittings, Class 150 and 300 (ANSI B16.3) are not considered adequate.

1.2 Service shall include up to 650°F (345°C).[2]

2. Referenced Documents

2.1 *ASTM Standards:* [3]

A 47 Specification for Ferritic Malleable Iron Castings

A 153 Specification for Zinc Coating (Hot-Dip) on Iron and Steel Hardware

2.2 *American National Standards:*[4]

B 2.1 Pipe Threads

B 16.3 Malleable Iron Threaded Fittings, Class 150 and 300

2.3 *Other Standards:*

Hand Book H28, Section VI, Screw-Thread Standards for Federal Services, 1944[5]

SP-25-1936 Standard Marking System for Valves, Fittings, Flanges, and Unions[6]

3. Process

3.1 The castings shall be made in accordance with Specification A 47.

4. Materials and Manufacture

4.1 The sizes, shapes, and dimensions of the fittings, covered by ANSI B16.3 shall conform to the requirements therein specified.

4.2 Screwed pipe fittings, unions, union fittings, and globe and angle valves that are covered by the various standards and recommended practices as issued by the Association of American Railroads shall conform to the requirements therein specified.

4.3 All pipe threads, unless otherwise specified, shall be in accordance with ANSI B2.1. (Standards for pipe threads are also available in Section VI of Screw-Thread Standards for Federal Services.)

4.4 Zinc coatings on fittings which are required to be galvanized by the hot-dip process shall conform to the requirements for Class A castings as prescribed in Specification A 153, except on surfaces where it is the practice to machine after galvanizing.

5. Manufacture Control and Records

5.1 The iron shall be produced under constant control of chemical composition and physical properties. Records of the chemical composition of the iron and of the physical properties of the test specimens shall be systematically made and maintained.

6. Tests

6.1 Tests shall be made when required by the specifications listed herein.

7. Certification

7.1 The manufacturer shall be prepared to certify, upon request of the purchaser, that his product conforms to the requirements of this specification.

8. Product Marking

8.1 The castings shall be marked with the manufacturer's name or trademark.

8.2 Malleable iron products conforming to the standards of the Manufacturers Standardization Society of the Valve and Fittings Industry shall be marked in accordance with SP-25-1936 of that Society. Malleable iron products furnished in

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[1] This specification is under the jurisdiction of ASTM Committee A04 on Iron Castings and is the direct responsibility of Subcommittee A04.02 on Malleable and Ductile Iron Castings.

Current edition approved May 1, 2004. Published May 2004. Originally approved in 1954. Last previous edition approved in 1998 as A 338 – 84 (1998).

[2] Based on Marshall, L. C., and Sommer, G. F., "Stress Rupture Properties of Malleable Iron at Elevated Temperatures," *Proceedings*, ASTM International, Vol 58, 1958, p. 733.

[3] 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.

[4] Available from American National Standards Institute (ANSI), 25 W. 43rd St., 4th Floor, New York, NY 10036.

[5] Available from National Institute of Standards and Technology (NIST), 100 Bureau Dr., Stop 3460, Gaithersburg, MD 20899-3460.

[6] Available from Manufacturers Standardization Society of the Valve and Fittings Industry (MSS), 127 Park St., NE, Vienna, VA 22180-4602.

accordance with the standards issued by the American Standards Association or by the Association of American Railroads shall be marked as specified in the respective standards.

9. Keywords

9.1 flanges; heavy duty service; malleable iron; marine service; pipe fittings; railroad service; valve parts

Standard Specification for Castings, Austenitic, Austenitic-Ferritic (Duplex), for Pressure-Containing Parts[1]

This standard is issued under the fixed designation A 351/A 351M; 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[2] covers austenitic and austenitic-ferritic (duplex) steel castings for valves, flanges, fittings, and other pressure-containing parts (Note 1).

NOTE 1—Carbon steel castings for pressure-containing parts are covered by Specification A 216/A 216M, and low-alloy steel castings by Specification A 217/A 217M.

1.2 A number of grades of austenitic and austenitic-ferritic steel castings are included in this specification. Since these grades possess varying degrees of suitability for service at high temperatures or in corrosive environments, it is the responsibility of the purchaser to determine which grade shall be furnished. Selection will depend on design and service conditions, mechanical properties, and high-temperature or corrosion-resistant characteristics, or both.

1.2.1 Because of thermal instability, Grades CE20N, CF3A, CF3MA, and CF8A are not recommended for service at temperatures above 800°F [425°C].

1.2.2 Because of embrittlement phases, Grade CD4MCu is not recommended for service at temperatures above 600°F [316°C].

1.3 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 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 216/A 216M Specification for Steel Castings, Carbon, Suitable for Fusion Welding, for High-Temperature Service[3]

A 217/A 217M Specification for Steel Castings, Martensitic Stainless and Alloy, for Pressure-Containing Parts, Suitable for High-Temperature Service[3]

A 488/A 488M Practice for Steel Castings, Welding, Qualification of Procedures and Personnel[3]

A 703/A 703M Specification for Steel Castings, General Requirements, for Pressure-Containing Parts[3]

E 165 Test Method for Liquid Penetrant Examination[4]

E 709 Guide for Magnetic Particle Examination[4]

2.2 *Manufacturers Standardization Society of the Valve and Fittings Industry Standard:*

SP-55 Quality Standard for Steel Castings for Valves, Flanges, and Fittings and Other Components (Visual Method)[5]

3. General Conditions for Delivery

3.1 Material furnished to this specification shall conform to the requirements of Specification A 703/A 703M, including any supplementary requirements that are indicated in the purchase order. Failure to comply with the general requirements of Specification A 703/A 703M constitutes nonconformance with this specification. In case of conflict between the requirements of this specification and Specification A 703/A 703M, this specification shall prevail.

3.2 The post weld heat treatment requirements of Supplementary Requirement S11 may be specified when austenitic castings other than HK, HT, or CT15C are to be subjected to severe corrosive service.

[1] This specification is under the jurisdiction of ASTM Committee A01 on Steel, Stainless Steel, and Related Alloys and is the direct responsibility of Subcommittee A01.18 on Castings.

Current edition approved May 10, 2003. Published June 2003. Originally approved in 1952. Last previous edition approved in 2000 as A 351/A 351M – 00.

[2] For ASME Boiler and Pressure Vessel Code applications, see related Specification SA-351/SA-351M in Section II of that code.

[3] *Annual Book of ASTM Standards*, Vol 01.02.

[4] *Annual Book of ASTM Standards*, Vol 03.03.

[5] Available from Manufacturers' Standardization Society of the Valve and Fittings Industry, 1815 N. Fort Myer Drive, Arlington, VA 22209.

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

4. Ordering Information

4.1 The inquiry and order should include or indicate the following:

4.1.1 A description of the casting by pattern number or drawing (dimensional tolerances shall be included on the casting drawing),

4.1.2 Grade of steel,

4.1.3 Options in the specification, and

4.1.4 Supplementary requirements desired, including the standards of acceptance.

5. Process

5.1 The steel shall be made by the electric furnace process with or without separate refining such as argon-oxygen decarburization (AOD).

6. Heat Treatment

6.1 All castings shall receive a heat treatment at the temperature specified in Table 1, followed by a quench in water or rapid cool by other means except as noted.

NOTE 2—Proper heat treatment of these alloys is usually necessary to enhance corrosion resistance and in some cases to meet mechanical properties. Minimum heat-treat temperatures are specified; however, it is sometimes necessary to heat-treat at higher temperatures, hold for some minimum time at temperature and then rapidly cool the castings in order to enhance the corrosion resistance and meet mechanical properties.

7. Chemical Composition

7.1 The steel shall conform to the requirements as to chemical composition prescribed in Table 2.

TABLE 1 Heat-Treatment Requirements

Grade	Temperature, min	
	°F	°C
HK30, HK40, HT30, CT15C	as-cast	as-cast
CF3, CF3A, CF8, CF8A, CF3M, CF3MA, CF8M, CF3MN, CG3M, CF10, CF10M, CG8M, CD4MCu	1900	1040
CF10SMnN, CF8C, CF10MC	1950	1065
CD3MWCuN	2010	1100
CN7M, CG6MMN, CE8MN	2050	1120
CK3MCuN, CN3MN, CH8, CH10, CH20, CK20	2100	1150
CE20N[A]	2225	1220

[A] Grade shall be quenched in water or the castings may be furnace cooled to 2050°F [1120°C] minimum, held for 15 min minimum and then quenched in water or rapidly cooled by other means.

8. Tensile Properties

8.1 Steel used for the castings shall conform to the requirements as to tensile properties prescribed in Table 3.

9. Quality

9.1 The surface of the casting shall be examined visually and shall be free of adhering sand, scale, cracks, and hot tears. Other surface discontinuities shall meet the visual acceptance standards specified in the order. Visual Method SP 55 or other visual standards may be used to define acceptable surface discontinuities and finish. Unacceptable visual surface discontinuities shall be removed and their removal verified by visual examination of the resultant cavities.

9.2 When additional inspection is desired, Supplementary Requirements S5, S6, and S10 may be ordered.

9.3 The castings shall not be peened, plugged, or impregnated to stop leaks.

10. Repair by Welding

10.1 Repairs shall be made using procedures and welders qualified under Practice A 488/A 488M.

10.2 Weld repairs shall be inspected to the same quality standards that are used to inspect the castings. When castings are produced with Supplementary Requirement S5 specified, weld repairs on castings that have leaked on hydrostatic test, or on castings in which the depth of any cavity prepared for repair welding exceeds 20 % of the wall thickness or 1 in. [25 mm], whichever is smaller, or on castings in which any cavity prepared for welding is greater than approximately 10 in.^{2}[65 cm^2], shall be radiographed to the same standards that are used to inspect the castings. When castings are produced with Supplementary Requirement S6 specified, weld repairs shall be inspected by liquid penetrant examination to the same standards that are used to inspect the castings.

NOTE 3—When austenitic steel castings are to be used in services where they will be subject to stress corrosion, the purchaser should so indicate in his order and such castings should be solution-heat treated following all weld repairs.

11. Keywords

11.1 austenitic stainless steel; duplex stainless steel; pressure containing parts; stainless steel; steel castings

TABLE 2 Chemical Requirements

NOTE—Tungsten is a new element for Table 2.

Element, % (max, except where range is given)	CF3, CF3A J92700	CF8, CF8A J92600	CF3M, CF3MA J92800	CF8M J92900	CF3MN J92804	CF8C J92710	CF10 J92950	CF10M J92901	CH8 J93400	CH10 J93401	CH20 J93402	CK20 J94202	HK30 J94203	HK40 J94204
Carbon	0.03	0.08	0.03	0.08	0.03	0.08	0.04–0.10	0.04–0.10	0.08	0.04–0.10	0.04–0.20	0.04–0.20	0.25–0.35	0.35–0.45
Manganese	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
Silicon	2.00	2.00	1.50	1.50	1.50	2.00	2.00	1.50	1.50	2.00	2.00	1.75	1.75	1.75
Sulfur	0.040	0.040	0.040	0.040	0.040	0.040	0.040	0.040	0.040	0.040	0.040	0.040	0.040	0.040
Phosphorus	0.040	0.040	0.040	0.040	0.040	0.040	0.040	0.040	0.040	0.040	0.040	0.040	0.040	0.040
Chromium	17.0–21.0	18.0–21.0	17.0–21.0	18.0–21.0	17.0–21.0	18.0–21.0	18.0–21.0	18.0–21.0	22.0–26.0	22.0–26.0	22.0–26.0	23.0–27.0	23.0–27.0	23.0–27.0
Nickel	8.0–12.0	8.0–11.0	9.0–13.0	9.0–12.0	9.0–13.0	9.0–12.0	8.0–11.0	9.0–12.0	12.0–15.0	12.0–15.0	12.0–15.0	19.0–22.0	19.0–22.0	19.0–22.0
Molybdenum	0.50	0.50	2.0–3.0	2.0–3.0	2.0–3.0	0.50	0.50	2.0–3.0	0.50	0.50	0.50	0.50	0.50	0.50
Columbium (niobium)	. . .	. . .	. . .	. . .	. . .	[A]	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .
Vanadium	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .
Nitrogen	. . .	. . .	. . .	. . .	0.10–0.20	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .
Copper	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .
Tungsten	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .
Iron	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .

Element, % (max, except where range is given)	HT30 N08030	CF10MC	CN7M N08007	CN3MN J94651	CD-4MCu J93370	CE8MN	CG-6MMN J93790	CG8M J93000	CF10S-MnN J92972	CT15C N08151	CK-3MCuN J93254	CE20N J92802	CG3M J92999	CD3M-WCuN[B] J93380
Carbon	0.25–0.35	0.10	0.07	0.03 max	0.04	0.08	0.06	0.08	0.10	0.05–0.15	0.025	0.20	0.03	0.03
Manganese	2.00	1.50	1.50	2.00 max	1.00	1.00	4.00–6.00	1.50	7.00–9.00	0.15–1.50	1.20	1.50	1.50	1.00
Silicon	2.50	1.50	1.50	1.00 max	1.00	1.50	1.00	1.50	3.50–4.50	0.50–1.50	1.00	1.50	1.50	1.00
Sulfur	0.040	0.040	0.040	0.010 max	0.04	0.040	0.030	0.04	0.030	0.03	0.010	0.040	0.04	0.025
Phosphorus	0.040	0.040	0.040	0.040 max	0.04	0.040	0.040	0.04	0.060	0.03	0.045	0.040	0.04	0.030
Chromium	13.0–17.0	15.0–18.0	19.0–22.0	20.0–22.0	24.5–26.5	22.5–25.5	20.50–23.50	18.0–21.0	16.0–18.0	19.0–21.0	19.5–20.5	23.0–26.0	18.0–21.0	24.0–26.0
Nickel	33.0–37.0	13.0–16.0	27.5–30.5	23.5–25.5	4.75–6.00	8.0–11.0	11.50–13.50	9.0–13.0	8.0–9.0	31.0–34.0	17.5–19.5	8.0–11.0	9.0–13.0	6.5–8.5
Molybdenum	0.50	1.75–2.25	2.0–3.0	6.0–7.0	1.75–2.25	3.0–4.5	1.50–3.00	3.0–4.0	. . .	. . .	6.0–7.0	0.50	3.0–4.0	3.0–4.0
Columbium (niobium)	. . .	[C]	. . .	. . .	. . .	. . .	0.10–0.30	. . .	. . .	0.50–1.50	. . .	. . .	. . .	. . .
Vanadium	. . .	. . .	. . .	. . .	. . .	. . .	0.10–0.30	. . .	. . .	. . .	. . .	. . .	. . .	. . .
Nitrogen	. . .	. . .	. . .	0.18–0.26	. . .	0.10–0.30	0.20–0.40	. . .	0.08–0.18	. . .	0.18–0.24	0.08–0.20	. . .	0.20–0.30
Copper	. . .	. . .	3.0–4.0	0.75 max	2.75–3.25	. . .	. . .	. . .	. . .	. . .	0.50–1.00	. . .	. . .	0.5–1.0
Tungsten	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	0.5–1.0
Iron	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	Bal	. . .	. . .

[A] Grade CF8C shall have a columbium content of not less than 8 times the carbon content but not over 1.00 %.
[B] % Cr + 3.3 % Mo + 16 % N $\geq$ 40.
[C] Grade CF10MC shall have a columbium content of not less than 10 times the carbon content but not over 1.20 %.

TABLE 3 Tensile Requirements

	CF3 J92700	CF3A J92700	CF8 J92600	CF8A J92600	CF3M J92800	CF-3MA J92800	CF8M J92900	CF-3MN J92804	CF8C J92710	CF10 J92950	CF10M J92901	CH8 J93400	CH10 J93401	CH20 J93402	CK20 J94202	HK30 J94203	HK40 J94204
Tensile strength, min, ksi [MPa]	70 [485]	77 [530]	70 [485]	77 [530]	70 [485]	80 [550]	70 [485]	75 [515]	70 [485]	70 [485]	70 [485]	65 [450]	70 [485]	70 [485]	65 [450]	65 [450]	62 [425]
Yield strength,[A] min, ksi [MPa]	30 [205]	35 [240]	30 [205]	35 [240]	30 [205]	37 [255]	30 [205]	37 [255]	30 [205]	30 [205]	30 [205]	28 [195]	30 [205]	30 [205]	28 [195]	35 [240]	35 [240]
Elongation in 2 in. or 50 mm,[B] min, %	35.0	35.0	35.0	35.0	30.0	30.0	30.0	35.0	30.0	35.0	30.0	30.0	30.0	30.0	30.0	10.0	10.0
Reduction of area, min,%	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .

	HT30 N08030	CF-10MC	CN7M N08007	CN-3MN J94651	CD-4MCu J93370	CE-8MN	CG 6MMN J93790	CG8M J93000	CF10S-MnN J92972	CT15C N08151	CK-3MCuN J93254	CE20N J92802	CG3M J92999	CD3M-WCuN J93380
Tensile strength, min, ksi [MPa]	65 [450]	70 [485]	62 [425]	80 [550]	100 [690]	95 [655]	85 [585]	75 [515]	85 [585]	63 [435]	80 [550]	80 [550]	75 [515]	100 (700)
Yield strength,[A] min, ksi [MPa]	28 [195]	30 [205]	25 [170]	38 [260]	70 [485]	65 [450]	42.5 [295]	35 [240]	42.5 [295]	25 [170]	38 [260]	40 [275]	35 [240]	65 (450)
Elongation in 2 in. or 50 mm,[B] min, %	15.0	20.0	35.0	35	16.0	25.0	30.0	25.0	30.0	20.0	35	30.0	25	25.0
Reduction of area, min,%	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .

[A] Determine by the 0.2 % offset method.
[B] When ICI test bars are used in tensile testing as provided for in Specification A 703/A 703M, the gage length to reduced section diameter ratio shall be 4 to 1.

SUPPLEMENTARY REQUIREMENTS

The following supplementary requirements shall not apply unless specified in the purchase order. A list of standardized supplementary requirements for use at the option of the purchaser is included in Specification A 703/A 703M. Those which are ordinarily considered suitable for use with this specification are given below. Others enumerated in Specification A 703/A 703M may be used with this specification upon agreement between the manufacturer and purchaser.

S2. Destruction Tests
S5. Radiographic Inspection
S6. Liquid Penetrant Inspection
S10. Examination of Weld Preparation

S10.1 The method of performing the magnetic particle or liquid penetrant test shall be in accordance with Practice E 165 or Practice E 709.

S11. Post Weld Heat Treatment

S11.1 All austenitic castings, except Grades HK, HT, and CT15C, which have been subjected to weld repairs, shall be given a post weld solution heat treatment.

SUMMARY OF CHANGES

Committee A01 has identified the location of selected changes to this standard since the last issue (A 351/A 351M – 00) that may impact the use of this standard.

(1) UNS numbers were added to Table 2 and Table 3.

Standard Specification for Steel Castings, Ferritic and Martensitic, for Pressure-Containing Parts, Suitable for Low-Temperature Service[1]

This standard is issued under the fixed designation A 352/A 352M; 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[2] covers steel castings for valves, flanges, fittings, and other pressure-containing parts intended primarily for low-temperature service.

1.2 Several grades of ferritic steels and one grade of martensitic steel are covered. Selection of analysis will depend on design and service conditions (Note). The temperature shown is the lowest temperature at which the material ordinarily is required to meet the impact requirements of this specification (see Supplementary Requirement S22, Impact Test Temperatures). Users should note that hardenability of some of the grades mentioned may restrict the maximum size at which the required mechanical properties are obtainable (see Appendix X1).

Grade	Usual Minimum Testing Temperatures, °F [°C]
LCA	−25 [–32]
LCB	−50 [–46]
LCC	−50 [–46]
LC1	−75 [–59]
LC2	−100 [–73]
LC2–1	−100 [–73]
LC3	−150 [–101]
LC4	−175 [–115]
LC9	−320 [–196]
CA6NM	−100 [–73]

NOTE 1—This specification covers the low-temperature requirements particularly pertinent for ferritic and martensitic steels. Certain of the grades of austenitic steel castings furnished in accordance with Specification A 351/A 351M have been found suitable for low-temperature service down to −300°F [−184°C] and others down to −425°F [−254°C]. These grades may be used when impact tested in accordance with Specification A 352/A 352M with energy levels and temperatures of test mutually agreed upon between the purchaser and the manufacturer. As a guide to the selection of energy levels and testing temperatures, Appendix X1 should be consulted.

1.3 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 must be used independently of the other. Combining values from the two systems may result in nonconformance with the specification. Inch-pound units are applicable for material ordered to Specification A 352 and SI units for material ordered to Specification A 352M.

2. Referenced Documents

2.1 *ASTM Standards:*

A 351/A351M Specification for Castings, Austenitic, Austenitic–Ferritic (Duplex), for Pressure–Containing Parts[3]

A 370 Test Methods and Definitions for Mechanical Testing of Steel Products[4]

A 488/A488M Practice for Steel Castings, Welding, Qualifications of Procedures and Personnel[3]

A 703/A703M Specification for Steel Castings, General Requirements, for Pressure-Containing Parts[3]

E 165 Test Method for Liquid Penetrant Examination[5]

E 709 Guide for Magnetic Particle Examination[5]

2.2 *Manufacturers' Standardization Society of the Valve and Fittings Industry Standard:*

SP-55 Quality Standard for Steel Castings for Valves, Flanges, and Fittings and Other Piping Components (Visual Method)[6]

3. General Conditions for Delivery

3.1 Material furnished to this specification shall conform to the requirements of Specification A 703/A 703M including any supplementary requirements that are indicated in the purchase order. Failure to comply with the general requirements of Specification A 703/A 703M constitutes nonconformance with this specification. In case of conflict between the requirements

[1] This specification is under the jurisdiction of ASTM Committee A01 on Steel, Stainless Steel, and Related Alloys and is the direct responsibility of Subcommittee A01.18 on Castings.

Current edition approved May 10, 2003. Published May 2003. Originally approved in 1952. Last previous edition approved in 1998 as A 352/A 352M – 93 (1998).

[2] For ASME Boiler and Pressure Vessel Code applications, see related Specification SA-352, in Section II of that Code.

[3] *Annual Book of ASTM Standards*, Vol 01.02.

[4] *Annual Book of ASTM Standards*, Vol 01.03.

[5] *Annual Book of ASTM Standards*, Vol 03.03.

[6] Available from Manufacturers' Standardization Society of the Valve and Fittings Industry, 127 Park St., North East Vienna, VA 22180.

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

of this specification and Specification A 703/A 703M, this specification shall prevail.

4. Ordering Information

4.1 The inquiry and order should include or indicate the following:

4.1.1 A description of the casting by pattern number or drawing (dimensional tolerances shall be included on the casting drawing),

4.1.2 Grade of steel,

4.1.3 Options in the specification, and

4.1.4 The supplementary requirements desired, including the standards of acceptance.

5. Heat Treatment

5.1 All castings shall receive a heat treatment proper to their design and chemical composition. It should be recognized that liquid quenching of the ferritic grades is normally required to meet the mechanical properties of heavier sections and will greatly enhance the low-temperature properties of thinner sections.

5.2 Ferritic castings shall be furnished in the normalized and tempered or liquid-quenched and tempered condition, except for Grade LC9, which shall be liquid-quenched and tempered. Castings shall be tempered at a minimum of 1100°F [590°C], except Grade LC4, which shall be 1050°F [565°C], and Grade LC9, which shall be tempered in the range of 1050 to 1175°F [565 to 635°C], followed by cooling in air or liquid.

5.3 CA6NM castings shall be heat-treated by heating to 1850°F [1010°C] minimum, and air cooling to 200°F [95°C] maximum before any optional intermediate temper, but shall cool to 100°F [40°C] maximum before the final temper, which shall be between 1050 and 1150°F [565 and 620°C].

5.4 Castings shall be allowed to cool below the transformation range directly after pouring and solidification before they are reheated for normalizing or liquid quenching.

5.5 *Temperature Control*—Furnace temperature for heat treating shall be controlled by use of pyrometers.

6. Chemical Composition

6.1 The steel shall conform to the requirements as to chemical composition for the grade ordered as specified in Table 1.

7. Mechanical Requirements

7.1 *Tension Test*:

7.1.1 Tensile properties of steel used for the castings shall conform to the requirements specified in Table 1.

7.2 *Impact Test*:

7.2.1 The notched bar impact properties of the material shall be determined by testing a set of three Charpy V-notch impact specimens for each heat at one of the standard test temperatures shown in Table 1, depending on the intended service temperature (see Appendix X1). The average energy value of the three specimens shall not be less than specified, with not more than one value permitted below the average minimum specified and no value permitted below the minimum specified for a single specimen.

7.2.2 The notched bar impact test shall be made in accordance with Test Methods and Definitions A 370.

7.2.3 Impact test specimens shall be machined to the form and dimensions shown in Test Methods and Definitions A 370, Type A, Charpy V-Notch specimens, Fig. 11.

8. Quality

8.1 The surface of the casting shall be examined visually and shall be free of adhering sand, scale, cracks, and hot tears. Other surface discontinuities shall meet the visual acceptance standards specified in the order. Visual Method SP-55 or other visual standards may be used to define acceptable surface discontinuities and finish. Unacceptable visual surface discontinuities shall be removed and their removal verified by visual examination of the resultant cavities. When methods involving high temperature are used in the removal of discontinuities, castings shall be preheated to at least the minimum temperatures in Table 2.

8.2 When additional inspection is desired, Supplementary Requirements S4, S5, and S10, may be ordered.

8.3 The castings shall not be peened, plugged, or impregnated to stop leaks.

9. Repair by Welding

9.1 Repairs shall be made using procedures and welders in accordance with Practice A 488/A 488M.

9.2 Welding of Grade LC9 shall be accomplished using nonmagnetic filler material of AWS classification ENiCrFe-2, and shall require liquid penetrant inspection of the weld (Supplementary Requirement S6) when magnetic particle inspection (Supplementary Requirement S4) is specified for the casting.

9.3 Weld repairs shall be inspected to the same quality standards that are used to inspect the castings. When castings are produced with Supplementary Requirement S4 specified, weld repairs shall be inspected by magnetic particle examination to the same standards that are used to inspect the castings. When castings are produced with Supplementary Requirement S5 specified, weld repairs on castings that have leaked on hydrostatic tests, or on castings in which the depth of any cavity prepared for repair welding exceeds 20 % of the wall thickness or 1 in. [25 mm] whichever is smaller, or on castings in which any cavity prepared for welding is greater than approximately 10 in.^{2}[65 cm^{2}shall be radiographed to the same standards that are used to inspect the castings.

9.4 Castings containing any repair weld that exceeds 20 % of the wall thickness, or 1 in. [25 mm], whichever is smaller, or that exceeds approximately 10 in.^{2}[65 cm^2] in area, or that was made to correct hydrostatic test defects shall be stress relieved or heat treated after welding. This mandatory stress relief or heat treatment shall be in accordance with the procedure qualification used. When stress relief is required for Grade LC9, cooling shall be in still air.

10. Product Marking

10.1 All marking shall be on a raised pad using low-stress stamps.

TABLE 1 Chemical, Tensile, and Impact Requirements

Type	Carbon Steel	Carbon Steel	Carbon-Manganese Steel	Carbon-Molybdenum Steel	2 1/2 % Nickel Steel	Nickel-Chromium-Molybdenum Steel	3 1/2 % Nickel Steel	4 1/2 % Nickel Steel	9 % Nickel Steel	12 1/2 % Chromium, Nickel-Molybdenum Steel
Grade	LCA	LCB[A]	LCC	LC1	LC2	LC2-1	LC3	LC4	LC9	CA6NM
UNS Number	J02504	J03003	J02505	J12522	J22500	J42215	J31550	J41500	J31300	J91540
Element, % (max, except where range is given)										
Carbon	0.25[A]	0.30	0.25[A]	0.25	0.25	0.22	0.15	0.15	0.13	0.06
Silicon	0.60	0.60	0.60	0.60	0.60	0.50	0.60	0.60	0.45	1.00
Manganese	0.70[A]	1.00	1.20[A]	0.50–0.80	0.50–0.80	0.55–0.75	0.50–0.80	0.50–0.80	0.90	1.00
Phosphorus	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04
Sulfur	0.045	0.045	0.045	0.045	0.045	0.045	0.045	0.045	0.045	0.03
Nickel	0.50[B]	0.50[B]	0.50[B]	. . .	2.00–3.00	2.50–3.50	3.00–4.00	4.00–5.00	8.50–10.0	3.5–4.5
Chromium	0.50[B]	0.50[B]	0.50[B]	. . .	. . .	1.35–1.85	. . .	. . .	0.50	11.5–14.0
Molybdenum	0.20	0.20[B]	0.20[B]	0.45–0.65	. . .	0.30–0.60	. . .	. . .	0.20	0. 4–1.0
Copper 0.30	0.30[B]	0.30[B]	. . .	. . .	. . .	. . .	. . .	0.30	. . .	
Vanadium	0.03[B]	0.03[B]	0.03[B]	. . .	. . .	. . .	. . .	. . .	0.03	. . .
Tensile Requirements:[C]										
Tensile strength, ksi [MPa]	60.0–85.0 [415–585]	65.0–90.0 [450–620]	70.0–95.0 [485–655]	65.0–90.0 [450–620]	70.0–95.0 [485–655]	105.0–130.0 [725–895]	70.0–95.0 [485–655]	70.0–95.0 [485–655]	85.0 [585]	110.0–135.0 [760–930]
Yield strength,[D] min, ksi [MPa]	30.0 [205]	35.0 [240]	40.0 [275]	35.0 [240]	40.0 [275]	80.0 [550]	40.0 [275]	40.0 [275]	75.0 [515]	80.0 [550]
Elongation in 2 in. or 50 mm, min, %[E]	24	24	22	24	24	18	24	24	20	15
Reduction of area, min, %	35	35	35	35	35	30	35	35	30	35
Impact Requirements Charpy V-Notch[C,F]										
Energy value, ft·lbf [J], min value for two specimens and min avg of three specimens	13 [18]	13 [18]	15 [20]	13 [18]	15 [20]	30 [41]	15 [20]	15 [20]	20 [27]	20 [27]
Energy value, ft·lbf [J], min for single specimen	10 [14]	10 [14]	12 [16]	10 [14]	12 [16]	25 [34]	12 [16]	12 [16]	15 [20]	15 [20]
Testing temperature, °F [°C]	−25 [−32]	−50 [−46]	−50 [−46]	−75 [−59]	−100 [−73]	−100 [−73]	−150 [−101]	−175 [−115]	−320 [−196]	−100 [−73]

[A] For each reduction of 0.01 % below the specified maximum carbon content, an increase of 0.04 % manganese above the specified maximum will be permitted up to a maximum of 1.10 % for LCA, 1.28 % for LCB, and 1.40 % for LCC.

[B] Specified Residual Elements—The total content of these elements is 1.00 % maximum.

[C] See 1.2.

[D] Determine by either 0.2 % offset method or 0.5 % extension-under-load method.

[E] When ICI test bars are used in tensile testing as provided for in Specification A 703/A 703M, the gage length to reduced section diameter ratio shall be 4 to 1.

[F] See Appendix X1.

10.2 In addition to the marking required by Specification A 703/A 703M, castings that have been liquid quenched and tempered shall be marked with the letters “QT”.

11. Keywords

11.1 alloy steel; carbon steel; ferritic steel; low temperature applications; martensitic stainless steel; pressure containing parts; stainless steel; steel castings

TABLE 2 Minimum Preheat Temperatures

Grade	Thickness, in. [mm]	Minimum Preheat Temperature, °F [°C]
LCA	all	50 [10]
LCB	all	50 [10]
LCC	all	50 [10]
LC1	over 5/8 [15.9]	250 [120]
	5/8 and under	50 [10]
LC2	all	300 [150]
LC2-1	all	300 [150]
LC3	all	300 [150]
LC4	all	300 [150]
CA6NM	all	50 [10]

SUPPLEMENTARY REQUIREMENTS

The following supplementary requirements shall not apply unless specified in the purchase order. A list of standardized supplementary requirements for use at the option of the purchaser is included in Specification A 703/A 703M. Those which are ordinarily considered suitable for use with this specification are given below together with additional supplementary requirements that are applicable only to this specification. Other supplementary requirements enumerated in A 703/A 703M may be used with this specification upon agreement between the manufacturer and purchaser.

S1. Unspecified Elements
S2. Destruction Tests
S4. Magnetic Particle Inspection
S5. Radiographic Inspection
S9. Drop Weight Tests
S10. Examination of Weld Preparation

S10.1 The method of performing the magnetic particle or liquid penetrant test shall be in accordance with Practice E 709 or Practice E 165.

S21. Heat Treatment

S21.1 Castings shall be liquid quenched and tempered.

S22. Impact Test Temperatures

S22.1 When an impact test temperature other than that listed in Table 1 is used, the lowest test temperature at which the material met the impact test requirements shall be stamped with low-stress stamps on a raised pad located immediately ahead of the material symbol; for example, 25 LCB for +25°F [–4°C] and 025 LCB for –25°F [–32°C].

S22.2 Lateral expansion of V-notch specimens shall be measured in accordance with 23.2.3.1 of Test Methods and Definitions A 370, and reported for information.

S23. Carbon Equivalent

S23.1 When specified on the order the maximum carbon equivalent shall be:

Grade	Carbon Equivalent, max
LCA	0.50
LCB	0.50
LCC	0.55

S23.2 Determine carbon equivalent, *CE*, as follows:

$$CE = C + \frac{\mathrm{Mn}}{6} + \frac{\mathrm{Cr} + \mathrm{Mo} + \mathrm{V}}{5} + \frac{\mathrm{Ni} + \mathrm{Cu}}{15}$$

APPENDIX

(Nonmandatory Information)

X1. EXPLANATION OF THE USE OF NOTCHED BAR IMPACT TESTS IN DETERMINING THE ACCEPTABILITY OF STEELS FOR LOW-TEMPERATURE SERVICE

X1.1 Years of experience and test work have shown that some materials, particularly ferritic steels, change from tough to brittle behavior with a decrease in temperature. The transition temperatures and the levels of notch toughness vary with different materials, depending on many factors. When materials are used under conditions where brittle behavior may occur, there is danger that flaws, which would be considered nonhazardous if the material were tough, may propagate to disastrous failure of the equipment.

X1.2 Accordingly, many varieties of tests have been developed in an effort to evaluate the toughness of materials and the conditions under which they will transform from tough to brittle behavior. There are many opinions and shadings of opinion as to which test is most suitable for evaluating the suitability of materials for service at low temperatures; however, as yet, only the Charpy impact test has received sufficient general acceptance and has been used as a basis for purchasing for sufficient time to be included in ASTM standards. Furthermore, this test is required for low-temperature service vessels and piping constructed in accordance with ASME Code for Unfired Pressure Vessels and the American National Standard Code for Pressure Piping (ANSI B 31), respectively. These ASTM specifications for materials for low-temperature service are primarily used in piping and pressure vessel construction that are subjected to temperatures lower than ambient; consequently, the notched bar impact test requirements are written to provide material that in quality and by its testing can be validated for use under the construction codes.

X1.3 No assurance is offered that compliance with these requirements will provide a material that will resist brittle failure under all possible conditions of service to as low as the specified impact test temperature. It may eventually be possible that other types of tests will provide greater assurance of material suitability for low-temperature services, but at this time there is insufficient knowledge for agreement and general acceptance of some test other than the Charpy impact test.

X1.4 Attention is directed to the following subjects which have a bearing on the value of Charpy impact tests:

X1.4.1 Much of the original work in the field of notch toughness was done on wrought materials that had definite directional grain flow parallel to the axis of the bar, and the specimens were taken with the longitudinal axis of the specimen parallel to the axis of the bar. It has been well established that the results from impact testing of the same piece of steel may vary considerably, depending upon the orientation of the specimen to the direction of grain flow. Although it is known that specimens taken with their axis transverse to the direction of grain flow will have lower values depending on the amount of cross rolling or forging the material has received, there were insufficient test data to permit specific mandatory requirements on the impact properties of wrought materials determined in any direction other than parallel to the direction of grain flow. Except in special cases this limitation still exists.

X1.4.2 It is acknowledged that notched bar impact tests are of a qualitative rather than a quantitative nature. As yet, except possibly for ship steel, no satisfactory correlation has been possible between tests on small standardization specimens and the behavior of a structural part under any given conditions of loading in service. The required values as determined by the Charpy V-notch impact test are arbitrary values which can be met by carbon and low-alloy constructional steels when tested at temperatures above that where their behavior changes from tough to brittle as judged by this test. The acceptability of this dividing line seems to be justified by service experience on carbon and certain low-alloy steels.

X1.4.3 The literature shows that notched bar impact strengths in constructional steels differ widely in accordance with many variables. Consequently, there is bound to be some discrepancy between an individual test bar and the entire part that it represents. No system of test bar selection can guarantee that every sample would meet minimum requirements. Test bar selection must be a compromise to generally represent the product.

X1.4.4 The committees responsible for these material specifications have had as an objective the selection of test specimens that will represent the properties of the materials, in the form in which they will be used. However, accomplishment of this objective has only partially been realized. At this time it is impossible to select samples for testing that will represent all parts and sizes of the product involved. Particularly in ferritic steels, it is impractical to remove the test bars from heavy sections over about 4 in. [100 mm] and expect them to show results as high as tests from light sections of the same material. The practical commercial limits on the amount of testing possible, as well as limits to knowledge of what results may be expected from testing in non-standard locations, have been considered in drafting these specifications. With time and increased knowledge, it may be possible to require more representative testing.

SUMMARY OF CHANGES

Committee A01 has identified the location of selected changes to this standard since the last issue (A 352/A 352M – 93 (1998)) that may impact the use of this standard.

(1) Added UNS numbers to Table 1.

Designation: A 356/A 356M – 98 (Reapproved 2003)

Standard Specification for Steel Castings, Carbon, Low Alloy, and Stainless Steel, Heavy-Walled for Steam Turbines[1]

1. Scope

1.1 This specification covers one grade of martensitic stainless steel and several grades of ferritic steel castings for cylinders (shells), valve chests, throttle valves, and other heavy-walled castings for steam turbine applications.

1.2 Optional supplementary requirements (S1 through S5) shall apply as selected by and specified by the purchaser.

1.3 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 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 370 Test Methods and Definitions for Mechanical Testing of Steel Products[2]

A 488/A 488M Practice for Steel Castings, Welding, Qualifications of Procedures and Personnel[3]

E 94 Guide for Radiographic Examination[4]

E 125 Reference Photographs for Magnetic Particle Indications on Ferrous Castings[4]

E 142 Method for Controlling Quality of Radiographic Testing[5]

E 165 Test Method for Liquid Penetrant Examination[4]

E 186 Reference Radiographs for Heavy-Walled (2 to 4 ½-in. [51 to 114-mm]) Steel Castings[4]

E 280 Reference Radiographs for Heavy-Walled (4½ to 12-in. [114 to 305-mm]) Steel Castings[4]

E 446 Reference Radiographs for Steel Castings Up to 2 in. [51 mm] in Thickness[4]

E 709 Guide for Magnetic Particle Examination[4]

2.2 *Manufacturers' Standardization Society of the Valve and Fitting Industry Standard:*

SP-55 Quality Standard for Steel Castings for Valves, Flanges, and Fittings and Other Piping Components (Visual Method)[6]

3. Classification

3.1 The castings are furnished in the grades shown in Table 1.

4. Ordering Information

4.1 Orders for material to this specification should include the following information:

4.1.1 A description of the casting by pattern number or drawing (dimensional tolerances shall be included on the casting drawing),

4.1.2 Grade of steel,

4.1.3 Options in the specification, and

4.1.4 The supplementary requirements desired, including the standards of acceptance.

5. Melting Process

5.1 The steel shall be made by the open-hearth or electric-furnace process.

5.2 *Deoxidation Practice*:

5.2.1 Deoxidation of the carbon and low-alloy steel grades shall be by manganese and silicon. Furnace or ladle deoxidation with other agents is permissible with the approval of the purchaser.

5.2.2 The purchaser may specify that no aluminum be added.

5.2.3 Vacuum deoxidation is acceptable. The specific method shall be subject to approval by the purchaser.

6. Heat Treatment

6.1 *Preliminary Heat Treatment*—The castings may receive such preliminary heat treatment as the founder may elect to employ.

6.2 *Heat Treatment for Final Properties*:

[1] This specification is under the jurisdiction of ASTM Committee A01 on Steel, Stainless Steel, and Related Alloys and is the direct responsibility of Subcommittee A01.18 on Castings.

Current edition approved April 10, 2003. Published April 2003. Originally approved in 1952. Last previous edition approved in 1998 as A 356/A 356M – 98$^{\epsilon 1}$.

[2] *Annual Book of ASTM Standards*, Vol 01.03.

[3] *Annual Book of ASTM Standards*, Vol 01.02.

[4] *Annual Book of ASTM Standards*, Vol 03.03.

[5] Discontinued. Replaced by E 94. See 1999 *Annual Book of ASTM Standards*, Vol 03.03.

[6] Available from the Manufacturers' Standardization Society of the Valve and Fittings Industry, 127 Park St., NE, Vienna, VA 22180.

TABLE 1 Chemical Requirements

Grade	Material	Composition, %											
		Carbon	Manganese	Silicon	Phosphorus, max	Sulfur, max	Molybdenum	Chromium	Nickel	Vanadium	Columbium	Nitrogen	Aluminum
1	carbon steel	0.35[A] max	0.70[A] max	0.60 max	0.035	0.030	. . .	. . .	. . .	. . .	. . .	. . .	. . .
2	½% molybdenum	0.25[A] max	0.70[A] max	0.60 max	0.035	0.030	0.45-0.65	. . .	. . .	. . .	. . .	. . .	. . .
5	½% chromium, ½ % molybdenum	0.25[A] max	0.70[A] max	0.60 max	0.035	0.030	0.40-0.60	0.40-0.70	. . .	. . .	. . .	. . .	. . .
6	1 ¼% chromium, ½ % molybdenum	0.20 max	0.50-0.80	0.60 max	0.035	0.030	0.45-0.65	1.00-1.50	. . .	. . .	. . .	. . .	. . .
8	1 % chromium, 1 % molybdenum, vanadium	0.20 max	0.50-0.90	0.20-0.60	0.035	0.030	0.90-1.20	1.00-1.50	. . .	0.05-0.15	. . .	. . .	. . .
9	1 % chromium, 1 % molybdenum, vanadium	0.20 max	0.50-0.90	0.20-0.60	0.035	0.030	0.90-1.20	1.00-1.50	. . .	0.20-0.35	. . .	. . .	. . .
10	2 ¼% chromium, 1 % molybdenum	0.20 max	0.50-0.80	0.60 max	0.035	0.030	0.90-1.20	2.00-2.75	. . .	. . .	. . .	. . .	. . .
12 (J80490)	9 % chromium, 1 % molybdenum, vanadium	0.08-0.12	0.30-0.60	0.20-0.50	0.02 max	0.010 max	0.85-1.05	8.0-9.5	0.40 max	0.18-0.25	0.06-0.10	0.03-0.07	0.04 max
CA6NM	martensic chromium nickel	0.06 max	1.00 max	1.00 max	0.040	0.030	0.4-1.0	11.5-14.0	3.5-4.5	. . .	. . .	. . .	. . .

[A] For each 0.01 % reduction in carbon below the maximum specified, an increase of 0.04 percentage points of manganese over the maximum specified for that element will be permitted up to 1.00.

6.2.1 *Normalizing*—The castings shall be heated to and held at the proper temperature for a sufficient time to effect the desired transformation and withdrawn from the furnace and allowed to cool to effect complete transformation.

6.2.2 *Tempering*—The casting shall be heated to and held at the proper temperature, which shall be below the transformation range, and then cooled under suitable conditions. The tempering temperature shall not be less than 1100°F [595°C]. The minimum tempering temperature for Grade 12 shall be 1350°F [730°C].

6.2.3 *Stress Relieving*—The stress relieving operation shall be carried out in the same manner as tempering. The temperature shall be within 50°F [28°C], but not exceeding the final tempering temperature.

6.3 *Stainless Steel Casting*:

6.3.1 *Normalizing*—The castings shall be heated to 1850°F [1010°C] minimum, held sufficiently at that temperature to uniformly heat the castings, and air cooled to below 200°F [93°C].

6.3.2 *Tempering*—The castings shall be final tempered from 1050 to 1150°F [565 to 620°C].

6.3.3 *Stress Relieving*—The stress relieving operation shall be performed in the same manner as tempering. Temperature shall be between 1050°F [565°C] and 1150°F [620°C].

7. Chemical Composition

7.1 The steel shall conform to the requirements as to chemical composition prescribed in Table 1.

8. Tensile Requirements

8.1 Tensile properties shall conform to the requirements listed in Table 2 as determined by the test specimen set forth in Section 9.

8.2 Tension tests shall be performed in accordance with Test Methods and Definitions A 370.

9. Number of Tests and Retests

9.1 One tension test shall be made from each heat in each heat-treatment charge and from each casting on which attached coupons are specified. The bar from which the test specimen is taken shall be heat treated with the casting represented.

9.2 If any test specimen shows defective machining or develops flaws, it shall be discarded and another specimen substituted from the same heat.

9.3 If the results of the mechanical tests for any lot or casting do not conform to the requirements specified, the founder may reheat treat and retest such lot or casting.

10. Test Specimen

10.1 Tension test specimens and samples for microexamination may be taken from coupons conforming substantially to the dimensions shown in Fig. 1 and from the locations in the coupon as indicated in Fig. 1. These coupons shall have been cast attached to the castings, except as provided in 10.2 , and have remained attached, without partial severing, until the completion of the heat treatment for final properties.

10.2 If, in the opinion of the manufacturer, the design of any casting is such as to preclude the use of an attached coupon, then the tension test specimen and sample for microexamination for that casting may be taken from a coupon attached to a special block. The coupon shall conform substantially to the dimensions shown in Fig. 1 and shall have remained attached, without partial severing, to its special block until after all heat treatment for final properties.

10.3 Test specimens may be cut from heat-treated castings instead of from test coupons when agreed upon between the manufacturer and the purchaser.

10.4 Tension test specimens shall be machined to the form and dimensions of the standard round 2-in. [50-mm] gage-length specimen shown in Fig. 5 of Test Methods and Definitions A 370.

11. Inspection

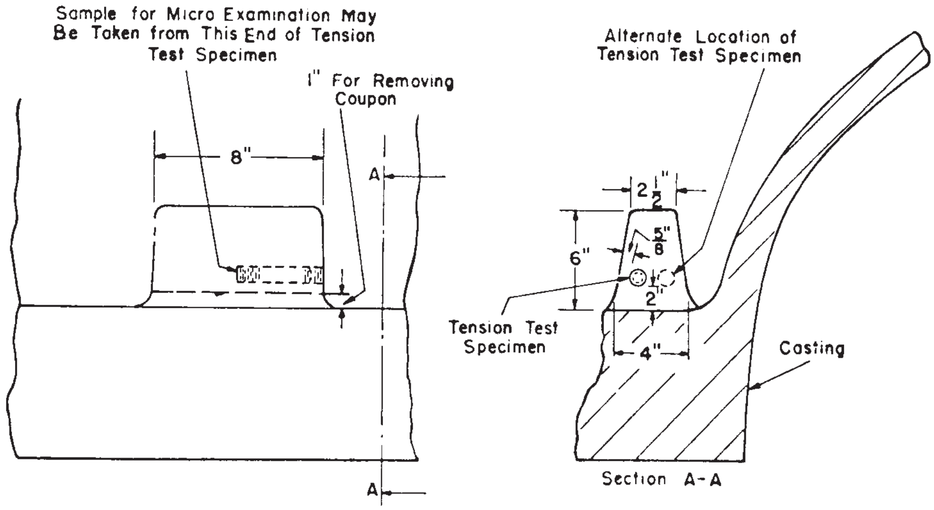
11.1 The inspector representing the purchaser shall have free entry, at all times while work on the contract of the purchaser is being performed, to all parts of the manufacturer's works that concern the manufacture of material ordered. The manufacturer shall afford the inspector all reasonable facilities to satisfy him that the material is being furnished in accordance with this specification. All tests (except product analysis) and inspection shall be made at the place of manufacture prior to shipment, and shall be so conducted as not to interfere unnecessarily with operation of the works.

12. Rejection and Rehearing

12.1 Any rejection based on tests made in accordance with Sections 7 or 8, or both, shall be reported to the manufacturer within 60 days from the receipt of samples by the purchaser.

TABLE 2 Tensile Requirements

Grade	Material	Tensile Strength, min, ksi [MPa]	Yield Strength, min, ksi [MPa]	Elongation in 2 in. [50 mm] min, %	Reduction of Area, min, %
1	carbon steel	70 [485]	36 [250]	20.0	35.0
2	½ % molybdenum	65 [450]	35 [240]	22.0	35.0
5	½ % chromium, ½ % molybdenum	70 [485]	40 [275]	22.0	35.0
6	1¼ % chromium, ½ % molybdenum	70 [485]	45 [310]	22.0	35.0
8	1 % chromium, 1 % molybdenum, vanadium	80 [550]	50 [345]	18.0	45.0
9	1 % chromium, 1 % molybdenum, vanadium	85 [585]	60 [415]	15.0	45.0
10	2¼ % chromium, 1 % molybdenum	85 [585]	55 [380]	20.0	35.0
12 (J80490)	9 % chromium, 1 % molybdenum, vanadium	85 [585]	60 [415]	20.0	. . .
CA6NM	martensitic chromium nickel	110 [760]	80 [550]	15.0	35.0



SI Units

in.	½	⅝	1	2½	4	6	8
[mm]	[13]	[16]	[25]	[64]	[102]	[152]	[203]

FIG. 1 Dimensions and Location of Test Coupons for Turbine Castings

12.2 Material that shows injurious defects subsequent to its acceptance at the manufacturer's works will be rejected, and the manufacturer shall be notified.

12.3 Samples tested in accordance with Section 7 that represent rejected material shall be preserved for 60 days from the date of transmission of the test report. In case of dissatisfaction with the result of the tests, the manufacturer may make claim for a rehearing within that time.

13. Certification

13.1 The manufacturer shall submit to the purchaser a certified record of the results of the chemical analysis and mechanical tests, together with a statement that all the requirements of this specification (including year date) have been met.

14. Product Marking

14.1 Pressure-containing castings, made in accordance with any of the grades of steel covered by this specification, shall be marked for material identification with the ASTM symbols for the grade of alloy steel (Grade 1, Grade 2, etc.) and the heat number or heat identification. Marking shall be positioned so as not to impair the usefulness of the castings.

15. Quality Assurance

15.1 *Surface Finish*—The castings shall be clean when offered for inspection. A standard practice which may be used as a basis for visual inspection is SP-55.

15.2 *Soundness*—The degree of soundness and the method for its determination shall be subject to agreement between the manufacturer and the purchaser. Castings may be produced in accordance with Supplementary Requirement S2, Supplementary Requirement S3, Supplementary Requirement S4, or any combination of these.

15.3 *Welding*—Assembly welds and repair welds shall be made using procedures and welders qualified under Practice A 488/A 488M.

15.3.1 Welding shall be accomplished with a filler material known to produce weld deposits having a chemical composition and mechanical properties compatible with those of the castings.

15.3.2 Welds shall be inspected to the same quality standards as are used to inspect the castings.

15.3.2.1 When castings are produced with Supplementary Requirement S2 specified, welds shall be inspected by magnetic particle examination to the same standards as are used to inspect the castings.

15.3.2.2 When castings are produced with Supplementary Requirement S3 specified, welds shall be inspected by radiography to the same standards as are used to inspect the castings.

15.3.3 Welds shall receive at least a stress-relief heat treatment. A complete heat treatment consisting of a normalize and temper may be required for certain welds, subject to agreement between the manufacturer and purchaser.

15.3.4 When methods involving high temperatures are used in the removal of discontinuities, casting shall be preheated to at least the minimum temperatures in Table 3.

16. Keywords

16.1 carbon steel; low-alloy steel; stainless steel; steam turbines; steel castings

TABLE 3 Minimum Preheat Temperatures

Grade	Thickness, in. [mm]	Minimum Preheat Temperature, °F [°C]
1	over 1 [25]	175 [80]
	1 [25] and under	50 [10]
2	over ⅝[16]	250 [120]
	⅝ [16] and under	50 [10]
5	over ⅝[16]	250 [120]
	⅝ [16] and under	50 [10]
6	over ½[13]	300 [150]
	½ [13] and under	50 [10]
8	over ½[13]	300 [150]
	½ [13] and under	50 [10]
9	over ½[13]	300 [150]
	½ [13] and under	50 [10]
10	over ½ [13]	400 [200]
	½ [13] and under	300 [150]
12 (J80490)	all thicknesses	400 [200]
CA6NM	all	50 [10]

SUPPLEMENTARY REQUIREMENTS

Any of the following supplementary requirements may become a part of the specification when specified on the inquiry or invitation to bid, and when made a part of the purchase order or contract after mutual agreement by the manufacturer and the purchaser on the exact standards to be applied to each method of inspection.

S1. Microstructural Requirements

S1.1 There shall be no microstructural requirements for Grade 1.

S1.2 The microstructural requirements of grades, other than Grade 1, may be specified by the purchaser.

S1.3 If microstructural requirements are specified by the purchaser, he shall furnish suitable standards to serve as a satisfactory basis for acceptance or rejection.

S1.4 If microstructural requirements are specified, the sample for examination may be taken from the end of the broken tension test specimens.

S2. Magnetic Particle Inspection

S2.1 The purchaser may specify magnetic particle inspection of castings made in accordance with this specification.

S2.2 If magnetic particle inspection is specified, the purchaser shall designate the zones of the casting to be so inspected.

S2.3 If magnetic particle inspection is specified, the purchaser shall designate acceptance standards for each type of discontinuity, preferably in accordance with Reference Photographs E125.

S2.4 Magnetic particle inspection shall preferably be performed in accordance with Guide E 709.

S2.5 The circular or coil method of overall magnetization or the wet method of magnetic particle inspection, or both, may be used subject to agreement between the manufacturer and purchaser.

S3. Radiographic Inspection

S3.1 The purchaser may specify radiographic inspection of castings made in accordance with this specification.

S3.2 If radiographic inspection is specified, radiography shall be performed in accordance with Guide E 94. The quality level of the radiographic images may be controlled by specifying adherence to Method E 142.

S3.3 If radiographic inspection is specified, the purchaser shall designate the areas of the castings to be so inspected.

S3.4 If radiographic inspection is specified, the purchaser shall designate acceptance standards for each type of discontinuity in each area of the castings to be so inspected.

S3.5 If radiographic inspection is specified, the basis for acceptance shall be subject to agreement between the manufacturer and the purchaser. The types and severity levels of discontinuities may be judged by reference to three ASTM standards: (*1*) Reference Radiographs E 446, (*2*) Reference Radiographs E 186, and (*3*) Reference Radiographs E 280.

S4. Examination of Weld Preparation

S4.1 Magnetic particle or liquid penetrant examination of cavities prepared for welding shall be performed to verify removal of those discontinuities found unacceptable by the inspection method specified for the casting. The method of performing the magnetic particle or liquid penetrant test shall be in accordance with Guide E 709 or Test Method E 165. Unless other degrees of shrinkage or types of discontinuities found in the cavities are specified, Type II, Internal Shrinkage, of Reference Photographs E 125 of Degree 2 in sections up to

2 in. [50.8 mm] thick and of Degree 3 in sections over 2 in. thick shall be acceptable.

S5. Aluminum Restriction (Carbon and Low-Alloy Steel)

S5.1 Aluminum shall not be added directly or as a constituent of other deoxidizers in an amount exceeding ½ lb/ton [0.25 g/kg] of steel.

Standard Test Methods of Chill Testing of Cast Iron[1]

This standard is issued under the fixed designation A 367; 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 These test methods of chill testing apply to gray irons that are to be free of chill in the casting and to chilled irons that are to have a specific depth of chill in the casting. Two test methods of determining the chilling tendencies of cast iron are covered as follows. For many applications either test method will be satisfactory if test pieces of the proper dimensions are selected.

1.1.1 *Test Method A, Wedge Test*—This test is generally better adapted to the higher strength gray irons. The accelerated cooling rate to induce the formation of a chill is brought about through the design of the test specimen. This test method is simpler than Test Method B since maintenance of chill blocks or plates is not necessary.

1.1.2 *Test Method B, Chill Test*—This test is better adapted to the softer grades of gray iron and should be used if the casting is to have a specified depth of chill. The chill in this type of test is induced by casting one edge of the test specimen against a metal or graphite chilled plate or block.

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.*

TEST METHOD A—WEDGE TEST

2. Application

2.1 Selection of a test specimen of appropriate dimensions will allow measurement of chilling tendencies of all gray iron compositions, with the exception of those having silicon contents much over 2.50 % together with carbon contents over 3.50 %.

3. Test Specimens

3.1 The patterns for the test specimens shall be made of metal to the dimensions shown in Fig. 1. With the exception of the length of the test specimen, dimensions shall not vary more than ±1⁄32 in. (0.8 mm). The tolerance on the length of the specimen shall be ±1⁄8 in. (3.2 mm). The radius on the apex of the wedge should be formed by filing a 1⁄32-in. flat on the sharp edge of the metal pattern and then carefully rounding the edges formed by the 1⁄32-in. flat and the sides of the wedge. If draft on the pattern is desired, it may be obtained by varying dimension *H* (Fig. 1) from one end of the specimen to the other. The pattern should be mounted in a core box so that the final core can be poured with the wedge in such a position that its length is vertical. There shall be 1-in. (25.4-mm) minimum sand at the bottom of the core.

4. Procedure

4.1 *Cores*—Make the test in a core. The cores may be either single cores or gang cores. If a gang core is used, the minimum amount of sand between adjacent test specimens shall be not less than 2½ × *B* (Fig. 1). The sand cores shall be well baked and may be either resin or oil bonded. The base sand shall be of such fineness that a smooth casting will be obtained. A sand with an AFS fineness[2] of about 70 will be found satisfactory, although a sand with a fineness of 100 or finer may be used for the smaller test specimens.

4.2 *Pouring Practice*—Pour all samples at as consistent a pouring temperature as possible since the amount of chill is clearly affected by the pouring temperature. Take precautions to obtain a representative sample of iron for the test specimen. Best results are obtained with a sample ladle lined with a refractory mixture which is free of graphite and chilled iron. The ladle should hold at least 5 lb (2.3 kg) of iron in order to avoid excessive chilling of the iron before the test specimen can be poured. Filling the ladle once with iron just prior to obtaining the sample for test is recommended.

4.3 *Cooling of Test Specimen*—If time is an important factor in control applications, the test specimen may be quenched in water as soon as it is completely solid. The quenching must be done carefully to avoid cracking of the chilled apex of the wedge. This may be accomplished by grasping the wedge with tongs at the apex of the wedge and immersing about ¼ to ½ in. (6.4 to 12.7 mm) of the base of the wedge in water. The wedge may then be gradually quenched but should be removed while there is still sufficient heat in the wedge to dry off the water. If speed of testing is not important, the test specimen may be either cooled in the core or in the air. If cooled to a very dull red before quenching in water, the demarcation between the chilled iron and the gray iron is somewhat clearer than if the test specimen is quenched as soon as it is solid.

[1] These test methods are under the jurisdiction of ASTM Committee A-4 on Iron Castings and are the direct responsibility of Subcommittee A 04.21 on Testing.

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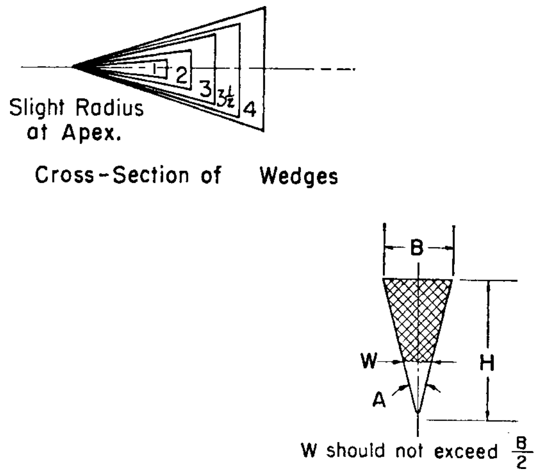
[2] *Foundry Sand Handbook*, Am. Foundrymen's Soc.



Wedge No.	Wedge Dimensions						
	B		*H*		A, deg	Length	
	in.	mm	in.	mm		in.	mm
W 1	0.20	5.1	1.00	25.4	11.5	4	101.6
W 2	0.40	10.2	1.25	31.8	18	4	101.6
W 3	0.75	19.1	1.50	38.1	28	4	101.6
W 3½	1.00	25.4	1.75	44.4	32	5	127.0
W 4	1.25	31.8	2.00	50.8	34.5	6	152.4

FIG. 1 Dimensions for Test Wedges

5. Measurement of Chill

5.1 Break the test specimen by striking with a hammer in such a manner that the fracture is straight and midway of its length. The chilled iron at the apex of the wedge with a few exceptions consists of two zones. That portion nearest the apex entirely free of any gray spots is designated as *clear chill.* That portion starting with the end of the clear chill and continuing to the location where the last spot of cementite or white iron is visible is designated as the *mottled zone.* The extent of the mottled zone may vary from virtually nothing to an amount equal to and even greater than the amount of the clear chill. If the wedge is measured at the junction of the gray fracture with the first appearance of chilled iron, the measurement shall be designated as *total chill.* In all cases, express the chill in 1⁄32 in. (0.8 mm) as measured across the wedge at the locations just described. The location of this measurement for a wedge having a narrow mottled zone is shown in Fig. 1. For structure control purposes, it is generally satisfactory to measure the wedge where the structure is approximately 50 % white iron and 50 % gray iron. This value will be found to be virtually the same as the average of the measurement of the clear chill measurement, designate the size of the test specimen. A chill reported as W3-12 would indicate that wedge W3 was used and the width at the junction of the chilled and gray portions of the fraction was 12⁄32 in. (9.5 mm).

TEST METHOD B—CHILL TEST

6. Application

6.1 This test method is better adapted than Test Method A to irons having silicon contents of 2.50 percent and over and carbon contents of 3.50 % and over. It is also useful for control purposes in high-production foundries making irons somewhat lower in carbon and silicon than indicated above. This test method is also preferable for applications in which the casting is to have a specified depth of chill.

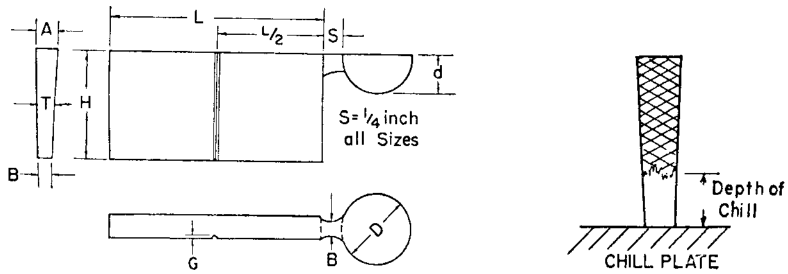
7. Test Specimens

7.1 The patterns shall be made of metal and conform to the dimensions shown in Fig. 2. All dimensions shall be within ±1⁄32 in. (0.8 mm) of those shown, with the exception of the length which may vary ± 1⁄8 in. (3.2 mm). The test specimens shown are designed to be cast in the position shown. This design is the preferred one, although for high-production work, a gang core box and pattern may be used. In this case, a test specimen with the chilled face in a vertical position may be found more convenient although it is not considered as satisfactory as the horizontally cast test specimen.

8. Procedure

8.1 *Cores*—Make the test in a core. For general application, a single core is considered more satisfactory than a gang core. If a gang core is used, the amount of sand between test specimens shall be 1 in. (25.4 mm) minimum or 2½× *A* (Fig. 2), whichever is greater. The remarks concerning cores in 4.1 apply here also.

8.2 *Chill Plates*—Chill plates may be cast iron, steel, copper, or graphite. Machine the surface of the chill plate. When single test specimens are cast, the chill plate shall extend at least 1 in. beyond the test specimens in all directions and shall be at least 1-in. thick. For high-production work, a sufficient number of chill plates must be available to keep the temperature of the plate below 500°F (260°C). A water-cooled steel plate will be found more satisfactory for high-production work. A water-cooled plate having a reservoir is preferable to one having circulating water. In the latter case the plate may



Chill Test No.	Recommended Dimensions, in.								Recommended Chill Depth Range, 1⁄23 in.[A]
	T	*A*	*B*	*H*	*L*	*D*	*d*	*G*	
1C	3⁄16	1⁄4	1⁄8	1 1⁄4	2 1⁄2	3⁄4	1⁄2	1⁄32	3 to 12
2C	1⁄4	5⁄16	3⁄16	1 1⁄2	3	7⁄8	1⁄2	1⁄32	4 to 16
3C	3⁄8	7⁄16	5⁄16	1 3⁄4	3 1⁄2	7⁄8	1⁄2	1⁄16	6 to 24
4C	1⁄2	9⁄16	7⁄16	2	4	1	5⁄8	1⁄16	8 to 32
5C	3⁄4	13⁄16	11⁄16	2 1⁄2	5	1	5⁄8	3⁄32	12 to 48

[A] *T*/2 to 2*T*.

Note 1—Casting to be made in a dry sand core.

Note 2—Allow 3⁄4 in. of sand on all sides.

Metric Equivalents

in.	mm	in.	mm	in.	mm
1⁄32	0.8	3⁄8	9.5	1	25.4
1⁄16	1.6	7⁄16	12.1	1 1⁄4	31.8
3⁄32	2.4	1⁄2	12.7	1 1⁄2	38.1
1⁄8	3.2	9⁄16	14.3	1 3⁄4	44.4
3⁄16	4.8	11⁄16	17.5	2	50.8
1⁄4	6.4	3⁄4	19.0	2 1⁄2	63.5
5⁄16	7.9	13⁄16	20.6		

FIG. 2 Recommended Dimensions for Test Method B Chill Test Specimens

become too cold, resulting in condensation of moisture on the plate. The chill plate must be kept free of the fire cracks and all foreign matter as the depth of chill is markedly affected by the presence of films of burned oil or other accumulations. The best practice is to clean off the plate with a wire brush as soon as the core and test specimen are removed.

8.3 *Pouring Practice*—Remarks on pouring practice in 4.2 apply here. In addition, do not pour iron directly on the chill plate as the depth of chill may be affected or the test specimen may burn on the chill plate. It may be desirable to place a weight on the core when pouring it as there may be a tendency for the core to lift as it is being poured. The opening in the core shall be free of sand fins and shall set flat on the chill plate. In the event the core does not fit the chill plate, rub it until it does.

8.4 *Cooling of Test Piece*— The remarks in 4.3 apply here. If rapid testing is desired, the chill test specimen may be quenched in water, starting with the edge farthest from the chilled edge.

9. Measurement of Chill

9.1 Break the test specimen in such a manner that the fracture is straight and follows the notch in the test specimen. The chill from the chilled face to the first appearance of a gray spot shall be designated as *clear chill.* The distance from the chilled face to the last appearance of a spot of white iron shall be designated as *total chill.* That portion of the chill affected zone between the clear chill and the total chill shall be designated as the *mottled zone.* As in Section 5, it will be found satisfactory for general structure and quality control purposes to measure chill from the chilled face to a location where the structure is approximately 50 % white iron which is roughly half-way through the mottled zone. If the chill test is used for the control of iron for castings having a chilled surface for wear resistant purposes, it would be desirable to measure and record clear chill. If the casting with a chilled surface is to have some machining operation in the proximity of the chilled surface, it may also be necessary to specify maximum depth of total chill as well as depth of clear chill. In all cases, the depth of chill shall be expressed in 1⁄32 in. (0.8 mm) and the size of the test specimen used shall be designated. For example, a measurement recorded as 4C-12 indicates that test specimen design 4C was used and the depth of chill was 12⁄32 in. (9.5 mm).

Designation: A 377 – 03

Standard Index of Specifications for Ductile-Iron Pressure Pipe[1]

This standard is issued under the fixed designation A 377; 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 index identifies specifications that cover ductile-iron pressure pipe suitable for carrying water and other liquids under pressure.

NOTE 1—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.

2. Method of Designation

2.1 The ASTM designation for these specifications is not sufficient to describe the particular items which a purchaser may desire; therefore, the ANSI designation for the applicable American National Standards shown in Section 3 shall be specified in the inquiry, contract, and order.

3. Reference Specifications

3.1 Ductile iron pipe furnished in accordance with this index are covered by the following American National Standards:

ANSI/AWWA C151/A21.51, Ductile-Iron Pipe, Centrifugally Cast for Water,[2,3]

3.2 Other American National Standards relating to ductile-iron pipe are the following:

ANSI/AWWA C104/A21.4, Cement-Mortar Lining for Ductile-Iron Pipe and Fittings for Water,[2,3]

ANSI/AWWA C105/A21.5, Polyethylene Encasement for Ductile-Iron Pipe Systems,[2,3]

ANSI/AWWA C106/A21.50, Thickness Design of Ductile-Iron Pipe,[2,3]

ANSI/AWWA C110/A21.10, Ductile-Iron and Gray-Iron Fittings, 3 in. through 48 in. (76 mm through 1219 mm) for Water,[2,3]

ANSI/AWWA C111/A21.11, Rubber–Gasket Joints for Ductile-Iron Pressure Pipe and Fittings,[2,3]

ANSI/AWWA C115/A21.15, Flanged Ductile-Iron Pipe with Ductile-Iron or Gray-Iron Threaded Flanges,[2,3]

ANSI/AWWA C116/A21.16, Protective Fusion-Bonded Epoxy Coatings for the Interior and Exterior Surfaces of Ductile-Iron and Gray-Iron Fittings for Water Supply Service,[2,3]

ANSI/AWWA C153/A21.53, Ductile Iron Compact Fittings for Water Service,[2,3]

ANSI/AWWA C600, Installation of Ductile-Iron Water Mains and Their Appurtenances, and[2,3]

ANSI/AWWA C606, Grooved and Shouldered Joints,[2,3]

NOTE 2—These specifications were prepared by appropriate subcommittees of American Water Works Association Committee A21 on Ductile Iron Pipe and Fittings. This committee was originally organized as an American National Standards Committee under the sponsorship of ASTM, American Gas Association (A.G.A), American Water Works Association (AWWA), and New England Water Works Association (NEWWA). The current sponsor is AWWA and the present scope of Committee A21 activity is to develop standards and manuals for ductile-iron and gray-iron fittings for use with such pipe. After these specifications were approved by Committee A21, they were approved as national standards by ANSI.

NOTE 3—The pipes described in these specifications have been designed for trench conditions and internal working pressures in accordance with the method developed by ANSI Standards Committee A21. These methods are described in ANSI/AWWA C150/A21.50, Thickness Design of Ductile-Iron Pipe.

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[1] This index is under the jurisdiction of ASTM Committee A04 on Iron Castings and is the direct responsibility of Subcommittee A04.12 on Pipes and Tubes.

Current edition approved Dec. 1, 2003. Published January 2004. Originally approved in 1954. Last previous edition approved in 1999 as A 377 – 99.

[2] Available from the American National Standards Institute, 25 W. 43rd St., 4th Floor, New York, NY 10036.

[3] Available from American Water Works Assoc., 6666 W. Quincy Ave., Denver, CO 80235.

Designation: A 389/A 389M – 03

Standard Specification for Steel Castings, Alloy, Specially Heat-Treated, for Pressure-Containing Parts, Suitable for High-Temperature Service[1]

This standard is issued under the fixed designation A 389/A 389M; 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 alloy steel castings, which have been subjected to special heat treatment, for valves, flanges, fittings, and other pressure-containing parts (Note 1) intended primarily for high-temperature service.

1.2 The high-temperature properties of the materials covered in this specification are dependent upon special heat treatment that is required. Although the high-temperature properties are not specified, they are implied by control of chemistry, heat treatment, and room-temperature properties.

1.3 Two grades of ferritic alloy steel are covered (Note 2). Selection will depend on the design and service conditions, mechanical properties, and high-temperature characteristics.

NOTE 1—Carbon steel castings for pressure-containing parts are covered by Specification A 216/A 216M. Alloy steel castings are covered by Specification A 217/A 217M.

NOTE 2—The grades covered by this specification represent materials that are generally suitable for assembly with other castings or wrought steel parts by fusion welding. It is not intended to imply that these grades possess equal degrees of weldability; therefore, it is the responsibility of the purchaser to establish for himself a suitable welding technique. Since these grades possess varying degrees of suitability for resistance to oxidation and for high-temperature service, it is also the responsibility of the purchaser to determine which grade shall be furnished, due consideration being given to the requirements of the applicable construction codes.

1.4 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 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 216/A 216M Specification for Steel Castings, Carbon, Suitable for Fusion Welding, for High-Temperature Service[2]

A 217/A 217M Specification for Steel Castings, Martensitic Stainless and Alloy, for Pressure-Containing Parts, Suitable for High-Temperature Service[2]

A 488/A 488M Practice for Steel Castings, Welding, Qualifications of Procedures and Personnel[2]

A 703/A 703M Specification for Steel Castings, General Requirements, for Pressure-Containing Parts[2]

2.2 *Manufacturers' Standardization Society of the Valve and Fittings Industry Standard:*

SP-55 Quality Standard for Steel Castings for Valves, Flanges, and Fittings and other Components (Visual Method)[3]

3. General Conditions for Delivery

3.1 Material furnished to this specification shall conform to the requirements of Specification A 703/A 703M, including any supplementary requirements that are indicated in the purchase order. Failure to comply with the general requirements of A 703/A 703M constitutes nonconformance with this specification. In case of conflict between the requirements of this specification and A 703/A 703M, this specification shall prevail.

4. Ordering Information

4.1 The inquiry and order should include or indicate the following:

4.1.1 A description of the casting by pattern number or drawing (dimensional tolerances shall be included on the casting drawing),

4.1.2 Grade of steel,

4.1.3 Options in the specification, and

4.1.4 The supplementary requirements desired including the standards of acceptance.

[1] This specification is under the jurisdiction of ASTM Committee A01 on Steel, Stainless Steel and Related Alloysand is the direct responsibility of Subcommittee A01.18 on Castings.

Current edition approved April, 10 2003. Published April 2003. Originally approved in 1955. Last previous edition approved in 1998 as A 389 – 93 (1998).

[2] *Annual Book of ASTM Standards*, Vol 01.02.

[3] Available from Manufacturers Standardization Society of the Valve and Fittings Industry (MSS), 127 Park St., NE, Vienna, VA 22180-4602.

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

5. Heat Treatment

5.1 All castings shall receive a heat treatment proper to their design and chemical composition. Heat treatment shall be performed before machining except in instances when reheat treating is necessary. All castings shall have been allowed to cool, after pouring, to a temperature below the critical range before heat treatment.

5.2 At the option of the manufacturer the castings may be given any preliminary heat treatment that will aid in their processing.

5.3 All castings shall receive a final heat treatment consisting of normalizing and tempering at the temperature prescribed for each grade in Table 1.

5.4 Furnace temperatures for heat treating shall be effectively controlled by use of pyrometers.

6. Chemical Composition

6.1 The steel shall conform to the requirements as to chemical composition prescribed in Table 2.

7. Tensile Requirements

7.1 Steel used for the castings shall conform to the requirements as to tensile properties prescribed in Table 3.

8. Quality

8.1 The surface of the casting shall be examined visually and shall be free of adhering sand, scale, cracks, and hot tears. Other surface discontinuities shall meet the visual acceptance standards specified in the order. Visual Method SP-55 or other visual standards may be used to define acceptable surface discontinuities and finish. Unacceptable visual surface discontinuities shall be removed and their removal verified by visual examination of the resultant cavities. When methods involving high temperature are used in the removal of discontinuities, castings shall be preheated to at least the minimum temperatures in Table 4.

8.2 The castings shall not be peened, plugged, or impregnated to stop leaks.

9. Repair by Welding

9.1 Repair shall be made by using a welding procedure and operators qualified in accordance with Practice A 488/A 488M. The composition of the deposit weld material shall be similar to that of the casting, or of other composition as may be agreed upon between the manufacturer and the purchaser. The castings after complement of weld repairing shall be retempered except that local tempering of the weld repairs will be permitted if, in the manufacturer's opinion, complete furnace-heat treatment would be damaging to the finished surfaces of a machined casting. Heat treatments after weld repair other than tempering shall be performed only when agreed upon between the manufacturer and the purchaser.

9.2 Weld repairs shall be considered major in the case of a casting that had leaked on hydrostatic test, or when the depth of cavity prepared for welding exceeds 20 % of the actual wall thickness or 1 in. [25.4 mm], whichever is smaller, or when the extent of the cavity exceeds approximately 10 in.^{2} [64.5 cm^2]. When requested by the purchaser's inspector, such weld repairs shall be subject to his approval. He shall also have the right to require complete reheat treatment of the repaired casting in accordance with 5.3. When mutually agreed upon between the purchaser and the manufacturer, major repair weld may be examined at the manufacturer's expense by magnetic particle examination or radiographing, or both, to check the adequacy of the repair.

10. Keywords

10.1 steel castings; alloy steel; pressure containing parts; high temperature applications

TABLE 1 Heat Treating Temperatures

Grade	Normalizing Temperature, °F[°C]	Tempering	
		Temperature, °F[°C]	Holding Time, h
C23	1850–1950 [1010–1065]	1250–1350 [675–730]	1^A
C24	1850–1950 [1010–1065]	1250–1350 [675–730]	12

^{A} Per inch or less of thickness.

TABLE 2 Chemical Requirements

Grade (UNS No.)	Composition, %	
	C23 (J12080)	C24 (J12092)
Carbon, max	0.20	0.20
Manganese	0.30–0.80	0.30–0.80
Phosphorus, max	0.04	0.04
Sulfur, max	0.045	0.045
Silicon, max	0.60	0.60
Chromium	1.00–1.50	0.80–1.25
Molybdenum	0.45–0.65	0.90–1.20
Vanadium	0.15–0.25	0.15–0.25

TABLE 3 Tensile Requirements

Grade	C23	C24
Tensile strength, min, ksi [MPa]	70 [483]	80 [552]
Yield strength,^{A} min, ksi [MPa]	40 [276]	50 [345]
Elongation in 2 in. [50 mm], min, %^{B}	18.0	15.0
Reduction of area, min, %	35.0	35.0

^{A} Determine by either 0.2 % offset or 0.5 % extension-under-load method.
^{B} When ICI test bars are used in tensile testing as provided for in Specification A 703/A 703M, the gage length to reduced section diameter ratio shall be 4 to 1.

TABLE 4 Minimum Preheat Temperature

Grade	Minimum Preheat Temperature, °F[°C]
C23	300 [150]
C24	300 [150]

SUPPLEMENTARY REQUIREMENTS

The following supplementary requirements shall not apply unless specified in the purchase order. A list of standardized supplementary requirements for use at the option of the purchaser is included in Specification A 703/A 703M. Those which are ordinarily considered suitable for use with this specification are given below. Others enumerated in Specification A 703/A 703M may be used with this specification upon agreement between the manufacturer and purchaser.

S1. Residual Elements Chemical Analysis

S2. Destruction Tests

S3. Bend Tests

S4. Magnetic Particle Inspection

S5. Radiographic Inspection

S10. Examination of Weld Preparation

SUMMARY OF CHANGES

Committee A01 has identified the location of selected changes made to this standard since the last issue (A 389/A 389M–93 (1998)) that may impact the use of this standard.

(1) Added the UNS Numbers to the grades in Table 2.

Designation: A 395/A 395M – 99$^{\epsilon 1}$

Standard Specification for Ferritic Ductile Iron Pressure-Retaining Castings for Use at Elevated Temperatures[1]

This standard is issued under the fixed designation A 395/A 395M; 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.

ε[1] NOTE—Figures 4 and 5 were editorially corrected in March 2004.

1. Scope

1.1 This specification covers ductile iron castings for pressure-retaining parts for use at elevated temperatures. Castings of all grades are suitable for use up to 450°F. For temperatures above 450°F and up to 650°F, only Grade 60–40–18 castings are suitable (Note 1).

1.2 Valves, flanges, pipe fittings, pumps, and other piping components are generally manufactured in advance and supplied from stock by the manufacturer, jobber, or dealer.

1.3 For supplemental casting requirements Specification A 834 may be utilized.

1.4 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 to the specification.

NOTE 1—For service other than as specified in this section, reference should be made to Specification A 536 for Ductile Iron Castings.[2]

2. Referenced Documents

2.1 *ASTM Standards:*

A 247 Test Method for Evaluating the Microstructure of Graphite in Iron Castings[2]

A 370 Test Methods and Definitions for Mechanical Testing of Steel Products[2]

A 536 Specification for Ductile Iron Castings[2]

A 732/A732M Specification for Castings, Investment, Carbon and Low Alloy Steel for General Application, and Cobalt Alloy for High Strength at Elevated Temperatures[2]

A 834 Specification for Common Requirements for Iron Castings for General Industrial Use[2]

E 8 Test Methods for Tension Testing of Metallic Materials[3]

E 10 Test Method for Brinell Hardness of Metallic Materials[3]

E 186 Reference Radiographs for Heavy-Walled (2 to 4½ in. (51 to 114-mm)) Steel Castings[4]

E 280 Reference Radiographs for Heavy-Walled (4½ to 12-in. (114 to 305-mm)) Steel Castings[4]

E 446 Reference Radiographs for Steel Castings up to 2 in. (51 mm) in Thickness[4]

E 689 Reference Radiographs for Ductile Iron Castings[4]

E 1806 Practice for Sampling Steel and Iron for Determination of Chemical Composition[5]

F 1476 Specification for Performance of Gasketed Mechanical Couplings for Piping Applications[6]

F 1548 Specification for the Performance of Fittings for Use with Gasketed Mechanical Couplings used in Piping Applications[6]

2.2 *Manufacturer's Standardization Society of the Valve and Fittings Industry Standard:*

SP 25 Standard Marking Systems for Valves, Flanges, Pipe Fittings, and Unions[7]

3. Classification

3.1 Castings ordered to this specification are classified by grades based on mechanical property requirements, as listed in Table 1. See note following Table 1.

4. Ordering Information

4.1 Orders for material under this specification shall include the following applicable information:

4.1.1 Drawing, catalog number or part identifications,

4.1.1.1 For grade 65-45-15, drawing indicating critical area(s) of casting (see 7.2.2 and 7.3.2).

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[1] This specification is under the jurisdiction of ASTM Committee A-4 on Iron Castings and is the direct responsibility of Subcommittee A04.02 on Malleable and Ductile Iron Castings.

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[2] *Annual Book of ASTM Standards*, Vol 01.02.

[3] *Annual Book of ASTM Standards*, Vol 03.01.

[4] *Annual Book of ASTM Standards*, Vol 03.03.

[5] *Annual Book of ASTM Standards*, Vol 03.06.

[6] *Annual Book of ASTM Standards*, Vol 01.07.

[7] Available from the Manufacturers' Standardization Society of the Valves and Fittings Industry, 1815 N. Fort Myer Drive, Arlington, VA 22209.

TABLE 1 Mechanical Property Requirements

Property	Grade 60-40-18	Grade 65-45-15
Tensile Strength Minimum, Psi [MPa]	60 000 [415]	65 000 [450]
Yield Strength Minimum, Psi [MPa]	40 000 [275]	45 000 [310]
Elongation in 2 in. Minimum, %	18	15
Hardness HB, 3000 Kgf Load	143-187	156-201

NOTE—If a grade is not specified in the ordering information, grade 60–40–18 will be supplied.

4.1.2 Quantity (weight or number of pieces),

4.1.3 ASTM designation and year of issue,

4.1.4 Grade (See Table 1), if a Grade is not specified, the manufacturer shall supply grade 60-40-18.

4.1.5 Heat treating requirements (see 5.2.1),

4.1.6 Pressure test requirements (see 7.4.3),

4.1.7 Test samples from castings (see 11.1.1 and 12.1.1),

4.1.8 Test coupons size (see 11.2),

4.1.9 Metallographic option (see 12.1.1),

4.1.10 Place of inspection (see 16.1),

4.1.11 Certification requirements (see 17.1),

4.1.12 Identification marking (see 18.2), and

4.1.13 Supplemental Requirements (see 1.4, 7.4.2, S1 and S2).

5. Materials and Manufacture

5.1 The melting method and the nodularizing practice shall be optional with the foundry.

5.2 Except as provided in 5.2.1, all castings Grade 60-40-18 shall be given a ferritizing heat treatment that produces essentially a ferritic structure that contains no massive carbides.

5.2.1 When specified in the purchase order, Grade 60-40-18 castings may be provided in an as cast condition provided they comply with the requirements of 7.1 and 7.2.1.

5.2.2 Castings supplied in accordance with 5.2.1 may be stress relieved by agreement between the manufacturer and purchaser.

5.3 Castings Grade 65-45-15 may be provided in as cast condition or heat treated, provided they comply with the requirements of 7.1, 7.2.2 and 7.3.2.

6. Chemical Requirements

6.1 The casting shall conform to the following requirements for chemical composition (Note 2):

Total carbon, min, %	3.00
Silicon, max, %	2.50
Phosphorus, max, %	0.08

6.1.1 The chemical analysis for total carbon shall be made on chilled cast pencil type specimens or from thin wafers approximately 1⁄32 in. [0.8 mm] thick cut from test coupons. Drillings are not reliable because of the probable loss of graphite.

6.1.2 For each reduction of 0.01 % below the maximum specified phosphorus content, an increase of 0.08 % silicon above the specified maximum will be permitted up to a maximum of 2.75 %.

NOTE 2—Silicon contents above 2.75 %, or phosphorus contents above 0.08 % have a tendency to lower the impact resistance of the material. If the carbon content is below 3.00 %, excess cementite may form during cooling and if this is not removed during heat treatment, the impact resistance of the material may be lowered.

7. Requirements

7.1 *Tensile Properties*:

7.1.1 The ductile iron as represented by the test specimens shall conform to the mechanical property requirements in Table 1.

7.2 *Hardness*:

7.2.1 For Grade 60–40–18 the hardness of the castings and test specimens shall be within the limits in Table 1.

7.2.2 For Grade 65–45–15 the hardness of test specimen and the critical area(s) of the casting, as identified on the casting drawing, shall be within the limits in Table 1. If the grade 65–45–15 casting drawing does not have critical area(s) of the casting identified, all areas of the casting shall be within the hardness limits in Table 1.

7.3 *Microstructure*:

7.3.1 For Grade 60-40-18 the microstructure of the separately cast test coupon or the casting shall be essentially ferritic and contain no massive carbides, and have a minimum of 90 % Type I and Type II Graphite as in Fig. 1 or Plate I of Test Method A 247.

7.3.2 For Grade 60-45-15 the microstructure of the critical areas of the casting, as identified on the casting drawing, shall be 45 % pearlitic, maximum, contain no massive carbides, and have a minimum 90 % Type I and Type II Graphite as in Fig. 1 or Plate I of Test Method A 247.

7.4 *Pressure Test Requirements*:

7.4.1 Each pressure retaining Grade 60-40-18 casting shall be tested after machining to the test pressure specified by the applicable standard of ANSI, ASME Boiler and Pressure Vessel Code, or other pertinent code, and shall show no leaks.

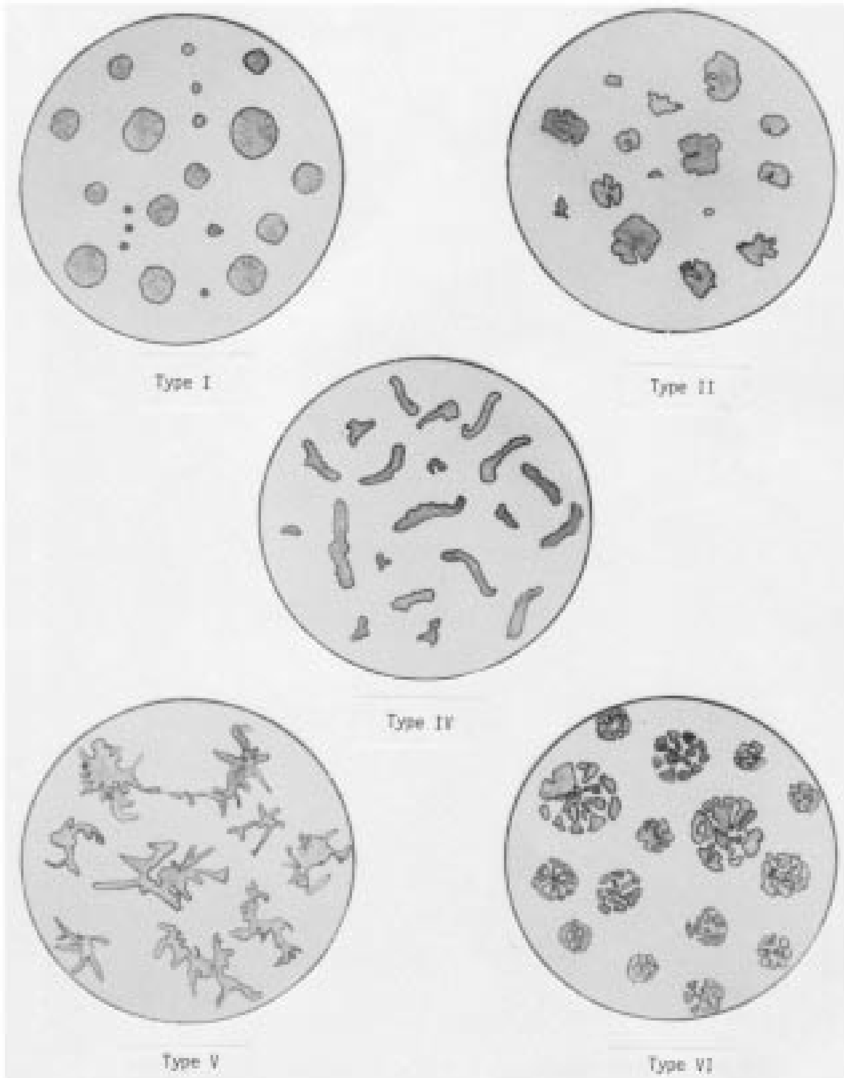
7.4.2 Castings, Grade 65-45-15 manufactured under this specification shall be capable of passing hydrostatic test(s) compatible with the rating of the finished cast component. Such tests shall be conducted by the casting manufacturer only when supplementary requirement S2 is specified.

7.4.3 Castings Grade 60-40-18, ordered under this specification not covered by ANSI standards and ASME Pressure Vessel Code, and castings for special service applications, shall be tested to such pressures as may be agreed upon by the manufacturer and the purchaser.

7.4.4 For castings Grade 60-40-18, it is realized that the foundry may be unable to perform the hydrostatic test prior to shipment, or that the purchaser may wish to defer testing until additional work or machining has been performed on the casting. Castings ordered in the rough state for final machining by the purchaser may be tested hydrostatically prior to shipment by the manufacturer at pressures to be agreed upon with the purchaser. However, the foundry is responsible for the satisfactory performance of the castings under the final hydrostatic test.

8. Workmanship and Finish

8.1 The surface of the casting shall be examined visually and shall be free from adhering sand, scale, cracks, and hot tears. Any other surface discontinuities shall meet visual acceptance standards specified in the order.



NOTE—Graphite types are identical with Plate 1 of Method A 247 and are so identified.

FIG. 1 Suggested Classification of Graphite Form in Ductile Cast Iron

9. Repair

9.1 Castings for valves, flanges, pipe fittings, pumps, and other piping components ordered under applicable ANSI standards shall not be repaired by plugging, welding, brazing, or impregnation.

9.2 Castings Grade 60-40-18 not covered in 9.1 which leak on hydrostatic tests may be repaired by plugging, provided the following requirements are met:

9.2.1 No welding or brazing is permitted.

9.2.2 The diameter of the plug shall not exceed the diameter of a standard 2 in. [ISO R2] pipe plug.

9.2.3 The plugs, where practical, shall conform in all dimensions to the standard ISO 3⁄8 plugs. In addition, they shall have full thread engagement corresponding to the thickness in the repaired section. Where a tapered plug is impractical because of the excess wall thickness in terms of plug diameter and coincident thread engagement, other types of plugs may be used provided both full engagement and effective sealing against pressure are obtained. Where possible, the ends of the plug should be ground smooth after installation to conform to the inside and outside contours of the wall of the pressure vessel or pressure part.

9.2.4 The material from which the plug is manufactured shall conform in all respects to the materials specifications which apply to the pressure vessel or pressure part.

9.2.5 The area adjacent to the drilled hole shall be examined by radiography, and shall meet the Level 3 acceptance requirements of Reference Radiographs E 689 and supporting Reference Radiographs E 446, E 186, or E 280 as applicable and defined in accordance with Reference Radiographs E 689.

9.2.6 The thickness of any repaired section in relation to the size of the plug used shall not be less than that given in Table 2.

9.2.7 The minimum radius of repaired sections of cylinders or cones in relation to the size of plug used shall not be less than that given in Table 3.

TABLE 2 Minimum Thickness of Repaired Sections

Iron Pipe Size Plug, in.	Minimum Thickness Repaired Section, in. [mm]
⅛	11⁄32 [8]
¼	7⁄16 [10]
⅜	½ [13]
½	21⁄32 [17]
¾	¾ [19]
1	13⁄16 [21]
1¼	⅞ [23]
1½	15⁄16 [24]
2	1 [26]

TABLE 3 Minimum Radius of Repaired Sections

Iron Pipe Size Plug, in.	Minimum Radius of Cylinder or Cone, in. [mm]
⅛	9⁄16 [15]
¼	11⁄16 [18]
⅜	1 1⁄16 [28]
½	1¼ [32]
¾	2 [52]
1	2½ [64]
1¼	4 [104]
1½	5¼ [136]
2	8⅛ [208]

9.2.8 A repaired area may consist of a maximum of three plugs with a spacing such that the ligaments between adjacent plugs shall not be less than listed in Table 4. Other defective areas may also be repaired by plugging provided the minimum ligament between plugs in adjacent areas is not less than twice the distance from the nearest plug, the values for which are listed in Table 4.

9.3 Surface imperfections in castings Grade 60-40-18 other than valves, flanges, pipe fittings, pumps, and other piping components may be repaired by plugging provided the depth of the plug is not greater than 20 % of the thickness of the casting section and the diameter of the plug is not greater than its length. Repair of surface defects may not be done on pressure containing portions of castings. The plug need not be threaded. The conditions of 9.2.1 and 9.2.4 shall also be satisfied.

10. Sampling

10.1 A lot shall consist of one of the following:

10.1.1 All the metal from a single heating in a batch—type melting furnace.

TABLE 4 Minimum Ligament Between Plugs[A,B]

Nominal Plug Diameter, in.	Minimum Ligament Between Plugs, in. [mm]			
	⅛ , ¼ , ⅜	½ , ¼	1, 1¼	1½ , 2
⅛ , ¼ , ⅜	2⅝ [67]	4⅛ [105]	6⅝ [169]	9½ [242]
½ , ¾	4⅛ [105]	4⅛ [105]	6⅝ [169]	9½ [242]
1, 1¼	6⅝ [169]	6⅝ [169]	6⅝ [169]	9½ [242]
1½ , 2	9½ [242]	9½ [242]	9½ [242]	9½ [242]

[A]Based on efficiency of 80 %.

[B]Example: Assume three plugs are required for repair, one ⅛ in., one ⅜ in., and one 1½ in. The minimum distance permitted is as follows:

Ligament distance between ⅛ and ⅜-in. plugs is 2⅝ in. [67mm].
Ligament distance between ⅛ and 1½-in. plugs is 9½ in. [242 mm].
Ligament distance between ⅜ and 1½-in. plugs is 9½ in. [242 mm].

10.1.2 All the metal poured from two or more batch-type melting furnaces into a single ladle or a single casting.

10.1.3 All the metal poured from a continuous melting furnace for a given period of time between changes in charge, processing conditions, or aim-for chemistry, or 8 h, whichever is the shorter period.

11. Test Coupon

11.1 The separately cast test coupons poured from the same lot as the castings they represent from which the tension test specimen is machined shall be cast to the size and shape shown in Fig. 2, Fig. 3, or Fig. 4. Cast coupons shall be identified with the castings they represent. Sectioning procedure for removing test specimens from Y-blocks is shown in Fig. 5.

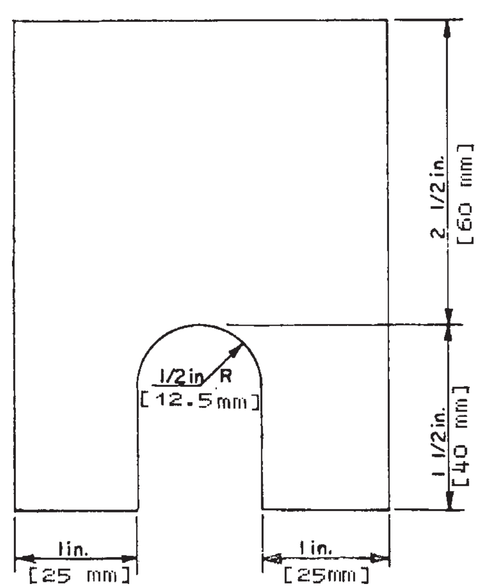
11.1.1 Test samples may be removed from castings at locations designated on a drawing or as agreed to by manufacturer and purchaser.

11.1.2 Test bars removed from castings shall conform to Fig. 6. The testing diameter shall be ½ in. [12.5 mm] if possible. Smaller diameters shall be utilized if necessary.

11.2 The test coupon size shall be as mutually agreed upon between the manufacturer and purchaser. In the absence of agreement, it shall be the option of the manufacturer.

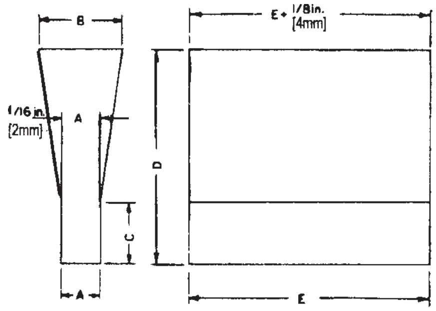
11.3 The test coupons shall be cast in molds made of suitable core sand having a minimum wall thickness of 1½ in. [38 mm] for the ½ in. [12.5 mm], 1 in. [25 mm] sizes, and 3 in. [75 mm] for the 3 in. [75 mm] size. The coupons shall be left in the mold until they have changed to a black color (approximately 900°F [480°C]or less). The keel block as shown in Fig. 2 or the modified keel block produced from the mold shown in Fig. 4 may be substituted for the 1 in. [25 mm] block shown in Fig. 3.

11.4 When investment castings are made to this specification, the manufacturer may use test specimens cast to size incorporated in the mold with the castings or separately cast to size using the same type of mold and the same thermal



NOTE—The length of the keel block shall be 6 in. [152 mm]

FIG. 2 Keel Block for Test Coupons



Dimensions	For Castings of Thickness Less Than ½ in. [13 mm]	For Castings of Thickness ½ in. [13 mm] to 1½ in. [38 mm]	For Castings of Thickness of 1½ in. [38 mm] and Over
	in. [mm]	in. [mm]	in. [mm]
A	½ [13]	1 [25]	3 [75]
B	1⅝ [40]	2⅛ [55]	5 [125]
C	2 [50]	3 [75]	4 [100]
D	4 [100]	6 [150]	8 [200]
E	7 [175] approx	7 [175] approx	7 [175] approx

"Y" Block Size

FIG. 3 Y-Blocks for Test Coupons

conditions that are used to produce the castings. These test specimens shall be made to the dimensions shown in Fig. 1 of Specification A 732 or Fig. 5 and Fig. 6 of Test Methods and Definitions A 370.

11.5 The manufacturer shall cast a sufficient number of test coupons to provide for each ferritizing anneal. The test coupons shall be heat treated with the castings they represent. Sectioning of the test coupons prior to heat treating is not permitted.

11.6 The metallographic examination shall be made on a test lug from the test coupon shown in Fig. 7 or from a casting; or from a representative test coupon poured with the casting(s). The test coupon shall represent the metal treated with the nodularizing agent.

12. Number of Tests and Retests

12.1 One tension test shall be made from sections cut from the test coupons (Fig. 5) required by Section 11.

12.1.1 Unless otherwise stated in the contract or order for castings, a metallographic examination may be substituted for the tension test when separately cast test coupons are used. When the microstructure option is used, a minimum of one tension test is required from each day's melt and for each heat treatment (see 12.2).

12.2 If any tension test specimen shows obvious defects, another from the same coupon, or from another coupon/or representing the same metal and the same anneal charge, may be tested. If an apparently sound test specimen fails to conform to this specification, castings may be re-annealed, if required, and two retests made. If either retest fails to conform to this specification, the castings they represent shall be rejected.

13. Tension Test Specimen Preparation

13.1 The standard machined ½ in. [12.5 mm] round tension test specimen with 2 in. [50 mm] gauge length as shown in Fig. 6 shall be used except where the ½ in. [12.5 mm] Y-block test coupon is required. In this case, either of the small size specimens, 0.375 or 0.250 in. [9 or 6.5 mm] round as shown in Fig. 6 shall be used.

14. Test Methods

14.1 Chemical analysis shall be made in accordance with Test Method E 1806.

14.2 The yield strength shall be determined in accordance with Test Methods E 8 using one of the following methods:

14.2.1 The 0.2 % off-set method, or

14.2.2 Extension under load method where the yield strength may be determined as the stress producing an elongation under load of 0.375 %; that is, 0.0075 in. [0.19 mm] in a gauge length of 2 in. [50 mm].

14.3 The hardness of the ductile iron as represented by the test specimens and castings shall be determined in accordance with Test Method E 10.

14.4 The percentage of each graphite type shall be determined by manual counting, semi-automatic or automatic image analysis methods. The sum of all graphite types shall total to 100 %.

15. Records

15.1 Records of the chemical composition, mechanical properties, and metallographic examination, when applicable, shall be systematically made and maintained.

16. Inspection

16.1 Unless otherwise specified in the contract or purchase order, the manufacturer shall be responsible for carrying out all the tests and inspection required by this specification.

16.2 The inspector representing the purchaser shall have entry at all time, while work on the contract of the purchaser is being performed, to all parts of the manufacturer's works which concern the manufacturer of the material ordered. The manufacturer shall afford the inspector all reasonable facilities to satisfy him that the material is being furnished in accordance with these specifications. Unless otherwise specified, all tests and inspection shall be made at the place of manufacture or by an approved independent laboratory prior to shipment, and shall be so conducted as not to interfere unnecessarily with the operation of the works.

17. Certification

17.1 When agreed upon in writing by the purchaser and the supplier, a certification shall be made on the basis of acceptance of the material. This shall consist of a copy of the manufacturer's test report or a statement by the supplier accompanied by a copy of the test results, that the material has been sampled, tested, and inspected in accordance with the provisions of this specification. Each certification so furnished shall be signed by an authorized agent of the supplier or manufacturer.

18. Product Marking

18.1 Castings for valves, flanges, pipe fittings, and unions shall be marked for material identification in accordance with

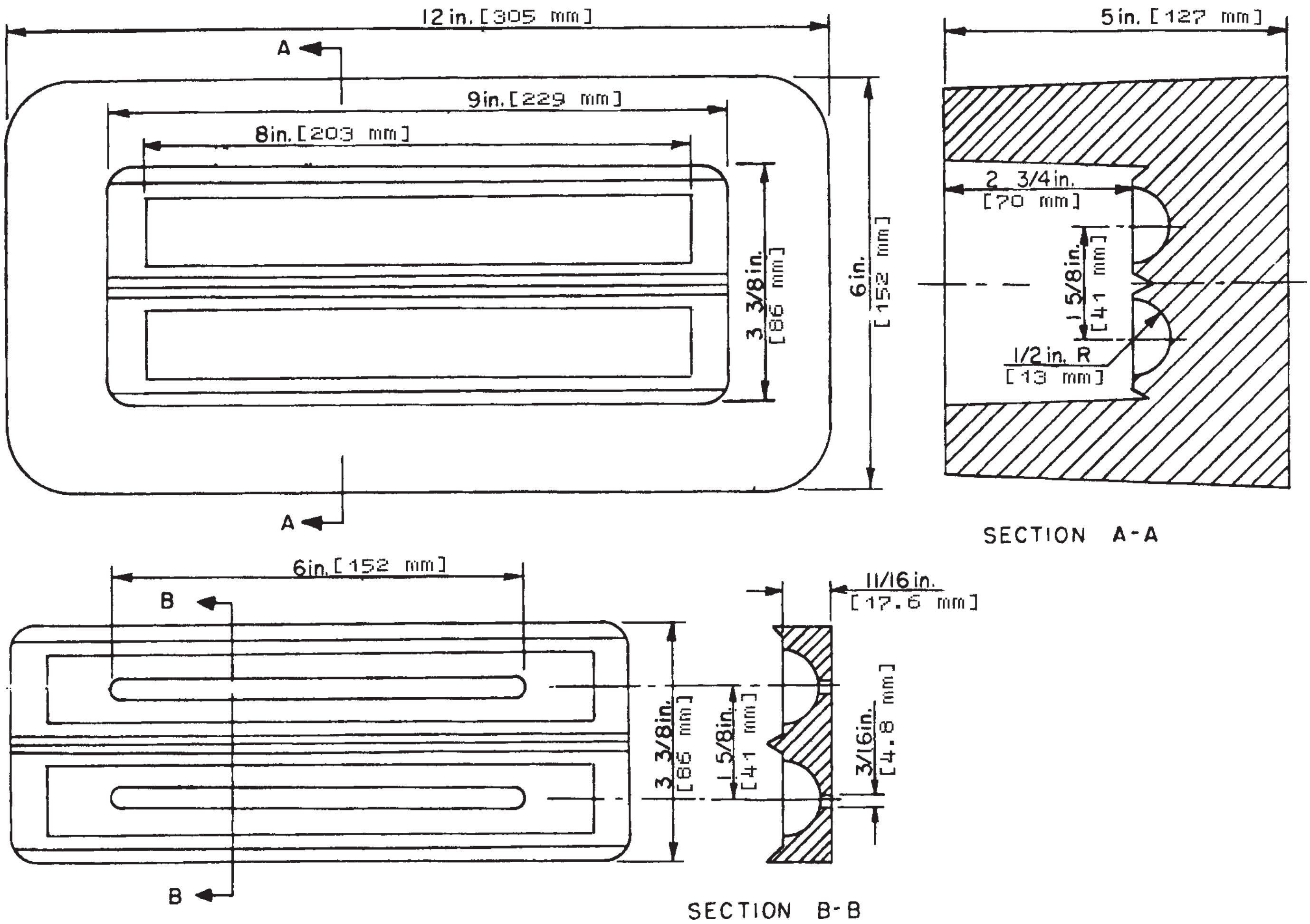
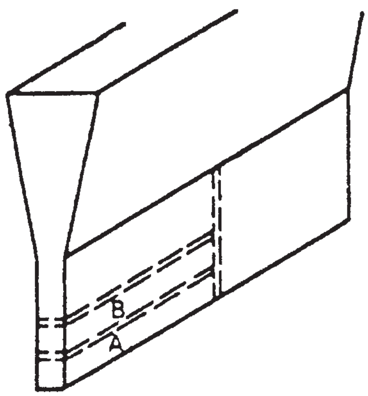


FIG. 4 Mold for Modified Keel Block

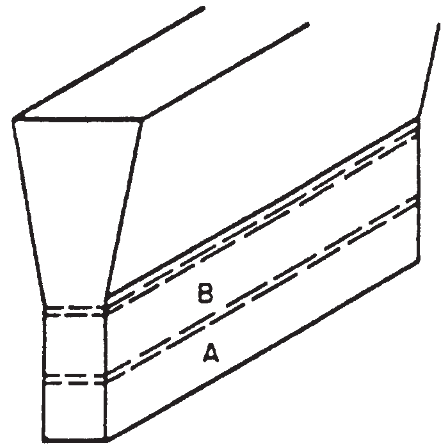
the Standard Marking System for Valves, Flanges, Pipe Fittings, and Unions, SP-25. Castings for gasketed mechanical couplings and fittings may be marked in accordance with F 1476 or F 1548 respectively.

18.2 Castings, other than valves, flanges, pipe fittings, and unions shall be identified subject to agreement by the manufacturer and the purchaser.

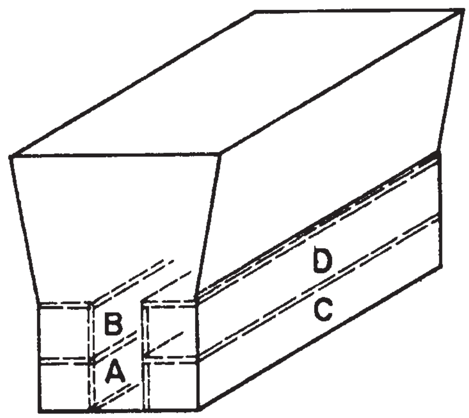
18.3 Marking shall be in such a position as not to injure the usefulness of the castings.



(a) ½-in. [13 mm] Y-Block—Two blanks for 0.252-in. [6.40 mm] diameter tension test specimens.

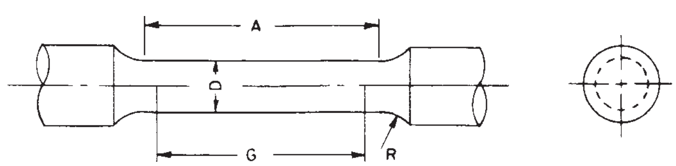


(b) 1-in. [25 mm] Y Block—Two blanks for 0.50-in. [12.5 mm] diameter tension test specimens.



(c) 3-in. [75 mm] Y-Block—Two blanks for 0.50-in. [12.5 mm] diameter tension test specimens.

FIG. 5 Sectioning Procedure for Y-Blocks



Note 1—The reduced section may have a gradual taper from the ends toward the center, with the ends not more than 0.005 in. [0.13 mm] larger in diameter than the center on the standard specimen, and not more than 0.003 in. [0.076 mm] larger in diameter than the center on the small size specimens.

Note 2—If desired, on the small size specimens the length of the reduced section may be increased to accommodate an extensometer. However, reference marks for measurement of elongation should nevertheless be spaced at the indicated gage length.

Note 3—The gage length and fillets shall be as shown, but the ends may be of any form to fit the holders of the testing machine in such a way that the load shall be axial. If the ends are to be held in grips, it is desirable to make the length of the grip section great enough to allow the specimen to extend into the grips a distance equal to two thirds or more of the length of the grips.

Dimensions	Standard Specimen, in. [mm]	Small Size Specimens Proportionate to Standard, in. [mm]	
	½ [12.5] Round	0.350 [9] Round	0.250 [6.5] Round
G—Gage length	2.000 ± 0.005 [50 ± 0.13]	1.4 ± 0.005 [35 ± 0.13]	1.0 ± 0.005 [25 ± 0.13]
D—Diameter (Note 1)	0.500 ± 0.010 [12.5 ± 0.25]	0.350 ± 0.007 [9 ± 0.18]	0.250 ± 0.005 [6.5 ± 0.13]
R—Radius of fillet	⅜ [9.5], min	⅜ [9.5], min	¼ [6.5], min
A—Length of reduced section (Note 2)	2¼ [58], min	1¾ [45], min	1¼ [32], min

FIG. 6 Standard ½-in. [12.5–mm] Round Tension Test Specimen with 2-in. [50.0–mm] Gage Length and Examples of Small Size Specimens Proportional to the Standard Specimen

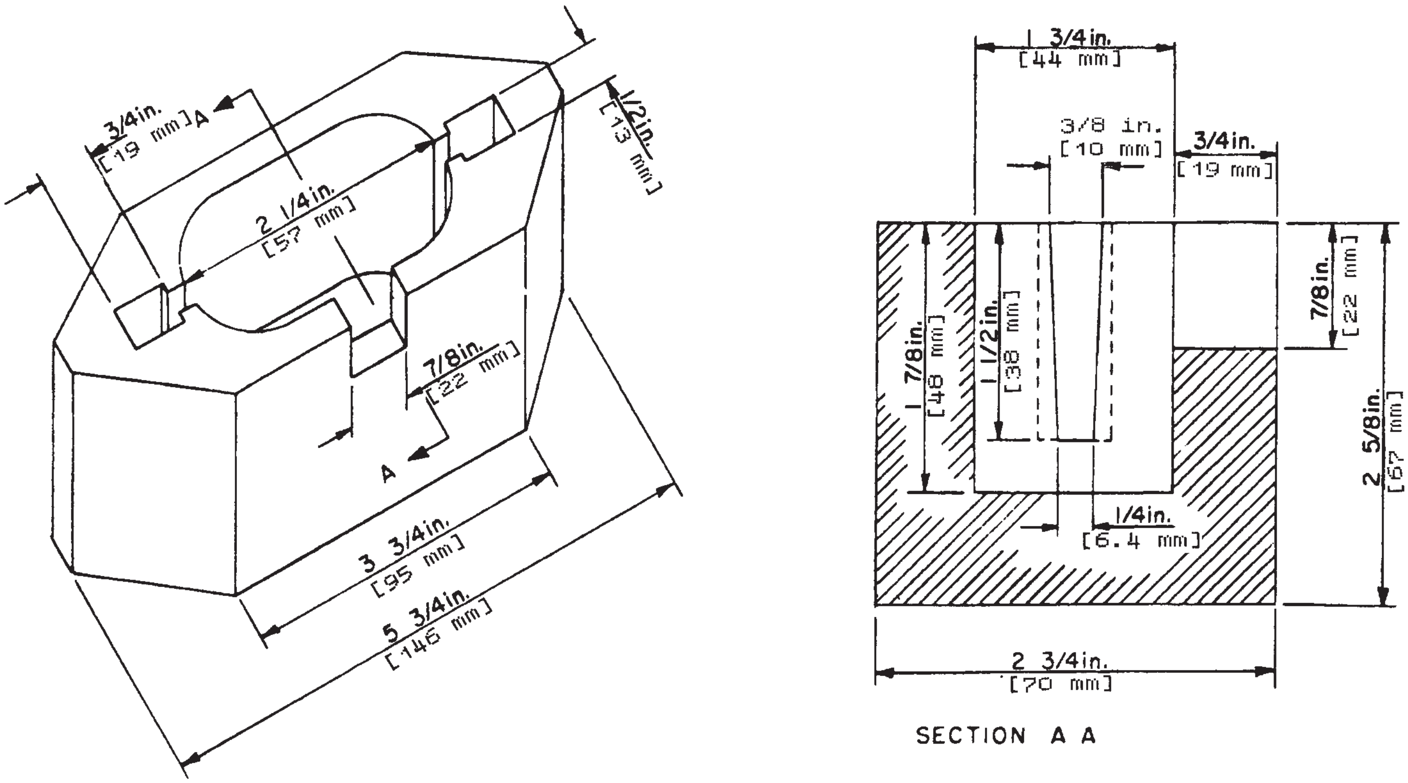


FIG. 7 Test Coupon for Microscopical Examination of Ductile Iron

19. Keywords

19.1 casting; ductile iron; mechanical properties; pressure-retaining; pressure test; tensile strength; tension testing; yield strength

SUPPLEMENTARY REQUIREMENTS

The following supplementary requirement shall not apply unless specified in the purchase order.

S1. For Castings Grade 60-40-18, a microstructure test lug is to be cast attached to the casting at the location designated on the casting drawing. The microstructure of the test lug shall be essentially ferritic and contain no massive carbides.

S2. Pressure Test, Casting Grade 65-45-15

S2.1 A hydrostatic test at a pressure agreed upon by the manufacturer and the purchaser shall be applied by the manufacturer.

Designation: A 436 – 84 (Reapproved 2001)

Standard Specification for Austenitic Gray Iron Castings[1]

This standard is issued under the fixed designation A 436; 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 austenitic gray iron castings that are used primarily for their resistance to heat, corrosion, and wear. Austenitic gray iron is characterized by uniformly distributed graphite flakes, some carbides, and the presence of sufficient alloy content to produce an austenitic structure.

1.2 The values stated in inch-pound units are to be regarded as the standard.

2. Referenced Documents

2.1 *ASTM Standards:*

E 30 Test Methods for Chemical Analysis of Steel, Cast Iron, Open-Hearth Iron, and Wrought Iron[2]

E 59 Practice for Sampling Steel and Iron for Determination of Chemical Composition[2]

E 94 Guide for Radiographic Examination[3]

E 165 Test Method for Liquid Penetrant Examination[3]

E 351 Test Methods for Chemical Analysis of Cast Iron—All Types[2]

E 433 Reference Photographs for Liquid Penetrant Inspection[3]

E 446 Reference Radiographs for Steel Castings Up to 2 in. (51 mm) in Thickness[3]

3. Ordering Information

3.1 Orders for material to this specification shall include the following information:

3.1.1 ASTM designation and date of issue,

3.1.2 Type of austenitic gray iron required (see 5.1),

3.1.3 Heat treatment required (see 4.2 through 4.5),

3.1.4 If repair of castings is permitted (see 4.6),

3.1.5 Size and number of test bars required (see 11 through 8.4 and 12.1),

3.1.6 If special tests are required (see Section 7 and 9.1),

3.1.7 If certification is required (see 14.1), and

3.1.8 If different preparation for delivery requirements are needed (see 15.1).

4. Materials and Manufacture

4.1 Melting may be done in any furnace that produces castings meeting the chemical compositions and mechanical properties outlined in this specification. These include cupolas, air furnaces, electric furnaces, crucible furnaces, and so forth.

4.2 By agreement between the manufacturer and the purchaser, the castings may be stress relieved by heating to and holding in the temperature range from 1150 to 1200°F (620 to 650°C) for not less than 1 nor more than 2 h/in. of thickness in the thickest section. Heating and cooling shall be uniform and shall be not more than 400°F (222°C)/h for castings less than 1 in. in maximum thickness, nor more than 400°F/h divided by the maximum section thickness in inches for thicker castings. During the cooling cycle, castings may be cooled in still air after the temperature has dropped to 600°F (315°C).

4.3 If the manufacturer can demonstrate that another treatment provides satisfactory stress relief, it may be used by agreement between the manufacturer and the purchaser.

4.4 Whenever dimensional changes in high-temperature service are a problem, by agreement between the manufacturer and the purchaser, the castings may be stabilized by heating at 1600°F (870°C) for 1 h/in. of section, for a minimum of 1 h. Otherwise, the austenite that is supersaturated with respect to carbon may reject carbon during service and produce dimensional changes.

4.5 By agreement between the manufacturer and the purchaser, castings with chilled edges or excessive carbides may be annealed at 1750 to 1900°F (955 to 1040°C) for ½ to 5 h, followed by uniform cooling, preferably in still air.

4.6 Castings shall not be repaired by welding, plugging, or other methods without written permission from the purchaser.

5. Chemical Composition

5.1 Many combinations of alloys can be used to obtain an austenitic gray iron. This specification includes only the six types defined by the chemical composition limits specified in Table 1.

5.2 The chemical analysis for total carbon shall be made on

[1] This specification is under the jurisdiction of ASTM Committee A04 on Iron Castings and is the direct responsibility of Subcommittee A04.01 on Gray and White Iron Castings.

Current edition approved Jan. 27, 1984. Published May 1984. Originally published as A 436–59 T. Last previous edition A 436–78.

[2] *Annual Book of ASTM Standards*, Vol 03.05.

[3] *Annual Book of ASTM Standards*, Vol 03.03.

TABLE 1 Chemical Requirements

Element	Composition, %							
	Type 1	Type 1b	Type 2	Type 2b	Type 3	Type 4	Type 5	Type 6
Carbon, total, max	3.00	3.00	3.00	3.00	2.60	2.60	2.40	3.00
Silicon	1.00–2.80	1.00–2.80	1.00–2.80	1.00–2.80	1.00–2.00	5.00–6.00	1.00–2.00	1.50–2.50
Manganese	0.5–1.5	0.5–1.5	0.5–1.5	0.5–1.5	0.5–1.5	0.5–1.5	0.5–1.5	0.5–1.5
Nickel	13.50–17.50	13.50–17.50	18.00–22.00	18.00–22.00	28.00–32.00	29.00–32.00	34.00–36.00	18.00–22.00
Copper	5.50–7.50	5.50–7.50	0.50 max	0.50 max	0.50 max	0.50 max	0.50 max	3.50–5.50
Chromium	1.5–2.5	2.50–3.50	1.5–2.5	3.00–6.00[A]	2.50–3.50	4.50–5.50	0.10 max	1.00–2.00
Sulfur, max	0.12	0.12	0.12	0.12	0.12	0.12	0.12	0.12
Molybdenum, max	...	...	...	...	...	...	...	1.00

[A] Where some machining is required, the 3.00–4.00 % chromium range is recommended.

chilled cast pencil-type specimens or from thin wafers approximately 1⁄32 in. (0.8 mm) thick cut from test coupons. Drillings are not reliable because of the probable loss of graphite.

5.3 Drillings taken from test coupons, broken test specimens, or castings shall conform to the requirements for chemical composition as given in Table 1. Sampling shall be conducted in accordance with Practice E 59 and chemical analysis in accordance with Test Methods E 351 and Test Methods E 30. Test Methods E 30 should only be used for analyzing those elements for which specific coverage is not provided for in Test Methods E 351.

5.4 Spectrometric techniques may also be used for analysis, but should a dispute arise concerning chemical composition, chemical analyses determined by Test Methods E 351 and Test Methods E 30 shall be used for referee analysis.

6. Mechanical Properties

6.1 Although these irons are not used primarily for their strength, the tensile strength and Brinell hardness are indicative of the correct metallurgical structure. The six types shall conform to the requirements given in Table 2.

7. Magnetic Property Requirements

7.1 A convenient shop test for differentiating the various types of austenitic gray iron is based on the fact that a ground face of either the test bars or the castings of Types 1, 2, and 4 will not attract a small steel horseshoe-type magnet, that is normally attracted to steel. Types 1*b*, 2*b*, 3, and 5 may be attracted to a magnet. This nonmagnetic test is a convenient qualitative test only for Types 1, 2, and 4 and shall not be used as a basis for acceptance. In the event that nonmagnetic castings are specified, the magnetic permeability test shall be used. The specific test conditions and magnetic permeability limits shall be agreed upon between the manufacturer and the purchaser.

NOTE 1—Alnico magnets should not be used.

8. Test Bars

8.1 The separately cast test bars from which tension test specimens are to be machined shall be cast to the size and shape shown in Fig. 1. The size of bar cast to represent the casting shall be at the option of the purchaser. In case no option is expressed, the manufacturer shall make the choice. The test bars shall be cast in open molds made of suitable core sand with a minimum of 1½in. (38 mm) of sand on all sides and bottom of the ½-in. (13-mm) and 1-in. (25-mm) sizes, and 3 in. (76 mm) of sand for the 3-in. test bar.

8.2 By agreement between the manufacturer and the purchaser, the 1-in. (25-mm) keel block shown in Fig. 2 may be used. It shall be an open mold made of suitable core sand with a minimum of 1½ in. (38 mm) of sand on all sides and bottom.

8.3 It is recommended that test bars be poured immediately after the castings and from the same ladle of metal. If castings are to be heat treated, test bars shall be included in the same furnace load.

8.4 By agreement between the manufacturer and the purchaser, tension test specimens may be cut directly from centrifugal or other permanent mold castings. The location and orientation of such tension test specimens cut from castings shall be specified as agreed upon by the manufacturer and the purchaser.

9. Workmanship, Finish, and Appearance

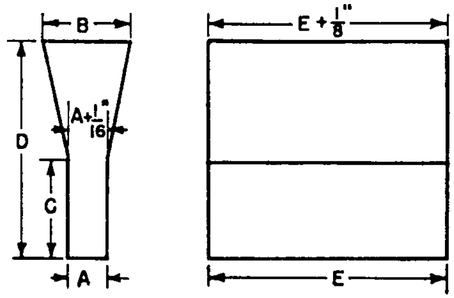
9.1 The castings shall conform substantially to the dimensions on the drawings furnished by the purchaser, or if no drawing has been provided, to the dimensions predicated by the pattern supplied by the purchaser. The castings shall be free of injurious defects. Surfaces of the castings shall be free of burnt-on sand and shall be reasonably smooth. In other respects, the castings shall conform to whatever points may be specifically agreed upon between the manufacturer and the purchaser.

10. Tension Test Specimens

10.1 The round tension test specimen with 2-in. or 50-mm gage length shown in Fig. 3 shall be used, except when the ½-in. (13-mm) "Y" block is used or when specimens are cut from castings under ¾-in. (19.0-mm) thickness. In these cases, either of the test specimens shown in Fig. 4 shall be satisfactory.

TABLE 2 Mechanical Requirements

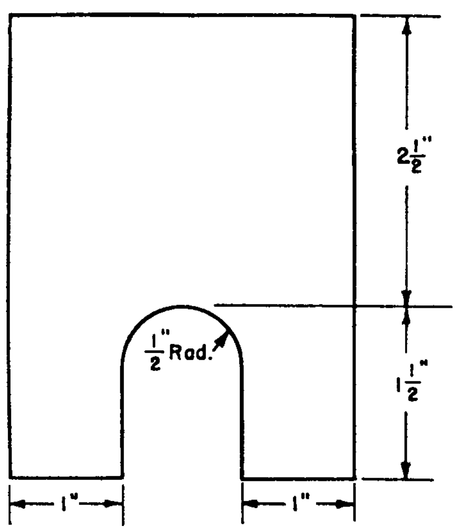
	Type 1	Type 1b	Type 2	Type 2b	Type 3	Type 4	Type 5	Type 6
Tensile strength, min, ksi (MPa)	25 (172)	30 (207)	25 (172)	30 (207)	25 (172)	25 (172)	20 (138)	25 (172)
Brinell hardness (3000 kg)	131 183	149 212	118 174	171 248	118 159	149 212	99 124	124 174



Dimensions	"Y" Block Size					
	For Castings of Thickness Less than ½ in. (13 mm)		For Castings of Thickness ½ in. (13 mm) to 1½ in. (38 mm)		For Castings of Thickness of 1½ in. (38 mm) and Over	
	in.	mm	in.	mm	in.	mm
A	½	13	1	25	3	75
B	1⅝	40	2⅛	54	5	125
C	2	50	3	75	4	100
D	4	100	6	150	8	200
E	7 approx	175 approx	7 approx	175 approx	7 approx	175 approx

NOTE—1⁄16 in. = 1.6 mm; ⅛ in. = 3.2 mm.

FIG. 1 "Y" Blocks for Test Coupons

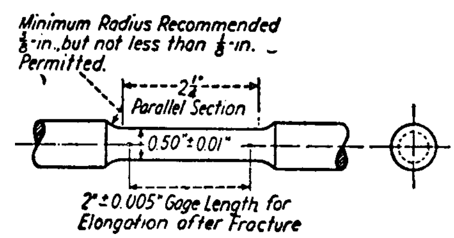


Metric Equivalents

in.	½	1	1½	2
mm	13	25	38	51

NOTE—The length of the keel block shall be 6 in. (152 mm).

FIG. 2 Keel Block for Test Coupons



Metric Equivalents

in.	mm	in.	mm
0.005	0.13	0.50	12.7
0.01	2.5	2	50.8
⅛	3.2	2¼	57.2
⅜	9.5		

NOTE—The gage length and fillets shall be as shown but the ends may be of any shape to fit the holders of the testing machine in such a way that the load shall be axial. The reduced section shall have a gradual taper from the ends toward the center, with the ends 0.003 to 0.005 in. (0.08 to 0.13 mm) larger in diameter than the center.

FIG. 3 Standard Round Tension Test Specimen with 2-in. or 50-mm Gage Length

11. Number of Test

11.1 The number of test bars cast shall be agreed upon by the manufacturer and the purchaser.

11.2 One tension test shall be made from sections cut from the test bars as shown in Fig. 5. If any tension test specimen shows obvious defects, another may be cut from the same test bar or from another test bar representing the same metal.

12. Other Tests

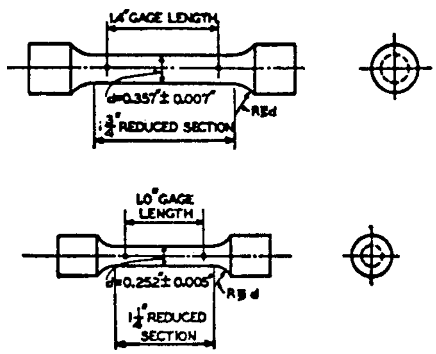
12.1 Hydrostatic tests for pressure castings, fracture tests, microstructure standards, radiography standards, and liquid penetrant inspection may be set up by mutual agreement between the manufacturer and the purchaser.

12.2 Radiography, when required, shall be in accordance with Guide E 94 and Reference Radiographs E 446.

12.3 Liquid penetrant inspection, when required, shall be in accordance with Test Method E 165 and Reference Photographs E 433.

13. Responsibility for Inspection

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



Metric Equivalents

in.	mm	in.	mm
0.005	0.13	1.0	25.4
0.007	0.18	1¼	31.8
0.252	6.40	1.4	35.6
0.357	9.07	1¾	44.4

NOTE 1—If desired, the length of the reduced section may be increased to accommodate an extensometer.

FIG. 4 Examples of Small-Size Specimens Proportional to Standard ½-in. (12.7-mm) Round Specimen

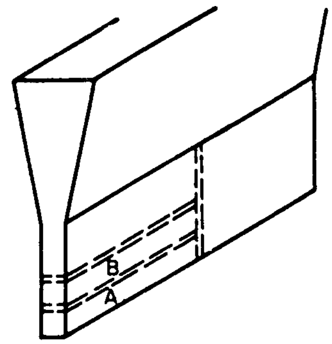
all inspection requirements as specified herein. Except as otherwise specified in the contract or order, the manufacturer may use his own or any other facilities suitable for the performance of the inspection requirements specified herein, unless disapproved by the purchaser. The purchaser reserves the right to perform any of the inspections set forth in the specification where such inspections are deemed necessary to assure supplies and services conform to the prescribed requirements.

14. Waiving of Inspection by Agreement

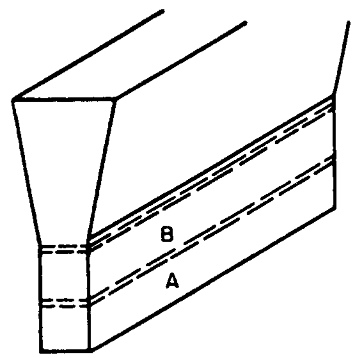
14.1 When agreed upon in writing by the purchaser and the supplier, a certification shall be made the basis of acceptance of the material. This shall consist of a copy of the manufacturer's test report or a statement by the supplier, accompanied by a copy of the test results, that the material has been sampled, tested, and inspected in accordance with the provisions of the specification specified. Each certification so furnished shall be signed by an authorized agent of the supplier or manufacturer.

15. Preparation for Delivery

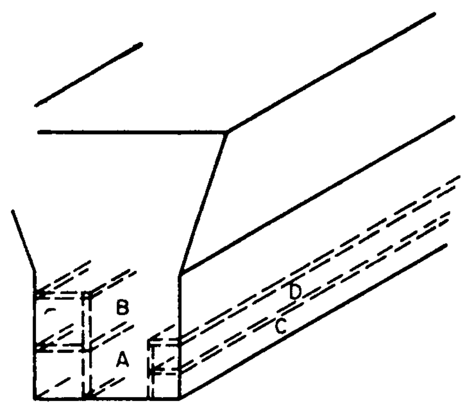
15.1 Unless otherwise specified in the contract or purchase order, cleaning, preservation, and packaging of castings shall be in accordance with the manufacturer's commercial practice. Packing and marking shall also be adequate to ensure acceptance and safe delivery by the carrier for the mode of transportation employed.



(*a*) ½-in. (13-mm) "Y" Block.—Two blanks for 0.252-in. (6.40-mm) diameter tension test specimens.



(*b*) 1-in. (25-mm) "Y" Block.—Two blanks for 0.50-in. (12.7-mm) diameter tension test specimens or transverse tests.



(*c*) 3-in. (76-mm) "Y" Block.—Two blanks for 0.50-in. (12.7-mm) diameter tension test specimens and two blanks for transverse test.

FIG. 5 Sectioning Procedure for "Y" Blocks

16. Keywords

16.1 austenitic; gray iron castings; high-nickel

Designation: A 439 – 83 (Reapproved 1999)

Standard Specification for Austenitic Ductile Iron Castings[1]

This standard is issued under the fixed designation A 439; 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 austenitic ductile iron castings which are used primarily for their resistance to heat, corrosion, and wear, and for other special purposes.

1.2 Austenitic ductile iron, also known as austenitic nodular iron or austenitic spheroidal iron, is characterized by having its graphite substantially in a spheroidal form and substantially free of flake graphite. It contains some carbides and sufficient alloy content to produce an austenitic structure.

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 370 Test Methods and Definitions for Mechanical Testing of Steel Products[2]

A 732/A 732M Specification for Castings, Investment, Carbon and Low Alloy Steel for General Application, and Cobalt Alloy for High Strength at Elevated Temperatures[3]

E 8 Test Methods for Tension Testing of Metallic Materials[4]

E 30 Test Methods for Chemical Analysis of Steel, Cast Iron, Open-Hearth Iron, and Wrought Iron[5]

E 59 Practice for Sampling Steel and Iron for Determination of Chemical Composition[5]

E 351 Test Methods for Chemical Analysis of Cast Iron—All Types[5]

3. Ordering Information

3.1 Orders for material to this specification shall include the following information:

3.1.1 ASTM designation,

3.1.2 Type of austenitic ductile iron required (see 6.1),

3.1.3 Heat treatment required (see 4.2 through 4.4),

3.1.4 If repair of castings is permitted (see 4.5),

3.1.5 Size and number of test bars required (see 9.1 through 9.4 and 10.1),

3.1.6 Special tests, if required (see 12.1),

3.1.7 Certification, if required (see 14.1), and

3.1.8 Different preparation for delivery requirements, if needed (see 15.1).

4. Manufacture

4.1 Melting may be done in any furnaces that produce castings meeting the chemical and mechanical requirements outlined in this specification. These include cupolas, air furnaces, electric furnaces, crucible furnaces, etc.

4.2 By agreement between the manufacturer and the purchaser, the castings may be stress relieved by heating to 1150 to 1200°F (621 to 650°C) for not less than 1 h nor more than 2 h per inch of thickness in the thickest section. Heating and cooling shall be uniform and shall not be more than 400°F (222°C)/h for castings less than 1 in. (25.4 mm) in maximum thickness, nor more than 400°F (222°C) divided by the maximum section thickness in inches for thicker castings. During the cooling cycle, castings may be cooled in still air after the temperature has dropped to 600°F (315°C).

4.3 Whenever dimensional changes in high-temperature service are a problem, by agreement between the manufacturer and the purchaser, the castings may be stabilized by heating at 1600°F (870°C) for 1 h per inch of section, with a minimum of 1 h. Otherwise, the austenite which is super-saturated with respect to carbon may reject carbon during service and produce dimensional changes.

4.4 By agreement between the manufacturer and the purchaser, castings with chilled edges or excessive carbides may be annealed at 1750 to 1900°F (955 to 1040°C) for ½ to 5 h followed by uniform cooling, preferably in still air.

4.5 Repair by welding, plugging, or other approved methods may be done only with written permission from the purchaser.

5. Magnetic Properties

5.1 In the event that nonmagnetic castings are specified, the magnetic permeability test shall be used. The maximum magnetic permeability value shall be agreed upon between the manufacturer and the purchaser.

NOTE 1—A convenient shop test for differentiating the various types of austenitic ductile iron is based on the fact that a ground face of either the test bar or the castings of Types D-2 and D-2C will not attract a small steel

[1] This specification is under the jurisdiction of ASTM Committee A-4 on Iron Castings and is the direct responsibility of Subcommittee A04.02 on Malleable and Ductile Iron Castings.

Current edition approved July 29, 1983. Published September 1983. Originally published as A439–60T. Last previous edition A439–82.

[2] *Annual Book of ASTM Standards*, Vol 01.03.

[3] *Annual Book of ASTM Standards*, Vol 01.02.

[4] *Annual Book of ASTM Standards*, Vol 03.01.

[5] *Annual Book of ASTM Standards*, Vol 03.05.

horseshoe-type magnet which is normally attracted to steel (Alnico magnet should not be used). Types D-3, D-3A, D-5, and D-5B are attracted, and types D-2B and D-4 may be slightly attracted. This nonmagnetic test is a convenient qualitative test only for Types D-2 and D-2C and shall not be used as a basis for acceptance.

6. Chemical Requirements

6.1 Many combinations of alloys can be used to obtain an austenitic ductile iron. This specification includes nine general types defined by the composition limits in Table 1.

6.2 Samples taken from test coupons, broken test specimens, or castings shall conform to the requirements as to chemical composition prescribed in Table 1. Sampling shall be conducted in accordance with Method E 59 and chemical analyses in accordance with Test Methods E 351 and Methods E 30. Methods E 30 should only be used for analyzing those elements for which specific coverage is not provided for in Test Methods E 351.

6.3 Spectrometric techniques may also be used for analysis, but should a dispute arise concerning chemical composition, Test Methods E 351 and Methods E 30 shall be used for referee methods.

6.4 The chemical analysis for total carbon shall be made on either chilled cast pencil-type specimens or thin wafers approximately 1⁄32 in. (0.8 mm) thick cut from test coupons. Drillings shall not be used because of attendant loss of graphite.

7. Mechanical Requirements

7.1 Test specimens of austenitic ductile iron made according to this specification shall meet the test requirements prescribed in Table 2.

7.2 The yield strength shall be determined in accordance with Test Methods E 8, using one of the following procedures: the 0.2 % off-set method or the extension under load method may be used, by agreement between the purchaser and the manufacturer.

8. Workmanship, Finish, and Appearance

8.1 The castings shall conform substantially to the dimensions on the drawings furnished by the purchaser, or if no drawing has been provided, to the dimensions predicated by the pattern supplied by the purchaser. The castings shall be free of injurious defects. Surfaces of the castings shall be free of burnt-on sand and shall be reasonably smooth. Runners, risers, fins, and other useless cast-on pieces shall be removed. In other respects, the castings shall conform to whatever points may be specifically agreed upon between the manufacturer and the purchaser.

9. Test Bars

9.1 The standard test bars shall be the 1-in. (25.4-mm) “Y” block and 1-in. (25.4-mm) keel block as shown in Fig. 1 and Fig. 2, respectively. A modified keel block cast from the mold shown in Fig. 3 may be substituted for the 1-in. (25.4-mm) “Y” block or the 1-in. keel block.

9.2 Whenever the section size of the castings is considerably less or greater than 1 in. (25.4 mm) and by agreement between the purchaser and the manufacturer, the ½-in. (12.7-mm) or 3-in. (76.2-mm) “Y” blocks shown in Fig. 1 may be used.

9.3 The test bars shall be cast in open molds made of a suitable core sand with a minimum of 1½ in. (38.1 mm) of sand on all sides and bottom of the ½ and 1-in. (12.7 and 25.4-mm) test bars and 3 in. (76.2 mm) of sand for the 3-in. (76.2-mm) test bar.

9.4 When investment castings are made to this specification, the manufacturer may use test specimens cast to size incorporated in the mold with the castings, or separately cast to size using the same type of mold and the same thermal conditions that are used to produce the castings. These test specimens shall be made to the dimensions shown in Fig. 1 of Specification A 732 or Fig. 4 and Fig. 3 of Test Methods and Definitions A 370.

9.5 It is recommended that test bars be poured immediately after the castings and from the same ladle of metal. Test bars shall be left in the mold until they have cooled to a black appearance. If castings are to be heat treated, test bars shall be included in the same furnace load.

10. Number of Tests

10.1 Test bars shall be poured from each ladle treated with nodularizing agent, unless otherwise specified.

10.2 The number of test bars cast shall be agreed upon by the manufacturer and the purchaser.

10.3 One tension test shall be made from sections cut from the test bars as shown in Fig. 4. If any tension test shows obvious foundry or machining defects, another specimen may be cut from the same test bar or from another test bar representing the same metal. If the retest specimen fails to conform to this specification, the castings they represent shall be rejected.

11. Tension Test Specimens

11.1 The standard round tension test specimen with 2-in. or 50-mm gage length shown in Fig. 5 shall be used, except when the ½-in. (12.7-mm) “Y” block is used or when specimens are cut from castings under ¾-in. (19.0-mm) thickness. In these

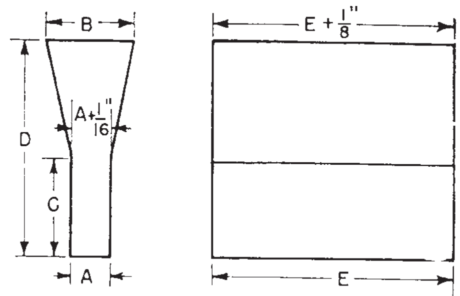
TABLE 1 Chemical Requirements

Element	Type								
	D-2[A]	D-2B	D-2C	D-3[A]	D-3A	D-4	D-5	D-5B	D-5S
	Composition, %								
Total carbon, max	3.00	3.00	2.90	2.60	2.60	2.60	2.40	2.40	2.30
Silicon	1.50–3.00	1.50–3.00	1.00–3.00	1.00–2.80	1.00–2.80	5.00–6.00	1.00–2.80	1.00–2.80	4.90–5.50
Manganese	0.70–1.25	0.70–1.25	1.80–2.40	1.00 max[B]	1.00 max[B]	1.00 max[B]	1.00 max[B]	1.00 max[B]	1.00 max
Phosphorus, max	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08
Nickel	18.00–22.00	18.00–22.00	21.00–24.00	28.00–32.00	28.00–32.00	28.00–32.00	34.00–36.00	34.00–36.00	34.00–37.00
Chromium	1.75–2.75	2.75–4.00	0.50 max[B]	2.50–3.50	1.00–1.50	4.50–5.50	0.10 max	2.00–3.00	1.75–2.25

[A] Additions of 0.7 to 1.0 % of molybdenum will increase the mechanical properties above 800°F (425°C).
[B] Not intentionally added.

TABLE 2 Mechanical Requirements

Element	Type								
	D-2	D-2B	D-2C	D-3	D-3A	D-4	D-5	D-5B	D-5S
	Properties								
Tensile strength, min, ksi (MPa)	58 (400)	58 (400)	58 (400)	55 (379)	55 (379)	60 (414)	55 (379)	55 (379)	65 (449)
Yield strength (0.2 percent offset), min, ksi (MPa)	30 (207)	30 (207)	28 (193)	30 (207)	30 (207)	. . .	30 (207)	30 (207)	30 (207)
Elongation in 2 in. or 50 mm, min, %	8.0	7.0	20.0	6.0	10.0	. . .	20.0	6.0	10
Brinell hardness (3000 kg)	139–202	148–211	121–171	139–202	131–193	202–273	131–185	139–193	131–193



Dimensions	"Y" Block Size					
	For Castings of Thickness Less than ½ in. (13 mm)		For Castings of Thickness ½ in. (13 mm) to 1½ in. (38 mm)		For Castings of Thickness 1½ in. (38 mm) and Over	
	in.	mm	in.	mm	in.	mm
A	½	13	1	25	3	75
B	1⅝	40	2⅛	54	5	125
C	2	50	3	75	4	100
D	4	100	6	150	8	200
E	7	175	7	175	7	175
	approx	approx	approx	approx	approx	approx

FIG. 1 "Y" Blocks for Test Coupons

cases, either of the test specimens shown in Fig. 6 shall be satisfactory.

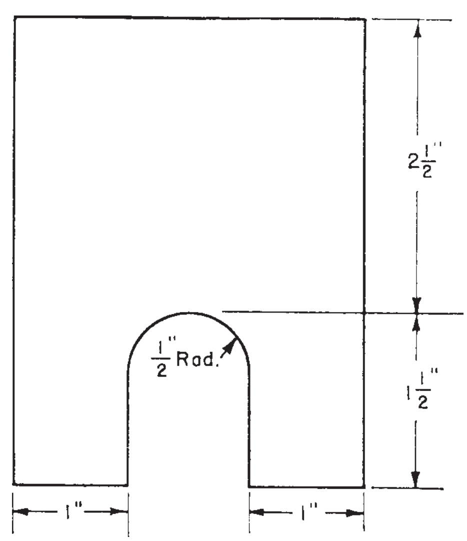
11.2 By agreement between the manufacturer and the purchaser, tension test specimens may be cut directly from centrifugal or other permanent mold castings. The location and orientation of such tension test specimens cut from castings shall be specified as agreed upon by the manufacturer and the purchaser.

12. Additional Tests

12.1 Hydrostatic tests for pressure castings, radiography standards, fracture tests, microstructure standards, or any other special tests may be set up by mutual agreement between the manufacturer and the purchaser.

13. Responsibility for Inspection

13.1 Unless otherwise specified in the contract or purchase order, the manufacturer is responsible for the performance of all inspection requirements as specified herein. Except as otherwise specified in the contract or order, the manufacturer may use his own or any other facilities suitable for the performance of the inspection requirements specified herein, unless disapproved by the purchaser. The purchaser reserves the right to perform any of the inspections set forth in the specification where such inspections are deemed necessary to assure supplies and services conform to prescribed requirements.



Metric Equivalents

in.	½	1	1½	2½
mm	13	25	38	63

NOTE—The length of the keel block shall be 6 in. (150 mm).

FIG. 2 Keel Block for Test Coupons

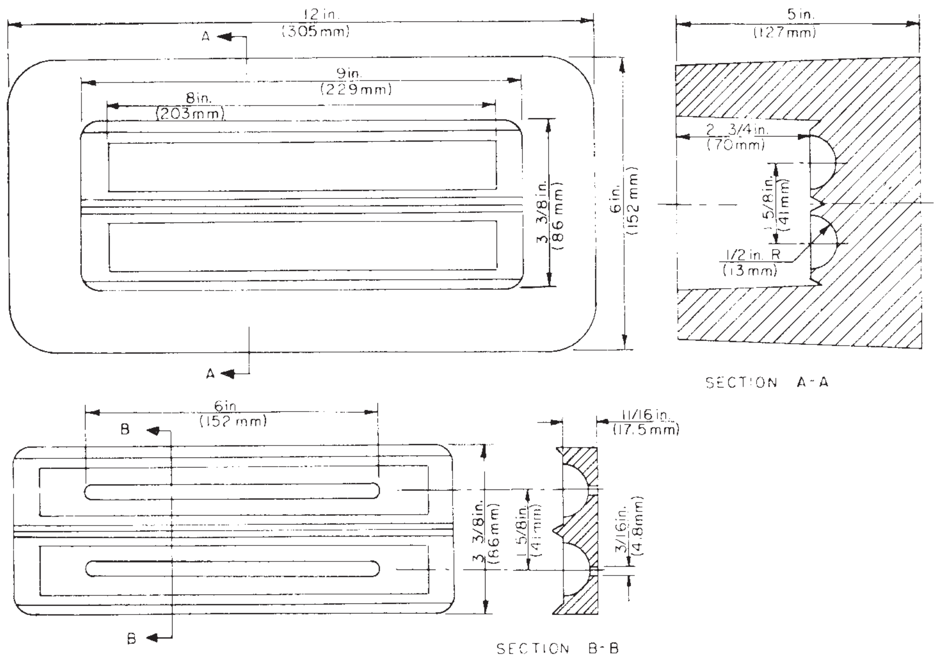


FIG. 3 Mold for Modified Keel Block

14. Certification

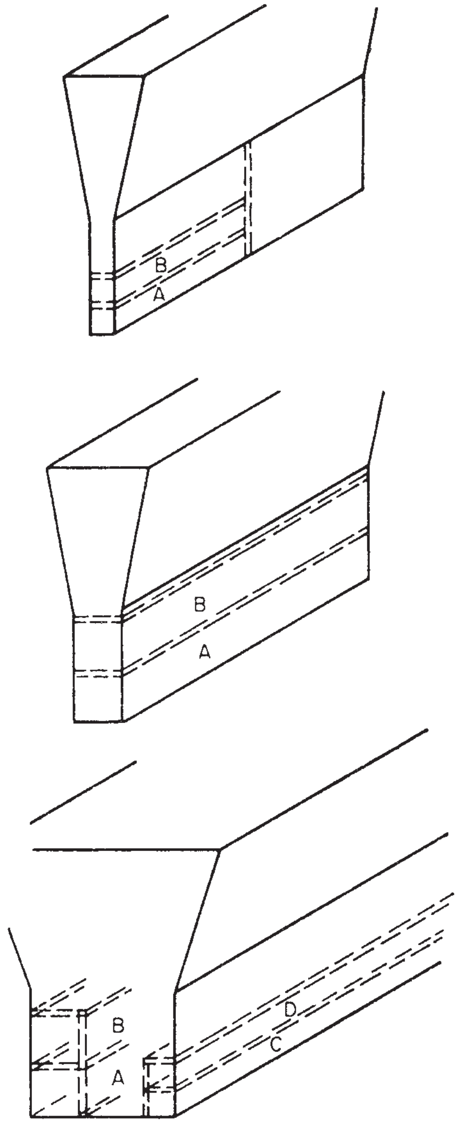
14.1 When agreed upon in writing by the purchaser and the supplier, a certification shall be made the basis of acceptance of the material. This shall consist of a copy of the manufacturer's test report or a statement by the supplier, accompanied by a copy of the test results that the material has been tested and inspected in accordance with the provisions of this specification. Each certification so furnished shall be signed by an authorized agent of the supplier or manufacturer.

15. Packaging and Package Marking

15.1 Unless otherwise specified in the contract or purchase order, preservation and packaging of casting shall be in accordance with the manufacturer's commercial practice. Packing and marking shall also be adequate to ensure acceptance and safe delivery by the carrier for the mode of transportation employed.

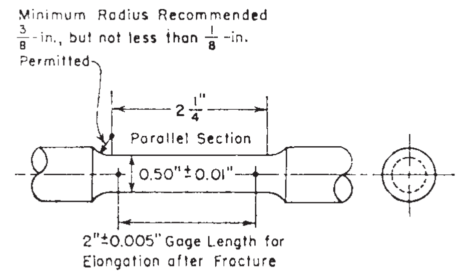
16. Keywords

16.1 austenitic; corrosion resistant; ductile iron; mechanical properties; nodular iron; tensile strength; yield strength



(a) ½-in. (13-mm) "Y" Block—Two blanks for 0.252-in. (6.40-mm) diameter tension test specimens.
(b) 1-in. (25-mm) "Y" Block—Two blanks for 0.50-in. (12.7-mm) diameter tension test specimens.
(c) 3-in. (75-mm) "Y" Block—Two blanks for 0.50-in. (12.7-mm) diameter tension test specimens.

FIG. 4 Sectioning Procedure for "Y'' Blocks

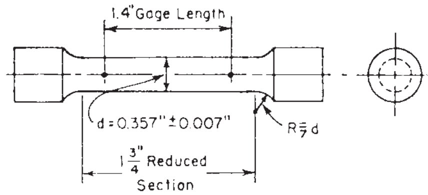


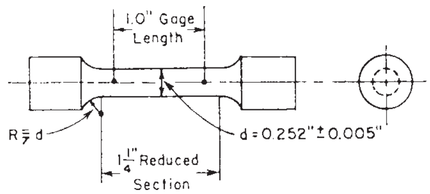
Metric Equivalents

in.	mm	in.	mm
0.005	0.01	0.50	12.7
0.01	0.3	2	50.8
⅛	3.2	2¼	57.2
⅜	9.5		

NOTE—The gage length and fillets shall be as shown but the ends may be of any shape to fit the holders of the testing machine in such a way that the load shall be axial. The reduced section shall have a gradual taper from the ends toward the center, with the ends 0.003 to 0.005 in. (0.08 to 0.13 mm) larger in diameter than the center.

FIG. 5 Standard Round Tension Test Specimen with 2-in. (50.8-mm) Gage Length





Metric Equivalents

in.	mm	in.	mm
0.005	0.13	1.0	25.4
0.007	0.18	1¼	31.8
0.252	6.40	1.4	35.6
0.357	9.07	1¾	44.4

NOTE—If desired, the length of the reduced section may be increased to accommodate an extensometer.

FIG. 6 Examples of Small-Size Specimens Proportional to Standard ½-in. (12.7-mm) Round Specimen

Standard Specification for Steel Castings, Chromium-Nickel-Iron Alloy (25-12 Class), for High-Temperature Service[1]

This standard is issued under the fixed designation A 447/A447M; 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 iron-base, heat-resisting alloy castings of the 25 % chromium, 12 % nickel class, intended for structural elements, containers, and supports in electric furnaces, petroleum still tube supports, and for similar applications up to 2000°F [1095°C]. The purchaser should inform the manufacturer when the service temperatures are to exceed 1800°F [980°C].

1.2 In the absence of significant proportions of elements other than those prescribed in Section 4, the two types of alloys covered by this specification may in general be distinguished as follows:

1.2.1 *Type I*—Alloys characterized by relatively low limiting creep stress at temperatures between 1500 and 2000°F [815 and 1095°C], and relatively high ductility at ordinary temperatures after aging for short periods at temperatures between 1300 and 1500°F [705 and 815°C].

1.2.2 *Type II*—Alloys having relatively high limiting creep stress but which may develop low ductility at ordinary temperatures when aged for short periods at temperatures between 1350 and 1500°F [730 and 815°C].

1.3 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 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 781/A781M Specification for Castings, Steel and Alloy, Common Requirements, for General Industrial Use[2]

A 800/A800M Practice for Steel Castings, Austenitic Alloy, Estimating Ferrite Content Thereof[2]

E 8 Test Methods for Tension Testing of Metallic Materials[3]

E 21 Test Methods for Elevated Temperature Tension Tests of Metallic Materials[3]

3. General Conditions for Delivery

3.1 Material furnished to this specification shall conform to the requirements of Specification A 781/A 781M, including any supplementary requirements that are indicated in the purchase order. Failure to comply with the general requirements of Specification A 781/A 781M constitutes nonconformance with this specification. In case of conflict between the requirements of this specification and Specification A 781/A 781M, this specification shall prevail.

4. Process

4.1 The alloy for the castings shall be made by the electric-furnace process or by any other process approved by the purchaser.

5. Heat Treatment

5.1 Except as otherwise agreed upon between the manufacturer and the purchaser, the manufacturer shall not be required to heat treat the castings.

6. Chemical Composition

6.1 The castings shall conform to the requirements of Table 1 as to chemical composition.

7. Sampling

7.1 Material for the tests specified in Sections 10, 12, and 13 may be taken from separately cast test blocks of a form such as that shown in Fig. 1, from another type of test block, from the castings, or from coupons attached to the castings, as may be agreed upon between the manufacturer and the purchaser.

7.2 Material for the magnetic permeability test specimen (Section 11) may be taken, prior to heat treatment, from the same coupon as the specimen for the tension test after aging;

[1] This specification is under the jurisdiction of ASTM Committee A01 on Steel, Stainless Steel and Related Alloys and is the direct responsibility of Subcommittee A01.18 on Castings.

Current edition approved Oct. 1, 2003. Published October 2003. Originally approved in 1944. Redesignated as A 447 in 1961. Last previous edition approved in 1998 as A 447/A 447M – 93 (1998).

[2] *Annual Book of ASTM Standards*, Vol 01.02.

[3] *Annual Book of ASTM Standards*, Vol 03.01.

TABLE 1 Chemical Requirements

Element	Composition, %
Ni[A]	10.00–14.00
Cr	23.00–28.00
C	0.20–0.45
N, max	0.20
Mn, max	2.50
Si, max	1.75
P, max	0.05
S, max	0.05
Fe and other elements	as may be agreed upon between the manufacturer and the purchaser

[A] Commercial nickel usually carries a small amount of cobalt, and within the usual limits cobalt shall be counted as nickel.

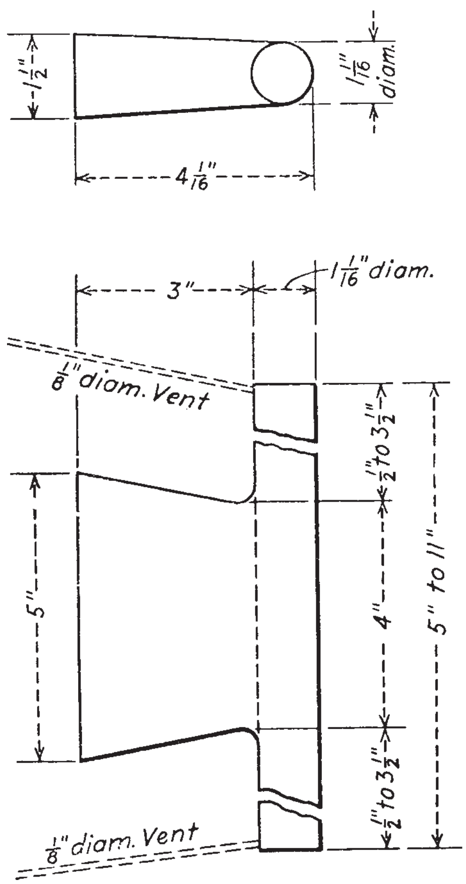


TABLE *Continued*

Metric Equivalents			
in.	[mm]	in.	[mm]
⅛	[3.2]	3½	[88.9]
½	[12.7]	4	[101.6]
1 1/16	[27.0]	4 1/16	[103.2]
1½	[38.1]	5	[127.0]
3	[76.2]	11	[279.4]

NOTE—Pour through head; cover molten head with powdered charcoal, coke dust, etc., immediately after pouring, in order to keep head fluid as long as possible.

FIG. 1 Test Block for Tension Test Specimen

from suitable specimens cast as parts of separately cast test blocks; or, by agreement between the manufacturer and the purchaser, from castings representing the melt.

7.3 In the case of castings for unusual or severe service, the test coupons shall be attached to the castings at convenient locations as may be agreed upon between the manufacturer and the purchaser.

7.4 In all cases, it shall be the manufacturer's duty to provide a sufficient number of samples for the specified tests.

8. Number of Tests

8.1 The purchaser shall specify not more than two tests. The tests shall be selected from the following list, with the restriction that not more than one of the tension tests at high temperature (that is, 8.1.3 or 8.1.4) may be required:

8.1.1 Tension test after aging,

8.1.2 Magnetic permeability test,

8.1.3 Stress-rupture test, and

8.1.4 Short-time high-temperature tension test.

9. Retests

9.1 *Mechanical Tests*—If any of the specimens first chosen for any of the mechanical tests agreed upon fail to conform to the specified requirements, an additional specimen from the same melt may be tested. This additional specimen shall conform to the requirements prescribed for the test in question.

9.2 *Magnetic Test*—If the magnetic permeability of the specimen first tested does not conform to the requirement prescribed in 11.1, three additional specimens from the same melt may be tested. At least two of these shall conform to the prescribed requirement.

10. Tensile Properties After Aging

10.1 The tensile properties of the material after aging shall conform to the following requirements:

	Type I	Type II
Tensile strength, min, ksi [MPa]	80 [550]	80 [550]
Elongation in 2 in. [50 mm], min, %	9	4

10.2 Samples from which the tension specimens are to be taken shall be heated for 24 h at 1400 ± 25°F [760 ± 14°C] and allowed to cool at least down to 400°F [205°C] at rates not exceeding 200°F [110°C]/h. The tension test specimens shall be machined from the heat-treated sample, and shall conform to the dimensions shown in Fig. 1 of Test Methods E 8.

10.3 The tension test shall be made in accordance with Test Methods E 8. The speed of head of the testing machine shall be so adjusted that the rate of separation of the gage marks on the test specimen shall not exceed 0.1 in. [3 mm]/min.

11. Magnetic Permeability

11.1 The magnetic permeability of the material shall conform to the following requirements:

	Magnetic Permeability, max
Type I	1.70
Type II	1.05

NOTE 1—The magnetic permeability test gives a qualitative indication of the ferrite content for alloys falling within the range of chemical composition specified in Section 6, excluding iron and other elements as may be agreed upon. When special alloying elements are specified, the magnetic permeability test is not recommended because its significance

has not yet been established for such alloys.

11.2 The specimen shall be heated in air to 2000 ± 25°F [1095 ± 14°C], held within this range for 24 h, and then quenched in water. After quenching, all scale and superficial oxidized metal shall be removed in order to avoid errors that might arise from the presence of magnetizable oxides formed during heating.

11.3 Unless otherwise agreed upon between the purchaser and the manufacturer, the magnetic permeability shall be determined in accordance with Supplementary Requirement S1 of Practice A 800/A 800M.

NOTE 2—Where the test method used measures volume percent ferrite, conversion to magnetic permeability may be accomplished using the following requirements:

Volume, Ferrite, %, max	Magnetic Permeability, max
1	1.05
8	1.70

12. Stress-Rupture Test

12.1 The following tensile stress shall be sustained for at least 16 h without rupturing the specimen:

	Tensile Stress, ksi [MPa]
Type I	5 [34]
Type II	8 [55]

12.2 The test specimen shall conform to the dimensions shown in Fig. 1 of Test Methods E 8.

12.3 The specimen in the as-cast condition shall be mounted in the testing machine and held for 1 h at 1600 ± 10°F [870 ± 5.5°C]. The specimen shall then be subjected to a steady tensile load while the temperature over the gage length is maintained at 1600 ± 10°F [870 ± 5.5°C] in an air atmosphere.

13. Short-Time, High-Temperature Tensile Properties

13.1 The short-time, high-temperature tensile properties shall conform to the following requirements:

	Tensile Strength, min, ksi [MPa]	Elongation in 2 in. [50 mm], min, %
Type I	as agreed upon between manufacturer and purchaser	as agreed upon between manufacturer and purchaser
Type II	20 [140]	8

13.2 The test specimen shall conform to the dimensions shown in Fig. 1 of Test Methods E 8.

13.3 The specimen in the as-cast condition, that is, without any heat treatment after cooling from the casting temperature, shall be subjected to a short-time tension test during which the temperature shall be maintained at 1600 ± 10°F [870 ± 5.5°C]. The specimen shall be mounted in the testing furnace and held within this range of temperature for 1 h, and the test load then applied.

13.4 The test shall be made in accordance with Practice E 21 except that the speed of head of the testing machine shall be so adjusted that the rate of separation of the gage marks on the test specimen shall not exceed 0.03 in. [0.8 mm]/min.

14. Defective Test Specimens

14.1 If any specimen shows defective machining or develops flaws, it may be discarded and another specimen from the same melt substituted.

14.2 If any part of the fracture in any of the specimens subjected to tension tests is more than ¾ in. [19.0 mm] from the center of the gage length as indicated by gage marks placed on the specimen before testing, another specimen may be substituted.

15. Repair by Welding

15.1 Weld repairs shall be inspected to the same quality standards as are used to inspect the castings.

15.2 When heat treatment is specified, the castings shall be heat treated after welding.

16. Keywords

16.1 ausenitic stainless steel; high temperature applications; stainless steel; steel castings

SUPPLEMENTARY REQUIREMENTS

The following supplementary requirements shall not be applied unless specified in the purchase order. A list of standardized supplementary requirements for use at the option of the purchaser is included in Specification A 781/A 781M. Those which are ordinarily considered suitable for use with the specification are given below. Others enumerated in Specification A 781/A 781M may be used with this specification upon agreement between manufacturer and purchaser.

S5. Examination of Weld Preparation

S8. Marking

S6. Certification

APPENDIX

(Nonmandatory Information)

X1. BIBLIOGRAPHY

X1.1 The following selected bibliography is appended for use by those who may be interested in gaining some information about the complex behavior of metals under stress at elevated temperatures. The bibliography is by no means complete, but will serve as an introduction to the subject.

(1) Brophy, G. R., and Furman, D. E., "The Cyclic Temperature Acceleration of Strain in Heat Resisting Alloys," *Transactions*, TA-SEA, Am. Soc. Metals, Vol 30, No. 4, December 1942, pp. 1115–1138.

(2) Fellows, J. A., Cook, E., and Avery, H. S., "Precision in Creep Testing," *Metals Technology*, METYA, Am. Inst. Mining and Metallurgical Engrs. Technical Publication 1443, Vol 9, No. 5, August 1942, pp. 1–15.

(3) Avery, H. S., Cook, E., and Fellows, J. A., "Engineering Properties of Heat-Resistant Alloys," *Metals Technology* , METYA, Am. Inst. Mining and Metallurgical Engrs. Technical Publication 1480, Vol 9, No. 5, August 1942, pp. 1–22.

(4) ASTM Recommended Practice E 22, for Conducting Long-Time High-Temperature Tension Tests of Metallic Materials, *1958 Book of ASTM Standards*, Part 3.

(5) Gow, J. T., and Harder, O. E., "Balancing the Composition of Cast 25 percent Chromium-12 percent Nickel Type Alloys," *Transactions*, TASEA, Am. Soc. Metals, Vol 30, No. 4, December 1942, pp. 855–935.

(6) Gillett, H. W., "Some Things We Do not Know About Creep," Henry Howe Memorial Lecture presented at a meeting of the Am. Inst. Mining and Metallurgical Engrs., August 1939.

(7) Tapsell, H. J., "Creep of Metals," Humphrey Milford, Oxford University Press, London (1931).

(8) Symposium on Effect of Temperature on the Properties of Metals, Am. Soc. Mech. Engrs. and ASTM (1931). (Symposium issued as a separate publication, *ASTM STP 12*, ASTTA).

(9) Compilation of Available High-Temperature Creep Characteristics of Metals and Alloys, Joint Research Committee on Effect of Temperature on the Properties of Metals (Joint Committee of Am. Soc. Mech. Engrs. and ASTM), March 1938. (*ASTM STP 37*, ASTTA).

(10) Manjoine, M. J., "New Machines for Creep and Creep-Rupture Tests."(Constant strain-rate tests) *Transactions*, TASEA, Am. Soc. Mech. Engrs., February 1945, pp. 111 and 116.

Designation: A 476/A 476M – 00

Standard Specification for Ductile Iron Castings for Paper Mill Dryer Rolls[1,2]

This standard is issued under the fixed designation A 476/A 476M; 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 ductile iron castings for use in pressure containing paper mill dryer rolls at temperatures up to 450°F [230°C].

1.2 No precise quantitative relationship can be stated between the properties of the iron in various locations of the same casting or between the properties of a casting and those of a test specimen cast from the same iron (see Appendix X1).

1.3 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.

2. Referenced Documents

2.1 *ASTM Standards:*

A 644 Terminology Relating to Iron Castings[3]

E 8 Test Methods for Tension Testing of Metallic Materials[4]

E 10 Test Method for Brinell Hardness of Metallic Materials[4]

E 94 Guide for Radiographic Testing[5]

E 446 Reference Radiographs for Steel Castings Up to 2 in. (51 mm) in Thickness[5]

3. Terminology

3.1 Definitions for many terms common to iron castings are found in Terminology A 644.

4. Ordering Information

4.1 Orders for material purchased to the requirements of this specification should include the following information:

4.1.1 Quantity,

4.1.2 Specification number and date of issue,

4.1.3 Description of casting by pattern number or drawing,

4.1.4 Heat treatment, if required (see 5.1),

4.1.5 Type of test coupon (see 9.2),

4.1.6 Certification, if required (see 13.1),

4.1.7 Marking location (see 14.1), and

4.1.8 Additional requirements.

5. Heat Treatment

5.1 The castings may be stress relieved at a temperature not to exceed 1200°F [650°C].

6. Chemical Requirements

6.1 The castings shall conform to the following chemical requirements:

Total carbon, min, %	3.0
Silicon, max, %	3.0
Phosphorus, max, %	0.08
Sulfur, max, %	0.05

6.2 The castings shall have a carbon equivalent of 3.8 to 4.5 inclusive.

NOTE 1—The carbon content equivalent is calculated as follows:

Total carbon + 0.3 (silicon + phosphorus)

6.3 The chemical analysis for total carbon shall be made on either chilled cast pencil-type specimens or on thin wafers approximately $\frac{1}{32}$ in. [0.8 mm] thick, cut from test coupons. Drillings shall not be used due to attendant loss of graphite.

7. Mechanical Properties

7.1 The iron represented by test coupons shall conform to tensile requirements prescribed in Table 1.

7.2 The yield strength prescribed in Table 1 may be determined by any of the approved procedures described in 7.3 of Test Methods E 8.

7.3 The Brinell hardness of the material shall be a minimum of 201 HB. Hardness tests shall be conducted in accordance with Test Method E 10, using a 3000-kgf load. The test may be made on either the casting or on a test coupon representing the casting.

8. Workmanship, Finish, and Appearance

8.1 The castings shall conform to the dimensions on the drawings furnished by the purchaser, or if no drawing has been provided, to the dimensions predicated by the pattern supplied by the purchaser. Surfaces of the castings shall be free of adhering sand. Runners, risers, fins, and other extraneous metal shall be removed.

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[1] This specification is under the jurisdiction of ASTM Committee A04 on Iron Castings and is the direct responsibility of Subcommittee A04.02 on Malleable and Ductile Iron Castings.

Current edition approved Sept. 10, 2000. Published November 2000. Originally published as A 476 – 62 T. Last previous edition A 476 – 95 (1997).

[2] For ASME Boiler and Pressure Vessel Code Applications see related Specifications SA-467 in Section II of that Code.

[3] *Annual Book of ASTM Standards*, Vol 01.02.

[4] *Annual Book of ASTM Standards*, Vol 03.01.

[5] *Annual Book of ASTM Standards*, Vol 03.03.

TABLE 1 Tensile Requirements

Test Coupon Section Thickness	1 in. [25 mm]	3 in. [75 mm]
Tensile strength, min, ksi [MPa]	80 [555]	80 [555]
Yield strength, min, ksi [MPa]	60 [415]	60 [415]
Elongation in 2 in. [50 mm], min, %	3.0 [3.0]	1.0 [1.0]

9. Sampling

9.1 Test coupons shall be poured from the same iron as the castings represented.

9.2 Test coupons shall be cast either to the "Y" block size and shape shown in Fig. 1 or to the dimensions of the 1-in. [25-mm] keel block shown in Fig. 2. The type of test coupon and, when selected, the size of the "Y" block shall be specified by the purchaser.

9.3 The test coupons shall be cast in open molds made of suitable core sand with a minimum 1½in. [38 mm] of sand for the 1-in. [25 mm] size and 3 in. [75 mm] of sand for the 3-in. [75-mm] size. The coupons shall be left in the mold until black.

9.4 Table 2 shows the equivalent geometrical shapes with various dimensions and the equivalent "Y" block, based on cooling rates, and may be used as a guide for selection of the proper "Y" block to be specified to represent the casting.

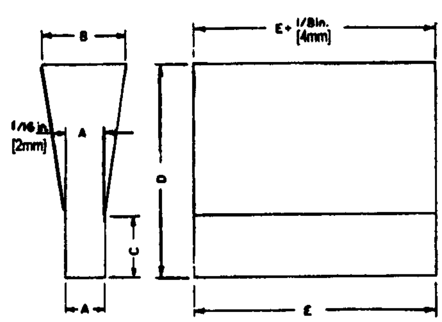
9.5 When the castings are heat treated, the test coupons shall be heat treated with the castings they represent.

10. Tension Test

10.1 Tension test specimens shall be obtained from test coupons shown in either Fig. 1 or Fig. 2, and machined to the dimensions shown in Fig. 3. Test coupons cast as "Y" blocks (Fig. 1) shall be sectioned as shown in Fig. 4.

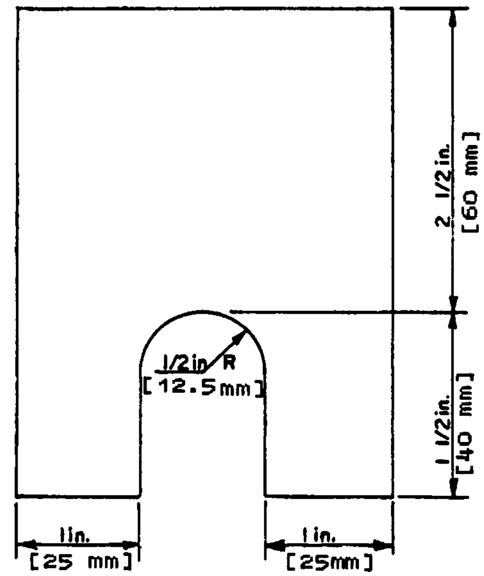
10.2 One tension test shall be performed for each casting.

10.3 If any specimen shows defective machining or flaws, it may be discarded and another substituted from the same casting represented.



Dimensions	"Y" Block Size: For Castings of Thickness ½in. to 1½ in. [12.5-40 mm]	"Y" Block Size: For Castings of Thickness of 1½ in. [40 mm] and Over
	in. [mm]	in. [mm]
A	1 [25]	3 [75]
B	1⅛[55]	5 [125]
C	3 [75]	4 [100]
D	6 [150]	8 [200]
E	7 [175] approx	7 [175] approx

FIG. 1 "Y" Blocks for Test Coupons

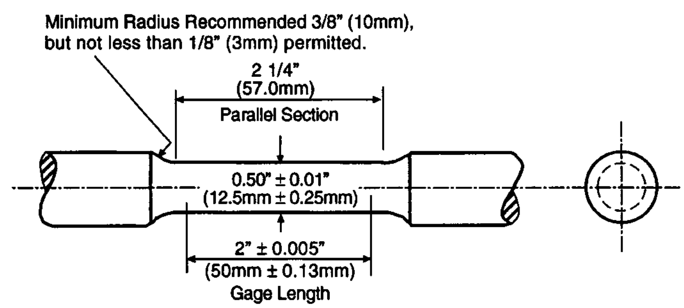


NOTE 1—The length of keel block shall be 6 in. [150 mm].

FIG. 2 Keel Block for Test Coupons

TABLE 2 Equivalent Geometric Shapes Corresponding to "Y" Blocks

"Y" Block Size, in. [mm]	Infinite Plate Thickness, in. [mm]	Round Diameter, in. [mm]	Cube Edge, in. [mm]
1 [25]	0.9 [22.5]	1.75 [44]	2.75 [44]
3 [75]	1.6 [40]	3.1 [78]	4.8 [120]



NOTE 1—The gage length and fillets shall be as shown, but the ends may be of any shape to fit the holders of the testing machine in such a way that the load shall be axial. The reduced section shall have a gradual taper from the ends toward the center, with the ends 0.003 to 0.005 in. [0.08–0.13 mm] larger in diameter than the center.

FIG. 3 Standard Round Tension Test Specimen with 2-in. [50-mm] Gage Length

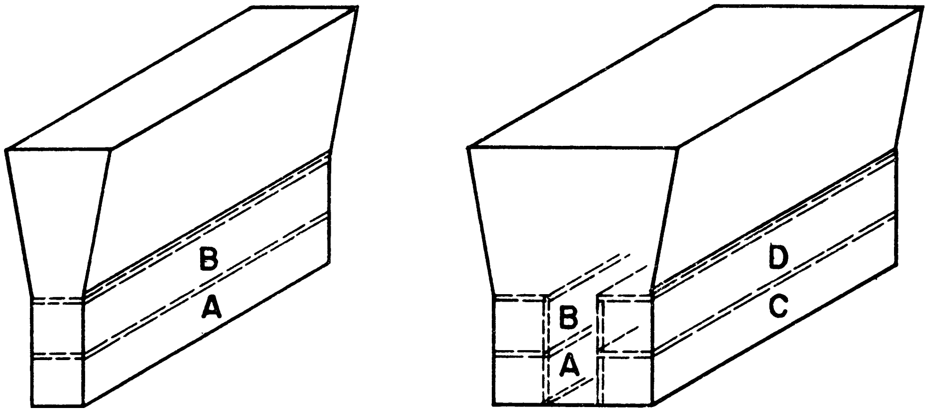
10.4 If an apparently sound test specimen fails to conform to the tensile requirements, two retests may be made. If either retest fails to conform to the requirements specified, the castings shall be rejected.

11. Repairs

11.1 Castings made to this specification that leak on subsequent hydrostatic testing may be repaired by using threaded plugs provided the following requirements are met.

11.1.1 No welding or brazing shall be permitted.

11.1.2 The diameter of the plug shall not exceed the diameter of a standard 2-in. [ISO R2] iron pipe size pipe plug.



(*a*) *1-in. [25-mm] "Y" Block*—Two blanks for 0.50-in. [12.5 mm] diameter tension test specimens.

(*b*) *3-in. [75 mm] "Y" Block*—Four blanks for 0.50-in. [12.5-mm] diameter tension test specimens.

FIG. 4 Sectioning Procedure for "Y" Blocks

11.1.3 The plugs, where practical, shall conform in all dimensions to the standard iron pipe size pipe plugs. In addition, they shall have full thread engagement corresponding to the thickness of the repaired section. Where a tapered plug is impractical because of the excess wall thickness in terms of plug diameter and coincident thread engagement, other types of plugs may be used provided both full thread engagement and effective sealing against pressure are obtained. Where possible the ends of the plugs should be ground smooth after installation to conform to the inside and outside contours of the cylinder.

11.1.4 The material from which the plug is manufactured shall conform in all respects to this specification.

11.1.5 The area adjacent to the drilled hole should be examined radiographically in accordance with Guide E 94. The area examined shall meet the requirements of Severity Level 3 of Reference Radiographs E 446.

11.1.6 The thickness of any repaired section in relation to the size of plug used shall be not less than that given in Table 3.

11.1.7 The minimum radius of curvature of the repaired section of the cylinder in relation to the size of plug used shall be not less than that given in Table 4.

11.1.8 A repaired area may consist of a maximum of three plugs with a spacing such that the distance between adjacent plugs shall not be less than those listed in Table 5. Adjacent areas of repair, in which each contains more than one plug, shall be separated by at least twice the distance required in Table 5 for the two nearest plugs separating the two areas.

11.2 Surface imperfections not exceeding 20 % of the thickness of the section and other minor defects may be repaired by plugging provided the diameter of the plug does not exceed its length.

TABLE 3 Minimum Thickness of Repaired Sections

Iron Pipe Size Plug, in. [ISO Pipe Plug Size]	Minimum Section Thickness, in. [mm]
⅛ [R ⅛]	11/32 [8]
¼ [R ¼]	7/16 [10]
⅜ [R ⅜]	½ [13]
½ [R ½]	21/32 [17]
¾ [R ¾]	¾ [19]
1 [R 1]	13/16 [21]
1¼ [R 1¼]	⅞ [23]
1½ [R 1½]	15/16 [24]
2 [R 2]	1 [26]

TABLE 4 Minimum Radius of Repaired Sections

Iron Pipe Size Plug, in. [ISO Pipe Plug Size]	Minimum Radius of Curvature, in. [mm]
⅛ [R ⅛]	9/16 [15]
¼ [R ¼]	11/16 [18]
⅜ [R ⅜]	1 1/16 [28]
½ [R ½]	1¼ [32]
¾ [R ¾]	2 [52]
1 [R 1]	2½ [64]
1¼ [R 1¼]	4 [104]
1½ [R 1½]	5¼ [136]
2 [R 2]	8⅛ [208]

TABLE 5 Minimum Distance Between Plug Centers (Based on Ligament Efficiency of 80 %)[A]

Adjacent Plug Diameters, in. [ISO Pipe Plug Size]	Minimum Distance Between Plug Centers, in. [mm]			
	⅛ [R ⅛], ¼ [R ¼], ⅜ [R ⅜]	½ [R ½], ¾ [R ¾]	1 [R 1], 1¼ [R 1¼]	1½ [R 1½], 2 [R 2]
⅛ [R ⅛], ¼ [R ¼], ⅜ [R ⅜]	2⅝ [67]	4⅛ [105]	6⅝ [169]	9½[242]
½ [R ½], ¾ [R ¾]	4⅛[105]	4⅛ [105]	6⅝ [169]	9½ [242]
1 [R 1], 1¼ [R 1¼]	6⅝ [169]	6⅝[169]	6⅝ [169]	9½ [242]
1½ [R 1½], 2 [R 2]	9½ [242]	9½ [242]	9½ [242]	9½ [242]

[A] *Example*—Assume three plugs are required for repair, one ⅛ in. [R ⅛], one ⅜in. [R ⅜], and one 1½ in. The minimum distance permitted is as follows.

Ligament distance between ⅛ [R ⅛] and ⅜-in. [R ⅜] plugs = 2⅝ in. [67 mm]
Ligament distance between ⅛ [R ⅛] and 1½-in. [R 1½] plugs = 9½in. [242 mm]
Ligament distance between ⅜ [R ⅜] and 1½-in. [R 1½] plugs = 9½ in. [242 mm]

12. Inspection

12.1 The manufacturer shall afford the purchaser's inspector all reasonable facilities necessary to satisfy that the material is being produced and furnished in accordance with this specification. Foundry 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.

13. Certification

13.1 When specified in the order, the manufacturer's certification shall be furnished stating that the material was manufactured, sampled, tested, and inspected in accordance with the requirements of this specification and was found to meet the requirements. In addition to the certification, a test report shall be furnished showing the results of all tests performed.

14. Product Marking

14.1 Castings made in accordance with this specification shall have the name of the manufacturer or his recognized trade mark and this specification number cast on or indelibly stamped on a surface designated by the purchaser.

APPENDIX

(Nonmandatory Information)

X1. MECHANICAL PROPERTIES OF CASTINGS

X1.1 The mechanical properties of iron castings are influenced by the cooling rate during and after solidification, by chemical composition, by heat treatment, by the design of the casting, by the design and nature of the mold, by the location and effectiveness of gates and risers, and by certain other factors.

X1.2 The cooling rate in the mold and, therefore, the properties developed in any particular section are influenced by the presence of cores, chills and chaplets, changes in section thickness, and the existence of bosses, projections, and intersections, such as junctions of ribs and bosses. Because of the complexity of the interactions of these factors, no precise quantitative relationship can be stated between the properties of the iron in various locations of the same casting or between the properties of a casting and those of a test specimen cast from the same iron. When such a relationship is important and must be known for a specific application, it may be more closely ascertained by appropriate experimentation.

X1.3 When reliable information is unavailable on the relationship between properties in a casting and those in a separately cast test specimen, and where experimentation would be unfeasible, the size of the test casting should be so selected as to approximate the thickness of the main or controlling section of the casting.

Designation: A 481 – 94 (Reapproved 2000)

Standard Specification for Chromium Metal[1]

This standard is issued under the fixed designation A 481; 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. This specification replaces Federal Specification QQ-F-145.

1. Scope

1.1 This specification covers two grades of chromium metal designated as A and B.

1.2 The values stated in inch-pound units are to be regarded as the standard.

2. Referenced Documents

2.1 *ASTM Standards:*

E 11 Specification for Wire-Cloth Sieves for Testing Purposes[2]

E 29 Practice for Using Significant Digits in Test Data to Determine Conformance with Specifications[2]

E 31 Methods for Chemical Analysis of Ferroalloys[3]

E 32 Practices for Sampling Ferroalloys and Steel Additives for Determination of Chemical Composition[3]

E 363 Methods for Chemical Analysis of Chromium and Ferrochromium[4]

3. Ordering Information

3.1 Orders for material under this specification shall include the following information:

3.1.1 Quantity,

3.1.2 Name of material,

3.1.3 ASTM designation and year of issue,

3.1.4 Size, and

3.1.5 Requirements for packaging, analysis reports, etc., as appropriate.

3.2 The customary basis of payments for chromium metal is per pound of alloy.

4. Chemical Composition

4.1 The various grades shall conform to the requirements as to chemical composition specified in Table 1 and Table 2.

TABLE 1 Chemical Requirements[A]

Element	Composition, %	
	Grade A	Grade B
Chromium, min	99.0	99.4
Carbon, max	0.050	0.050
Silicon, max	0.15	0.10
Sulfur, max	0.030	0.010
Phosphorus, max	0.010	0.010

[A]For purposes of determining conformance with this specification, the reported analysis shall be rounded to the nearest unit in the right-hand place of figures used in expressing the limiting value, in accordance with the rounding method of Practice E 29.

4.2 The manufacturer shall furnish an analysis of each shipment showing the elements specified in Table 1.

TABLE 2 Supplementary Chemical Requirements[A]

Element	Composition, %	
	Grade A	Grade B
Nitrogen, max	0.050	0.020
Iron, max	0.35	0.35
Manganese, max	0.01	0.01
Hydrogen, max	0.01	0.003
Oxygen, max	0.50	0.10
Vanadium, max	0.050	0.050
Copper, max	0.01	0.01
Molybdenum, max	0.050	0.01
Columbium, max	0.050	0.050
Tantalum, max	0.050	0.003
Cobalt, max	0.003	0.001
Aluminum, max	0.30	0.10
Titanium, max	0.050	0.003
Zirconism, max	0.050	0.003
Arsenic, max	0.005	0.003
Lead, max	0.003	0.001
Tin, max	0.001	0.001
Zinc, max	0.005	0.003
Boron, max	0.005	0.003
Antimony, max	0.005	0.003
Silver, max	0.003	0.001
Bismuth, max	0.003	0.001

[A] For purposes of determining conformance with this specification, the reported analysis shall be rounded to the nearest unit in the right-hand place of figures used in expressing the limiting value, in accordance with the rounding method of Recommended Practice E 29.

[1] This specification is under the jurisdiction of ASTM Committee A-1 on Steel, Stainless Steel, and Related Alloys and is the direct responsibility of Subcommittee A01.18 on Castings.

Current edition approved Aug. 15, 1994. Published October 1994. Originally published as A 481 – 63 T. Last previous edition A 481 – 73 (1985)ϵ [1].

[2] *Annual Book of ASTM Standards*, Vol 14.02.

[3] *Annual Book of ASTM Standards*, Vol 03.05.

[4] *Annual Book of ASTM Standards*, Vol 03.06.

4.3 The values shown in Table 2 are expected maximums. Upon request of the purchaser, the manufacturer shall furnish an analysis for any of these elements on a cumulative basis over a period mutually agreed upon between the manufacturer and the purchaser.

5. Size

5.1 The various grades are available in sizes as listed in Table 3.

5.2 The sizes listed in Table 3 are typical as shipped from the manufacturer's plant. These alloys exhibit varying degrees of friability; therefore, some attrition may be expected in transit, storage, and handling. A quantitative test is not available for rating relative friability of ferroalloys. A code system has been developed, therefore, for this purpose, and a number rating each product type is shown in the last column of Table 3. Definitions applicable to these code numbers are given in the Appendix.

TABLE 3 Standard Sizes and Tolerances

Product	Grade	Standard Sizes	Tolerances[A]	Friability Rating
Chromium Metal	A	Plate 2 in. by down	10 %, max retained on 2-in. (50-mm) sieve 10 %, max passing U.S. No. 8 (2.36-mm) sieve	2
	A and B	1 in. by down	15 %, max retained on 1-in. (25.0-mm) sieve 15 %, max passing U.S. No. 8 (2.36-mm) sieve	
		¼in. by down	5 %, max retained on ¼-in. (6.3-mm) sieve	
		8 mesh by down	5 %, max retained on U.S. No. 8 (2.36-mm) sieve	
		20 mesh by down	5 %, max retained on U.S. No. 20 (850 µm) sieve	
	B	Pellets 1½ in. by 1 in. by 1 in.	Designated by manufacturer	

[A]Specifications of sieve sizes used to define tolerances herein are as listed in Specification E 11.

6. Sampling

6.1 The material shall be sampled in accordance with Practices E 32.

6.2 Other methods of sampling mutually agreed upon by the manufacturer and the purchaser may be used; however, in case of discrepancy, Practices E 32 shall be used for referee.

7. Chemical Analysis

7.1 The chemical analysis of the material shall be made in accordance with the procedure for the ferroalloys as described in Methods E 31 and Test Methods E 363 or alternative methods that will yield equivalent results.

7.2 If alternative methods of analysis are used, in case of discrepancy, Methods E 31 and Methods E 363 shall be used for referee.

7.3 Where no method is given in Methods E 31 or Test Methods E 363 for the analysis for a particular element, the analysis shall be made in accordance with a procedure agreed upon between the manufacturer and the purchaser.

8. Inspection

8.1 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.

9. Rejection

9.1 Any claims or rejections shall be made to the manufacturer within 45 days from receipt of material by the purchaser.

10. Packaging and Package Marking

10.1 The material shall be packaged in sound containers, or shipped in bulk, in such a manner that none of the product is lost or contaminated in shipment.

APPENDIX

(Nonmandatory Information)

X1. FRIABILITY RATINGS

Code No.	Definition
1	Very tough materials which are susceptible to little, if any, breakage during shipment or handling. (Example: low-carbon ferrochrome)
2	Some breakage of large pieces probable in shipping and handling. No appreciable fines produced from either lump or crushed sizes. (Example: chrome metal)
3	Appreciable reduction in size of large pieces possible in shipping and handling. No appreciable production of fines in handling of crushed sizes. (Example: ferrovanadium)
4	Appreciable reduction in size of large pieces upon repeated handling. Some fines produced upon repeated handling of crushed sizes. (Example: standard ferromanganese)
5	Appreciable reduction in size in repeated handling of large pieces. Appreciable fines may be produced in the handling of crushed sizes. (Example: 50 percent ferrosilicon)

6 This category represents the most friable alloys.
(Example: calcium-silicon)

Designation: A 482 – 93 (Reapproved 2000)

Standard Specification for Ferrochrome-Silicon[1]

This standard is issued under the fixed designation A 482; 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 two grades of ferrochrome-silicon designated A and B.

2. Referenced Documents

2.1 *ASTM Standards:*

E 11 Specification for Wire-Cloth Sieves for Testing Purposes[2]

E 29 Practice for Using Significant Digits in Test Data to Determine Conformance with Specifications[2]

E 31 Methods for Chemical Analysis of Ferroalloys[3]

E 32 Practices for Sampling Ferroalloys and Steel Additives for Determination of Chemical Composition[3]

E 364 Test Methods for Chemical Analysis of Ferrochrome-Silicon[4]

3. Ordering Information

3.1 Orders for material under this specification shall include the following information:

3.1.1 Quantity,

3.1.2 Name of material,

3.1.3 ASTM designation,

3.1.4 Grade,

3.1.5 Size, and

3.1.6 Requirements for packaging, analysis reports, etc., as appropriate.

3.2 The basis of payment for ferrochrome-silicon may be per unit weight of alloy or per pound of contained chrome and silicon.

4. Chemical Composition

4.1 The various grades shall conform to the requirements as to chemical composition specified in Table 1 and Table 2.

4.2 The manufacturer shall furnish an analysis of each shipment showing the elements specified in Table 1.

TABLE 1 Chemical Requirements

Element	Composition, %	
	Grade A	Grade B
Chromium	34.0–38.0	38.0–42.0
Carbon, max	0.060	0.050
Silicon	38.0–42.0	41.0–45.0
Sulfur, max	0.030	0.030
Phosphorus, max	0.030	0.030

4.3 The values shown in Table 2 are expected maximums. Upon request of the purchaser, the manufacturer shall furnish an analysis for any of these elements on a cumulative basis over a period mutually agreed upon between the manufacturer and the purchaser.

5. Size

5.1 The various grades are available in sizes as listed in Table 3.

5.2 The sizes listed in Table 3 are typical as shipped from the manufacturer's plant. These alloys exhibit varying degrees

TABLE 2 Supplementary Chemical Requirements[A]

Element	Composition, max, percent Ferrochrome-Silicon (Grades A and B)
Nitrogen	0.050
Manganese	0.75
Nickel	0.50
Vanadium	0.50
Copper	0.050
Molybdenum	0.050
Columbium	0.050
Tantalum	0.050
Cobalt	0.10
Aluminum	0.50
Titanium	0.50
Zirconium	0.050
Arsenic	0.005
Lead	0.005
Tin	0.005
Zinc	0.005
Boron	0.005
Antimony	0.005
Silver	0.005
Bismuth	0.005

[A]For purposes of determining conformance with this specification, the reported analysis shall be rounded to the nearest unit in the right-hand place of figures used in expressing the limiting value, in accordance with the rounding method of Practice E 29.

[1] This specification is under the jurisdiction of ASTM Committee A-1 on Steel, Stainless Steel, and Related Alloys and is the direct responsibility of Subcommittee A01.18 on Castings.

Current edition approved Dec. 15, 1993. Published April 1994. Originally published as A 482 – 63 T. Last previous edition A 482 – 76 (1983).

[2] *Annual Book of ASTM Standards*, Vol 14.02.

[3] *Annual Book of ASTM Standards*, Vol 03.05.

[4] *Annual Book of ASTM Standards*, Vol 03.06.

TABLE 3 Standard Sizes and Tolerances

Product	Standard Sizes	Tolerances[A]	
Ferrochrome-Silicon	75 lb by down	90 lb lump, max	
	75 lb by 1 in. (25.4 mm)	90 lb lump, max	10% max, passing 1-in. (25.0-mm) sieve
	75 lb by 2 in. (50.8 mm)	90 lb lump, max	10% max, passing 2-in. (50-mm) sieve
	40 lb by down	50 lb lump, max	
	25 lb by down	30 lb lump, max	
	4 in. (101.6 mm) by down	10% max, retained on 4-in. (100-mm) sieve	
	3 in. (76.2 mm) by down	10% max, retained on 3 in. (75-mm) sieve	
	3 by ½ in. (76.2 by 12.7 mm)	10% max, retained on 3-in. (75-mm) sieve	10% max, passing ½in. (12.5 mm) sieve
	2 in. (50.8 mm) by down	10% max, retained on 2-in. (50-mm) sieve	
	2 by ¼ in. (50.8 by 6.35 mm)	10% max, retained on 2-in. (50-mm) sieve	10% max, passing ¼in. (6.3-mm) sieve
	¾ in. (19.05 mm) by down	10% max, retained on ¾ in. (19.0-mm) sieve	

[A]Specifications of sieve sizes used to define tolerances herein are as listed in Specification E 11.

of friability; therefore, some attrition may be expected in transit, storage, and handling. A quantitative test is not available for rating relative friability of ferroalloys. A code system has been developed, therefore, for this purpose, and a number rating each product type is shown in the last column of Table 3. Definitions applicable to these code numbers are given in the Appendix.

6. Sampling

6.1 The material shall be sampled in accordance with Practices E 32.

6.2 Other methods of sampling mutually agreed upon by the manufacturer and by the purchaser may be used; however, in case of discrepancy, Practices E 32 shall be used for referee.

7. Chemical Analysis

7.1 The chemical analysis of the material shall be made in accordance with the procedure for the ferroalloys as described in Methods E 31 and Test Methods E 364, or alternative methods which will yield equivalent results.

7.2 If alternative methods of analysis are used, in case of discrepancy, Methods E 31 and Test Methods E 364 shall be used for reference.

7.3 Wheren no method is given in Methods E 31 or Test Methods E 364 for the analysis of a particular element, the analysis shall be made in accordance with a procedure agreed upon between the manufacturer and the purchaser.

8. Inspection

8.1 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.

9. Rejection

9.1 Any claims or rejections shall be made to the manufacturer within 45 days from receipt of material by the purchaser.

10. Packaging

10.1 The material shall be packaged in sound containers, or shipped in bulk, in such a manner that none of the product is lost or contaminated in shipment.

10.2 Each package shall be identified with product name and other information required by OSHA regulations.

APPENDIX

(Nonmandatory Information)

X1. FRIABILITY RATINGS

Code No.	Definition
1	Very tough materials which are susceptible to little, if any, breakage during shipment or handling. (Example: low-carbon ferrochrome)
2	Some breakage of large pieces probable in shipping and handling. No appreciable fines produced from either lump or crushed sizes. (Example: chrome metal)
3	Appreciable reduction in size of large pieces possible in shipping and handling. No appreciable production of fines in handling of crushed sizes. (Example: ferrovanadium)
4	Appreciable reduction in size of large pieces upon repeated handling. Some fines produced upon repeated handling of crushed sizes. (Example: Standard ferromanganese)
5	Appreciable reduction in size in repeated handling of large pieces. Appreciable fines may be produced in the handling of crushed sizes. (Example: 50 percent ferrosilicon)
6	This category represents the most friable alloys. (Example: calcium-silicon)

Standard Specification for Silicomanganese[1]

1. Scope

1.1 This specification covers three grades of silicomanganese designated A, B, and C.

2. Referenced Documents

2.1 *ASTM Standards:*

E 11 Specification for Wire-Cloth Sieves for Testing Purposes[2]

E 29 Practice for Using Significant Digits in Test Data to Determine Conformance With Specifications[2]

E 31 Methods for Chemical Analysis of Ferroalloys[3]

E 32 Practices for Sampling Ferroalloys and Steel Additives for Determination of Chemical Composition[3]

3. Ordering Information

3.1 Orders for material under this specification shall include the following information:

3.1.1 Quantity,

3.1.2 Name of material,

3.1.3 ASTM designation and year of issue,

3.1.4 Grade,

3.1.5 Size, and

3.1.6 Requirements for packaging, analysis reports, etc. as appropriate.

3.2 The customary basis of payment for silicomanganese is per pound of ferroalloy, rather than per pound of contained manganese or silicon.

4. Chemical Composition

4.1 The various grades shall conform to the requirements as to chemical composition specified in Table 1 and Table 2.

4.2 The manufacturer shall furnish an analysis of each shipment showing the manganese, silicon, and carbon content and, when required, such of the other elements as are specified in Table 1.

4.3 The values shown in Table 2 are expected maximums. Upon request of the purchaser, the manufacturer shall furnish an analysis for these elements on a cumulative basis over a period mutually agreed upon by the manufacturer and the purchaser.

TABLE 1 Chemical Requirements[A]

Element	Composition, %		
	Grade A	Grade B	Grade C
Manganese[B]	65.0–68.0	65.0–68.0	65.0–68.0
Silicon[B]	18.5–21.0	16.0–18.5	12.5–16.0
Carbon, max	1.5	2.0	3.0
Phosphorus, max	0.20	0.20	0.20
Sulfur, max	0.04	0.04	0.04

[A] For purposes of determining conformance with this specification, the reported analysis shall be rounded to the nearest unit in the last right-hand place of figures used in expressing the limiting value, in accordance with the rounding method of Recommended Practice E 29.

[B] For purposes of determining the manganese and silicon content of any shipment, both elements shall be reported to the nearest 0.01 %, applying the same rounding procedure as prescribed in Footnote *A*.

5. Size

5.1 The various grades are available in sizes as listed in Table 3.

5.2 The sizes listed in Table 3 are typical as shipped from the manufacturer's plant. These alloys exhibit varying degrees of friability; therefore, some attrition may be expected in transit, storage, and handling.

6. Sampling

6.1 The material shall be sampled in accordance with Practices E 32.

6.2 Other methods of sampling mutually agreed upon by the manufacturer and the purchaser may be used; however, in case of discrepancy, Practices E 32 shall be used for referee.

TABLE 2 Supplementary Chemical Requirements[A]

	Composition, max, % All Grades
Arsenic	0.10
Tin	0.010
Lead	0.030
Chromium	0.50
Nickel	0.20
Molybdenum	0.10

[A] For purposes of determining conformance with this specification, the re-ported analysis shall be rounded to the nearest unit in the last right-hand place place of figures used in expressing the limiting value, in accordance with the rounding method of Recommended Practice E 29.

[1] This specification is under the jurisdiction of ASTM Committee A-1 on Steel, Stainless Steel, and Related Alloys and is the direct responsibility of Subcommittee A01.18 on Castings.

Current edition approved Dec. 1, 1964. Originally published as 1963. Replaces A 483 – 63 T.

[2] *Annual Book of ASTM Standards*, Vol 14.02.

[3] *Annual Book of ASTM Standards*, Vol 03.05.

TABLE 3 Standard Sizes and Tolerances

Standard Sizes (All Grades)	Tolerances[A]	
8 in. by 4 in.	90 lb lump, max	10 % max passing 4 in. (100 mm) sieve
8 in. by 2 in.	90 lb lump, max	10 % max passing 2 in. (50 mm) sieve
4 in. by 1 in.	10 % max retained on 4 in. (100 mm) sieve	10 % max passing 1 in. (25.0 mm) sieve
2 in. by ¼in.	10 % max retained on 2 in. (50 mm) sieve	10 % max passing ¼in. (6.3 mm) sieve
2 in. by down.	10 % max retained on 2 in. (50 mm) sieve	15 % max passing No. 8 (2.36 mm) sieve

[A]Specifications of sieve sizes used to define tolerances herein are as listed in Specification E 11.

7. Chemical Analysis

7.1 The chemical analysis of the material shall be made in accordance with the procedure for silicomanganese as described in Methods E 31 or alternative methods which will yield equivalent results.

7.2 If alternative methods of analysis are used, in case of discrepancy, Methods E 31 shall be used for referee.

7.3 Where no method is given in Methods E 31 for the analysis of a particular element, the analysis shall be made in accordance with a procedure agreed upon between the manufacturer and the purchaser.

8. Inspection

8.1 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.

9. Rejection

9.1 Any claims or rejections shall be made to the manufacturer within 45 days from receipt of material by the purchaser.

10. Packaging and Package Marking

10.1 Silicomanganese shall be packaged in sound containers, or shipped in bulk, in such manner that none of the product is lost or contaminated in shipment.

Standard Specification for Steel Castings Suitable for Pressure Service[1]

This standard is issued under the fixed designation A 487/A 487M; 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[2] covers low-alloy steels and martensitic stainless steels in the normalized and tempered, or quenched and tempered, condition suitable for pressure-containing parts. The weldability of the classes in this specification varies from readily weldable to weldable only with adequate precautions, and the weldability of each class should be considered prior to assembly by fusion welding.

1.2 Selection will depend on design, mechanical, and service conditions. Users should note that hardenability of some of the grades mentioned may restrict the maximum size at which the required mechanical properties are obtained.

1.3 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 must be used independently of the other. Combining values from the two systems may result in nonconformance with the specification. Inch-pound units are applicable for material ordered to Specification A 487 and SI units for material ordered to Specification A 487M.

2. Referenced Documents

2.1 *ASTM Standards:*

A 370 Test Methods and Definitions for Mechanical Testing of Steel Products[3]

A 488/A 488M Practice for Steel Castings, Welding, Qualifications of Procedures and Personnel[4]

A 703/A 703M Specification for Steel Castings, General Requirements, for Pressure-Containing Parts[4]

E 165 Test Method for Liquid Penetrant Examination[5]

E 709 Guide for Magnetic Particle Examination[5]

2.2 *American Society of Mechanical Engineers:*

ASME Boiler and Pressure Vessel Code, Section IX[6]

2.3 *Manufacturers Standardization Society of the Valve and Fittings Industry Standards:*[7]

SP-55 Quality Standard for Steel Castings-Visual Method

3. General Conditions for Delivery

3.1 Material furnished to this specification shall conform to the requirements of Specification A 703/A 703M including any supplementary requirements that are indicated in the purchase order. Failure to comply with the general requirements of Specification A 703/A 703M constitutes nonconformance with this specification. In case of conflict between the requirements of this specification and Specification A 703/A 703M, this specification shall prevail.

4. Ordering Information

4.1 The inquiry and order should include or indicate the following:

4.1.1 A description of the casting by pattern number or drawing (dimensional tolerances shall be included on the casting drawing),

4.1.2 ASTM designation and year of issue,

4.1.3 Grade and class of steel,

4.1.4 Options in the specification, and

4.1.5 The supplementary requirements desired including the standard of acceptance.

5. Heat Treatment

5.1 All castings shall receive a heat treatment indicated in Table 1. Preliminary heat treatment prior to final heat treatment as well as multiple tempering is permitted.

5.2 Heat treatment shall be performed after the castings have been allowed to cool below the transformation range.

5.3 The furnace temperature for heat treating shall be effectively controlled by use of recording-type pyrometers.

6. Chemical Composition

6.1 The steel shall conform to the requirements as to chemical composition prescribed in Table 2. Product analysis

[1] This specification is under the jurisdiction of ASTM Committee A01 on Steel, Stainless Steel, and Related Alloys and is the direct responsibility of Subcommittee A01.18 on Castings.

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[2] For ASME Boiler and Pressure Vessel Code applications see related Specifications SA-487 in Section II of that code.

[3] *Annual Book of ASTM Standards*, Vol 01.03.

[4] *Annual Book of ASTM Standards*, Vol 01.02.

[5] *Annual Book of ASTM Standards*, Vol 03.03.

[6] Available from American Society of Mechanical Engineers, Three Park Ave., New York, NY 10016.

[7] Available from Manufacturer's Standardization Society of the Valve and Fittings Industry, 127 Park St., N.E. Vienna, VA 22180.

TABLE 1 Heat Treat Requirement

Grade	Class	Austenitizing Temperature, min, °F [°C]	Media[A]	Quenching Cool Below °F [°C]	Tempering Temperature, °F [°C][B]
1	A	1600 [870]	A	450 [230]	1100 [595]
1	B	1600 [870]	L	500 [260]	1100 [595]
1	C	1600 [870]	A or L	500 [260]	1150 [620]
2	A	1600 [870]	A	450 [230]	1100 [595]
2	B	1600 [870]	L	500 [260]	1100 [595]
2	C	1600 [870]	A or L	500 [260]	1150 [620]
4	A	1600 [870]	A or L	500 [260]	1100 [595]
4	B	1600 [870]	L	500 [260]	1100 [595]
4	C	1600 [870]	A or L	500 [260]	1150 [620]
4	D	1600 [870]	L	500 [260]	1150 [620]
4	E	1600 [870]	L	500 [260]	1100 [595]
6	A	1550 [845]	A	500 [260]	1100 [595]
6	B	1550 [845]	L	500 [260]	1100 [595]
7	A	1650 [900]	L	600 [315]	1100 [595]
8	A	1750 [955]	A	500 [260]	1250 [675]
8	B	1750 [955]	L	500 [260]	1250 [675]
8	C	1750 [955]	L	500 [260]	1250 [675]
9	A	1600 [870]	A or L	500 [260]	1100 [595]
9	B	1600 [870]	L	500 [260]	1100 [595]
9	C	1600 [870]	A or L	500 [260]	1150 [620]
9	D	1600 [870]	L	500 [260]	1150 [620]
9	E	1600 [870]	L	500 [260]	1100 [595]
10	A	1550 [845]	A	500 [260]	1100 [595]
10	B	1550 [845]	L	500 [260]	1100 [595]
11	A	1650 [900]	A	600 [315]	1100 [595]
11	B	1650 [900]	L	600 [315]	1100 [595]
12	A	1750 [955]	A	600 [315]	1100 [595]
12	B	1750 [955]	L	400 [205]	1100 [595]
13	A	1550 [845]	A	500 [260]	1100 [595]
13	B	1550 [845]	L	500 [260]	1100 [595]
14	A	1550 [845]	L	500 [260]	1100 [595]
16 (J31200)	A	1600 [870][C]	A	600 [315]	1100 [595]
CA15	A	1750 [955]	A or L	400 [205]	900 [480]
CA15	B	1750 [955]	A or L	400 [205]	1100 [595]
CA15	C	1750 [955]	A or L	400 [205]	1150 [620][DE]
CA15	D	1750 [955]	A or L	400 [205]	1150 [260][DE]
CA15M	A	1750 [955]	A or L	400 [205]	1100 [595]
CA6NM	A	1850 [1010]	A or L	200 [95]	1050–1150 [565–620]
CA6NM	B	1850 [1010]	A or L	200 [95]	1225–1275 [665–690][E,F] 1050–1150 [565–620][G]

[A] A = air, L = Liquid.
[B] Minimum temperature unless range is specified.
[C] Double austenitize.
[D] Double temper with the final temper at a lower temperature than the intermediate temper.
[E] Air cool to below 200°F [95°C] after first temper.
[F] Intermediate.
[G] Final.

tolerance shall conform to the product analysis tolerance shown in Specification A 703/A 703M. Product analysis tolerances for stainless grades are not presently applicable pending development of these limits.

7. Tensile Requirements

7.1 Tensile properties of steel used for the castings shall conform to the requirements prescribed in Table 3.

8. Quality

8.1 The surface of the casting shall be free of adhering sand, scale, cracks, and hot tears as determined by visual examination. Other surface discontinuities shall meet the visual acceptance standards specified in the order. Visual Method SP-55 or other visual standards may be used to define acceptable surface discontinuities and finish. Unacceptable visual surface discontinuities shall be removed and their removal verified by visual examination of the resultant cavities. When methods involving high temperatures are used in the removal and repair of discontinuities, the casting shall be preheated to at least the minimum temperature in Table 4.

8.2 The castings shall not be peened, plugged, or impregnated to stop leaks.

9. Repair By Welding

9.1 For castings, other than those intended for use under ASME Boiler and Pressure Vessel Code, repairs shall be made using procedures and welders qualified under Practice A 488/A 488M.

9.2 On castings intended for use under the ASME Boiler and Pressure Vessel Code, repairs shall be made by procedures and welders qualified under Section IX of that code.

TABLE 2 Chemical Requirements (Maximum Percent Unless Range is Given)

Grade	1.	2.	4.	6.	7.	8.	9.	10.	11.	12.
Class Type	ABC Vanadium	ABC Manganese-Molybdenum	ABCDE Nickel-Chromium-Molybdenum	AB Manganese Nickel-Chromium-Molybdenum	A Nickel-Chromium-Molybdenum-Vanadium[A]	ABC Chromium-Molybdenum	ABCDE Chromium-Molybdenum	AB Nickel-Chromium-Molybdenum	AB Nickel-Chromium-Molybdenum	AB Nickel-Chromium-Molybdenum
Carbon	0.30	0.30	0.30	0.05–0.38	0.05–0.20	0.05–0.20	0.05–0.33	0.30	0.05–0.20	0.05–0.20
Manganese	1.00	1.00–1.40	1.00	1.30–1.70	0.60–1.00	0.50–0.90	0.60–1.00	0.60 to 1.00	0.50–0.80	0.40–0.70
Phosphorus	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04
Sulfur	0.045	0.045	0.045	0.045	0.045	0.045	0.045	0.045	0.045	0.045
Silicon	0.80	0.80	0.80	0.80	0.80	0.80	0.80	0.80	0.60	0.60
Nickel	. . .	. . .	0.40–0.80	0.40–0.80	0.70–1.00	. . .	. . .	1.40–2.00	0.70–1.10	0.60–1.00
Chromium	. . .	. . .	0.40–0.80	0.40–0.80	0.40–0.80	2.00–2.75	0.75–1.10	0.55–0.90	0.50–0.80	0.50–0.90
Molybdenum	. . .	0.10–0.30	0.15–0.30	0.30–0.40	0.40–0.60	0.90–1.10	0.15–0.30	0.20–0.40	0.45–0.65	0.90–1.20
Vanadium	0.04–0.12	. . .	. . .	. . .	0.03–0.10	. . .	. . .	. . .	. . .	. . .
Boron	. . .	. . .	. . .	. . .	0.002–0.006	. . .	. . .	. . .	. . .	. . .
Copper	. . .	. . .	. . .	. . .	0.15–0.50	. . .	. . .	. . .	. . .	. . .
Residual Elements:										
Copper	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50
Nickel	0.50	0.50	. . .	. . .	. . .	. . .	0.50	. . .	. . .	. . .
Chromium	0.35	0.35	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .
Mo + W	0.25	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .
Tungsten	. . .	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10
Vanadium	. . .	0.03	0.03	0.03	. . .	0.03	0.03	0.03	0.03	0.03
Total content of residual elements	1.00	1.00	0.60	0.60	0.60	0.60	1.00	0.60	0.50	0.50

Grade	13.	14.	16	CA15	CA15M	CA6NM
Class Type	AB Nickel-Molybdenum	A Nickel-Molybdenum	A Low Carbon Manganese-Nickel (J31200)	ABCD Martensitic Chromium	A Martensitic Chromium	AB Martensitic Chromium Nickel
Carbon	0.30	0.55	0.12[B]	0.15	0.15	0.06
Manganese	0.80–1.10	0.80–1.10	2.10[B]	1.00	1.00	1.00
Phosphorus	0.04	0.04	0.02	0.040	0.040	0.04
Sulfur	0.045	0.045	0.02	0.040	0.040	0.03
Silicon	0.60	0.60	0.50	1.50	0.65	1.00
Nickel	1.40–1.75	1.40–1.75	1.00–1.40	1.00	1.0	3.5–4.5
Chromium	. . .	. . .	. . .	11.5–14.0	11.5–14.0	11.5–14.0
Molybdenum	0.20–0.30	0.20–0.30	. . .	0.50	0.15–1.0	0.4–1.0
Boron	. . .	. . .	. . .	. . .	. . .	. . .
Copper	. . .	. . .	. . .	. . .	. . .	. . .
Residual Elements						
Copper	0.50	0.50	0.20	0.50	0.50	0.50
Nickel	. . .	. . .	. . .	. . .	. . .	. . .
Chromium	0.40	0.40	0.20	. . .	. . .	. . .
Molybdenum	. . .	. . .	0.10	. . .	. . .	. . .
Tungsten	0.10	0.10	0.10	0.10	0.10	0.10
Vanadium	0.03	0.03	0.02	0.05	0.05	0.05
Total content of residual elements	0.75	0.75	0.50	0.50	0.50	0.50

[A] Proprietary steel composition.
[B] For each reduction of 0.01 % below the specified maximum carbon content, an increase of 0.04 % manganese above the specified maximum will be permitted up to a maximum of 2.30 %.

9.3 After repair welding, all castings shall be postweld heat treated in accordance with Table 4 or reheat treated in accordance with Table 1.

9.4 Weld repairs shall be inspected using the same quality standards as are used to inspect the castings. Re–examination of the weld repair by radiography when Supplementary Requirement S 5 has been specified will not be necessary when an applicable surface inspection method was used to locate the discontinuity except for the following:

9.4.1 Weld repairs on castings which have leaked on hydrostatic test.

9.4.2 Weld repairs on castings in which the depth of any cavity prepared for repair welding is more than 20 % of the wall thickness or 1 in. [25 mm], whichever is smaller.

TABLE 3 Required Mechanical Properties

Previous Designation	Grade	Class	Tensile Strength,[A] min, ksi [MPa]	Yield Strength, min, ksi [MPa], at 0.2 % Offset	Elongation, 2 in. [50 mm] or 4*d*, min, %	Reduction of Area, min %	Hardness max, HRC [HB]	Max Thickness, in. [mm]
1N	1	A	85 [585]–110 [760]	55 [380]	22	40		
1Q		B	90 [620]–115 [795]	65 [450]	22	45		
	1							
	1	C	90 [620]	65 [450]	22	45	22 [235]	
2N	2	A	85 [585]–110 [760]	53 [365]	22	35		
2Q	2	B	90 [620]–115 [795]	65 [450]	22	40		
	2	C	90 [620]	65 [450]	22	40	22 [235]	
4N	4	A	90 [620]–115 [795]	60 [415]	18	40		
4Q	4	B	105 [725]–130 [895]	85 [585]	17	35		
	4	C	90 [620]	60 [415]	18	35	22 [235]	
	4	D	100 [690]	75 [515]	17	35	22 [235]	
4QA	4	E	115 [795]	95 [655]	15	35		
6N	6	A	115 [795]	80 [550]	18	30		
6Q	6	B	120 [825]	95 [655]	12	25		
7Q	7	A	115 [795]	100 [690]	15	30		2.5 [63.5]
8N	8	A	85 [585]–110 [760]	55 [380]	20	35		
8Q	8	B	105 [725]	85 [585]	17	30		
	8	C	100 [690]	75 [515]	17	35	22 [235]	
9N	9	A	90 [620]	60 [415]	18	35		
9Q	9	B	105 [725]	85 [585]	16	35		
	9	C	90 [620]	60 [415]	18	35	22 [235]	
	9	D	100 [690]	75 [515]	17	35	22 [235]	
	9	E	115 [795]	95 [655]	15	35		
10N	10	A	100 [690]	70 [485]	18	35		
10Q	10	B	125 [860]	100 [690]	15	35		
11N	11	A	70 [484]–95 [655]	40 [275]	20	35		
11Q	11	B	105 [725]–130 [895]	85 [585]	17	35		
12N	12	A	70 [485]–95 [655]	40 [275]	20	35		
12Q	12	B	105 [725]–130 [895]	85 [585]	17	35		
13N	13	A	90 [620]–115 [795]	60 [415]	18	35		
13Q	13	B	105 [725]–130 [895]	85 [585]	17	35		
14Q	14	A	120 [825]–145 [1000]	95 [655]	14	30		
16N	16 (J31200)	A	70 [485]–95 [655]	40 [275]	22	35		
CA15A	CA15	A	140 [965]–170 [1170]	110 [760]–130 [895]	10	25		
CA15	CA15	B	90 [620]–115 [795]	65 [450]	18	30		
	CA15	C	90 [620]	60 [415]	18	35	22 [235]	
	CA15	D	100 [690]	75 [515]	17	35	22 [235]	
CA15M	CA15M	A	90 [620]–115 [795]	65 [450]	18	30		
CA6NM	CA6NM	A	110 [760]–135 [930]	80 [550]	15	35		
CA6NM	CA6NM	B	100 [690]	75 [515]	17	35	23 [255][B]	

[A] Minimum ksi, unless range is given.
[B] Test Methods and Definitions A 370, Table 3a does not apply to CA6NM. The conversion given is based on CA6NM test coupons. (For example, see ASTM STP 756.[8])

9.4.3 Weld repairs on castings in which any cavity prepared for welding is greater than approximately 10 in.^{2} [65 cm^2].

10. Product Marking

10.1 Castings shall be marked for material identification with the grade and class symbols (1-A, 4-C, CA15-A).

11. Keywords

11.1 alloy steel; martensitic stainless steel; pressure containing parts; stainless steel; steel castings

TABLE 4 Minimum Pre-Heat and Post Weld Heat Treat Requirements

Grade	Class	Minimum Pre-Heat Temperature, °F [°C]	Post Weld Heat Treat, °F [°C]
1	A, B	200 [95]	1100 [595][A] minimum
1	C	200 [95]	1150 [620][A] minimum
2	A, B	200 [95]	1100 [595][A] minimum
2	C	200 [95]	1150 [620][A] minimum
4	A, B, E	200 [95]	1100 [595][A] minimum
4	C, D	200 [95]	1150 [620][A] minimum
6	A, B	300 [150]	1100 [595][A] minimum
7	A	300 [150]	1100 [595][A] minimum
8	A, B, C	300 [150]	1250 [675][A] minimum
9	A, B, E	300 [150]	1100 [595][A] minimum
9	C, D	300 [150]	1150 [620][A] minimum
10	A, B	300 [150]	1100 [595][A] minimum
11	A, B	300 [150]	1100 [595][A] minimum
12	A, B	300 [150]	1100 [595][A] minimum
13	A, B	400 [205]	1100 [595][A] minimum
14	A	400 [205]	1100 [595][A] minimum
16 (J31200)	A	50 [10]	1100 [595][A] minimum
CA15	A	400 [205]	1750 [955] air cool or liquid quench below 400°F [205°C] temper at 900°F [480°C] minimum
CA15	B	400 [205]	1100 [595][A] minimum
CA15	C, D	400 [205]	1150 [620][A] minimum
CA15M	A	400 [205]	1100 [595][A] minimum
CA6NM	A	50 [10]	Final temper between 1050 [565] and 1150 [620]
CA6NM	B	50 [10]	Intermediate PWHT between 1225 [665] and 1275 [690] Final temper PWHT 1050 [565] and 1150 [620][B]

[A] Post weld heat treat temperature must be at or below the final tempering temperature.
[B] The intermediate and final PWHT temperatures shall be the same as the intermediate and final tempering temperatures, respectively, as the original heat treatment of the castings. Cool to below 200°F [95°C] between the intermediate and final PWHT.

SUPPLEMENTARY REQUIREMENTS

The following supplementary requirements shall not apply unless specified in the purchase order. A list of standardized supplementary requirements for use at the option of the purchaser is included in Specification A 703/A 703M. Those which are ordinarily considered suitable for use with this specification are given below. Others enumerated in Specification A 703/A

S1. Unspecified Elements

S4. Magnetic Particle Inspection

S5. Radiographic Inspection

S8. Charpy Impact Test

S8.1 In addition to the requirements listed in S 8of Specification A 703/A 703M, the following specific requirements apply to this specification:

S8.1.1 When S 8 is specified for Grades 1B, 2B, 4B, 6B, 7A, 8B, 9B, or 10B, impact properties shall be determined by performing a Charpy V-notch impact test at −50°F [−46°C] with a specific minimum average value of 15 ft-lb [20 J] and a specified minimum single value of 10 ft-lb [14 J]. Other temperatures may be used upon agreement between the manufacturer and the purchaser, in which case S 8.1.3 shall apply. Other higher specified minimum average and single values may be used upon agreement between the manufacturer and the purchaser.

S8.1.2 Impact requirements for grades other than 1B, 2B, 4B, 6B, 7A, 8B, 9B, and 10B shall be agreed upon between the manufacturer and the purchaser.

S8.1.3 When an impact test temperature other than −50°F [−46°C] is used for those grades listed in S 8.1.1, the lowest test temperature at which the material meets the impact requirements shall be stamped with low stress stamps immediately ahead of the material symbol on the raised pad (for example, 25 10B for +25°F [−4°C] and 025 10B for −25°F [−32°C]).

S10. Examination of Weld Preparation

S10.1 The method of performing the magnetic particle or liquid penetrant test shall be in accordance with Practice E 709 or Practice E 165.

Designation: A 488/A 488M – 01

An American National Standard

Standard Practice for Steel Castings, Welding, Qualifications of Procedures and Personnel[1]

This standard is issued under the fixed designation A 488/A 488M; 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 practice establishes the qualification of procedures, welders, and operators for the fabrication and repair of steel castings by electric arc welding.

1.1.1 Qualifications of a procedure and either or both the operator or welder under Section IX of the ASME Boiler and Pressure Vessel Code shall automatically qualify the procedure and either or both the operator or welder under this practice. P-number designations in the ASME grouping of base metals for qualification may be different than the category numbers listed in Table 1. Refer to Appendix X1 for a comparison of ASTM category numbers with the corresponding ASME P-Number designations.

1.2 Each manufacturer or contractor is responsible for the welding done by his organization and shall conduct the tests required to qualify his welding procedures, welders, and operators.

1.3 Each manufacturer or contractor shall maintain a record of welding procedure qualification tests (Fig. 1), welder or operator performance qualification tests (Fig. 2), and welding procedure specification (Fig. 3), which shall be made available to the purchaser's representative on request.

1.4 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 must be used independently of the other. Combining values from the two systems may result in nonconformance with this practice.

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 27/A 27M Specification for Steel Castings, Carbon, for General Application[2]

A 148/A 148M Specification for Steel Castings, High Strength, for Structural Purposes[2]

A 216/A 216M Specification for Steel Castings, Carbon, Suitable for Fusion Welding, for High-Temperature Service[2]

A 217/A 217M Specification for Steel Castings, Martensitic Stainless and Alloy, for Pressure-Containing Parts, Suitable for High-Temperature Service[2]

A 351/A 351M Specification for Castings, Austenitic, Austenitic–Ferritic (Duplex), for Pressure–Containing Parts[2]

A 352/A 352M Specification for Steel Castings, Ferritic and Martensitic, for Pressure-Containing Parts, Suitable for Low-Temperature Service[2]

A 356/A 356M Specification for Steel Castings, Carbon, Low Alloy, and Stainless Steel, Heavy-Walled for Steam Turbines[2]

A 370 Test Methods and Definitions for Mechanical Testing of Steel Products[3]

A 389/A 389M Specification for Steel Castings, Alloy, Specially Heat-Treated, for Pressure-Containing Parts, Suitable for High-Temperature Service[2]

A 447/A 447M Specification for Steel Castings, Chromium-Nickel-Iron Alloy (25-12 Class), for High-Temperature Service[2]

A 487/A 487M Specification for Steel Castings Suitable for Pressure Service[2]

A 494/A 494M Specification for Castings, Nickel and Nickel Alloy[2]

A 732/A 732M Specification for Castings, Investment, Carbon and Low Alloy Steel for General Application, and Cobalt Alloy for High Strength at Elevated Temperatures[2]

A 743/A 743M Specification for Castings, Iron-Chromium, Iron-Chromium-Nickel, Corrosion-Resistant, for General Application[2]

A 744/A 744M Specification for Castings, Iron-Chromium-Nickel, Corrosion-Resistant, for Severe Service[2]

A 747/A 747M Specification for Steel Castings, Stainless, Precipitation Hardening[2]

[1] This practice is under the jurisdiction of ASTM Committee A01 on Steel, Stainless Steel and Related Alloys and is the direct responsibility of Subcommittee A01.18 on Castings.

Current edition approved Mar. 10, 2001. Published May 2001. Originally published as A 488 – 63 T. Last previous edition A 488/A 488M – 99.

[2] *Annual Book of ASTM Standards*, Vol 01.02.

[3] *Annual Book of ASTM Standards*, Vol 01.03.

RECOMMENDED FORM FOR MANUFACTURER'S RECORD OF WELDING PROCEDURE QUALIFICATION TESTS

Procedure No. ______ Date: ______ Welding Process: ______
Material Specification: ______ to ______ of category No. ______ to category No. ______
Plate Thickness: ______ Thickness Range Qualified ______
Filler Metal F Group No. ______ Weld Deposit A-Group No.: ______
Flux Designation: ______ Gas Composition: ______
Gas Flow Rate: ______ Backing Strip, if any: ______
Preheat Temperature Range: ______ Single or Multiple Pass: ______
Position of Groove: ______ Filler Wire Diameter: ______
Trade Name: ______ Type of Backing: ______
Forehand or Backhand: ______ Amps: ______ Volts ______ Inches/min: ______
Postheat Temperature ______ Time at Temperature ______

TENSION TEST RESULTS

Specimen No.	Width	Dimensions Thickness	Area	Ultimate Total Load, lb	Ultimate Unit Stress, psi	Nature of Failure and Location

GUIDED BEND TEST RESULTS

Specimen No.	Results	Specimen No.	Results

Welder's Name: ______ Clock No. ______ Stamp. No. ______
Who by virtue of these tests meets the welder performance qualification.
Test Conducted By: ______ Test No. ______
per ______
We certify that the statements in this record are correct and that the test welds were prepared, welded, and tested in accordance with the requirements of ASTM Standard ______
Signed: ______
Manufacturer or Contractor
Date: ______

FIG. 1 Report Form 1

RECOMMENDED FORM FOR MANUFACTURER'S OR CONTRACTOR'S RECORD OF WELDER OR OPERATOR PERFORMANCE QUALIFICATION TESTS

Welder or Operator's Name: Stamp No. ______
Clock No. ______ Welding Process: ______
Position: ______
In accordance with Procedure No. ______
Material Specification: ______ to ______ of category No. ______ to category No. ______
Plate Thickness: ______ Range of Thickness Qualified: ______
Filler Metal Specification No. ______ Group No. F. ______
Filler Metal A-Group No. ______ Filler Metal Diameter ______
Trade Name: ______ Flux Designation or Gas Analysis: ______
Was Backing Strip Used? ______

GUIDED BEND TEST RESULTS

Specimen No.	Results	Specimen No.	Results

Test Conducted By: ______ Laboratory Test No. ______
per ______
We certify that the statements in this record are correct and that the test welds were prepared, welded, and tested in accordance with ASTM Standard ______ .
Signed: ______
Manufacturer or Contractor
Date: ______

FIG. 2 Report Form 2

A 757/A 757M Specification for Steel Castings, Ferritic and Martensitic, for Pressure-Containing and Other Applications, for Low-Temperature Service[2]
A 872/A 872M Specification for Centrifugally Cast

REPORT FORM 3

RECOMMENDED FORM FOR WELDING PROCEDURE SPECIFICATION

1. Title

Welding of[A] ____ steel castings.

[A] Indicate general material description, such as carbon, Cr-Mo, 12 Cr, etc.

2. Specification No. __________ **Rev.** __________
Date ________

3. Scope

3.1 Procedure Specification No. ____ covers the welding of[A] ____ steel castings using the[B] ____ welding process.

[A] Indicate general material description as in Title.
[B] Indicate specific welding process, such as shielded metal arc, gas metal arc, etc.

4. Base Material

4.1 The base material shall conform to the specifications for[A] ____ which is found in materials category number[B] ____.

[A] Insert here reference to ASTM designation or indicate chemical analysis and physical properties.
[B] Indicate category number from Table 1.

4.2 Base material shall be in the[A] ____ heat treated condition before welding.

[A] Indicate heat treatment before welding.

5. Filler Metal

5.1 The filler metal shall conform to ANSI/AWS Specification[A] ____ which is found in weld metal analysis group A ____[B].

[A] Indicate appropriate American Welding Society specification number and filler metal classification (e.g., A5.1 E7018).
[B] Indicate A Number from Table 4.

5.2 Flux for submerged arc welding shall conform to the following nominal composition:[A] ____.

[A] Indicate chemical composition or trade designation.

5.3 Shielding gas for gas shielded arc welding shall conform to the following nominal composition: [A] ____.

[A] Indicate the single gas or proportional parts of mixed gases and flow rates.

6. Preparation of Base Material

6.1 Metal removal shall be performed by[A] ____.

[A] Indicate method of metal removal, such as chipping, grinding, carbon arc cutting, flame cutting etc. Also indicate whether preheat is required during metal removal.

6.2 Configuration of the weld preparation for partial penetration welds shall conform to the following geometry:[A] ____.

[A] Indicate minimum root radius and minimum side wall angle.

6.3 Configuration of the weld preparation for full penetration welds shall conform to the following geometry:[A] ____.

[A] Indicate minimum side wall angle.

6.4 Backing plates shall be used for welding full penetration welds. Backing plates shall be made from[A] ____ steel and shall fit the back of the cavity with a minimum gap of[B] ____.

[A] Indicate material of backing plate.
[B] Indicate dimension of maximum gap.

6.5 Surfaces of the weld preparation shall be cleaned of all oil, grease, dirt, scale, slag, shot blasting grit, or any foreign material which may be harmful to the quality of the weld. Surfaces of backing plates when used shall also meet the same cleanliness requirements.

6.6 All surfaces of the weld preparation shall be inspected as follows:[A] ____.

[A] Indicate type of inspection.

7. Preheat

7.1 Preheat and interpass temperature shall be maintained in the range from[A] ____ to[B] ____ during ____[C].

[A] Indicate minimum temperature.
[B] Indicate maximum temperature.
[C] Indicate if preheat maintenance is during welding or until postweld heat treatment is performed.

7.2 Preheat for tack welding of backing plates is the same as required for welding.

7.3 Minimum temperature before applying heat shall be[A] ____.

[A] Indicate temperature.

7.4 Local preheating to the temperatures indicated may be performed so that the heated area completely surrounds the weld preparation for a minimum distance of[A] ____ in any direction.

[A] Indicate minimum distance for local preheating.

8. Welding Position

8.1 Welds shall be made in the[A] ____ position.

[A] Indicate position or positions in which the welding will be performed. See Fig. 4.

9. Electrical Characteristics

9.1 The current used shall be ____[A]. The base material shall be attached to the ____[B] welding electrode lead.

[A] Indicate whether direct or alternating current. If direct, state whether non-pulsed or pulsed. If pulsed, state frequency.

[B] Indicate whether electrode positive (EP) or electrode negative (EN) output terminal of power supply is used.

Electrode Wire Diameter[A]	Amperage[A]	Range[A]	Voltage[A]
____	____	____	____
____	____	____	____
____	____	____	____

[A] Indicate for each diameter of electrode, the amperage, the range of amperage permitted, and the voltage requirements. For welding processes using wire, indicate wire diameter, wire feed speed, and current requirements.

9.3 Electrodes subject to moisture absorption must be stored and handled to maintain dryness according to the following:[A] ____.

[A] Where applicable, indicate electrode care instructions.

10. Welding Details

10.1 The width of any pass of welding shall not exceed[A] ____ times the size of the filler metal used.

[A] Indicate the number for controlling the maximum width.

10.2 Craters shall be properly filled before each interruption of the arc.

10.3 Slag or flux shall be removed on any bead before depositing the next successive bead.

10.4 Interpass inspection shall be performed according to the following:[A] ____.

[A] Indicate degree of interpass inspection required.

10.5 Peening shall be performed according to the following:[A] ____.

[A] Indicate the degree of peening required. Indicate any limits on peening first and last layers.

11. Post-Weld Heat Treatment

11.1 Post-weld heat treatment shall consist of the following:[A] ____.

[A] Indicate the heating and cooling rates, holding temperatures and times.

12. Inspection

12.1 Inspection of the completed weld shall be performed according to the following:[A] ____.

[A] Indicate degree of inspection.

FIG. 3 Report Form 3

Ferritic/Austenitic Stainless Steel Pipe for Corrosive Environments[4]

A 890/A 890M Specification for Castings, Iron-Chromium-Nickel-Molybdenum Corrosion-Resistant, Duplex (Austenitic/Ferritic) for General Application[2]

A 990/A 990M Specification for Castings, Iron-Nickel-Chromium and Nickel Alloys, Specially Controlled for Pressure Retaining Parts for Corrosive Service[2]

A 995/A 995M Specification for Castings, Austenitic-Ferritic (Duplex) Stainless Steel, for Pressure-Containing Parts[2]

2.2 *American Society of Mechanical Engineers:*

ASME Boiler and Pressure Vessel Code, Section IX[5]

2.3 *American Welding Society:*

ANSI/AWS 3.0 Definitions for Welding and Cutting[6]

[4] *Annual Book of ASTM Standards*, Vol 01.01.

[5] Available from the American Society of Mechanical Engineers, 345 E. 47th St., New York, NY 10017.

[6] Available from the American Welding Society, 550 NW LeJeune Rd., P.O. Box 351040, Miami, FL 33135.

TABLE 1 Categories of Base Materials

Category Number	Material Description	ASTM Specification	Grades
1	Carbon steel (carbon less than 0.35 %, tensile strength less than or equal to 70 ksi [480 MPa]).	A 27/A 27M	all grades
		A 216/A 216M	WCA, WCB
		A 352/A 352M	LCB, LCA
		A 356/A 356M	1
		A 732/A 732M	1A, 2A
		A 757/A 757M	A1Q
2	Carbon steel (tensile strength greater than 70 ksi [480 MPa]). Carbon-manganese steel (tensile strength equal to or greater than 70 ksi but less than 90 ksi [620 MPa]).	A 148/A 148M	80-40
		A 216/A 216M	WCC
		A 352/A 352M	LCC
		A 732/A 732M	2Q, 3A
		A 757/A 757M	A2Q
3	Carbon and carbon-manganese steel (tensile strength equal to or greater than 90 ksi [620 MPa]).	A 732/A 732M	3Q, 4A, 4Q, 5N
4	Low-alloy steel (annealed, normalized, or normalized and tempered. Tensile strength less than 85 ksi [585 MPa]).	A 148/A 148M	80-50
		A 217/A 217M	WC1, WC4, WC5, WC6, WC9
		A 352/A 352M	LC1, LC2, LC3, LC4
		A 356/A 356M	2, 5, 6, 8
		A 389/A 389M	C23, C24
		A 487/A 487M	11A, 12A, 16A
		A 757/A 757M	B2N, B3N, B4N
5	Low-alloy steel (annealed, normalized, or normalized and tempered. Tensile strength equal to or greater than 85 ksi [585 MPa]).	A 148/A 148M	90-60, 105-85
		A 217/A 217M	C5, C12, C12A, WC11
		A 356/A 356M	9, 10, C12
		A 487/A 487M	1A, 1C, 2A, 2C, 4A, 4C, 6A, 8A, 9A, 9C, 10A, 13A
		A 732/A 732M	6N, 15A
		A 757/A 757M	D1N1, D1N2, D1N3, E2N1, E2N2, E2N3
6	Low-alloy steel (quenched and tempered)	A 148/A 148M	90-60, 105-85, 115-95, 130-115, 135-125, 150-135, 160-145, 165-150, 165-150L, 210-180, 210-180L, 260-210, 260-210L
		A 352/A 352M	LC2-1, LC1, LC2, LC3, LC4, LC9
		A 487/A 487M	1B, 1C, 2B, 2C, 4B, 4C, 4D, 4E, 6B, 7A, 8B, 8C, 9A, 9B, 9C, 9D, 9E, 10B, 11B, 12B, 13B, 14A
		A 732/A 732M	7Q, 8Q, 9Q, 10Q, 11Q, 12Q, 13Q, 14Q
		A 757/A 757M	B2Q, B3Q, B4Q, C1Q, D1Q1, D1Q2, D1Q3, E1Q, E2Q1, E2Q2, E2Q3
7	Ferritic stainless steel	A 743/A 743M	CB-30, CC-50
8	Martensitic stainless steel	A 217/A 217M	CA-15
		A 352/A 352M	CA6NM
		A 356/A 356M	CA6NM
		A 487/A 487M	CA15-A, CA15-B, CA15-C, CA15-D, CA15M-A, CA6NM-A, CA6NM-B
		A 743/A 743M	CA-15, CA-15M, CA6NM, CA-40, CA6N, CB6
		A 757/A 757M	E3N

TABLE 1 *Continued*

Category Number	Material Description	ASTM Specification	Grades
9	Low-carbon austenitic stainless steel (carbon equal to or less than 0.03 %)	A 351/A 351M	CF-3, CF-3A, CF-3M, CF-3MA, CF-3MN, CK-3MCUN, CG3M, CN3MN
		A 743/A 743M	CF-3, CF-3M, CF-3MN, CK-3MCUN, CN-3M, CG3M, CN3MN
		A 744/A 744M	CF-3, CF-3M, CK-3MCUN, CG3M , CN3MN
10	Unstabilized austenitic stainless steel (carbon greater than 0.03 %)	A 351/A 351M	CE-8MN, CF-8, CF-8A, CF-8M, CF-10, CF-10M, CG-8M, CH-8, CH-10, CH-20, CG6MMN, CF10S1MNN, CE20N
		A 447/A 447M	Type I
		A 743/A 743M	CF-8, CG-12, CF-20, CF-8M, CF-16F, CF10SMNN, CH-20, CG-8M, CE-30, CG6MMN, CH10, CF16Fa
		A 744/A 744M	CF-8, CF-8M, CG-8M
11	Stabilized austenitic stainless steel	A 351/A 351M	CF-8C, CF-10MC, CK-20, HK-30, HK-40, HT-30, CN-7M, CT-15C
		A 447/A 447M	Type II
		A 743/A 743M	CF-8C, CN-7M, CN-7MS, CK-20
		A 744/A 744M	CF-8C, CN-7M, CN-7MS
12	Duplex (austenitic-ferritic) stainless steel	A 351/A 351M	CD3MWCuN, CD-4MCU
		A 872/A 872M	J93183, J93550
		A 890/A 890M	1A, 1B, 2A, 3A, 4A, 5A, 6A
		A 995/A 995M	1B, 2A, 3A, 4A, 5A, 6A
13	Precipitation-hardened austenitic stainless steel	A 747/A 747M	CB7CU-1, CB7CU-2
14	Nickel-base alloys	A 494/A 494M	CW-12MW, CY-40 Class 1, CY-40 Class 2, CZ-100, M-35-1, M-35-2, M-30C, N-12MV, N-7M, CW-6M, CW-2M, CW-6MC, CX-2MW, CU5MCUC
		A 990/A 990M	CW2M

3. Terminology

3.1 *Definitions*— Definitions of terms relating to welding shall be in agreement with the definitions of the American Welding Society, ANSI/AWS A3.0.

4. Weld Orientation

4.1 *Orientation*— The orientation of welds with respect to horizontal and vertical planes of reference are classified into four positions, namely, flat, horizontal, vertical, and overhead as shown in Fig. 4. Test material shall be oriented as shown in Fig. 4; however, an angular deviation of ±15° from the specified horizontal and vertical planes is permitted during welding.

4.2 *Flat Position* (Fig. 4(*a*))—This position covers plate in a horizontal plane with the weld metal deposited from above, or pipe or a cylindrical casting with its axis horizontal and rolled during welding so that the weld metal is deposited from above.

4.3 *Horizontal Position* (Fig. 4(*b*))—This position covers plate in a vertical plane with the axis of the weld horizontal, or pipe or a cylindrical casting with its axis vertical and the axis of the weld horizontal.

4.4 *Vertical Position* (Fig. 4(*c*))—In this position the plate is in a vertical plane with the axis of the weld vertical.

4.5 *Overhead Position* (Fig. 4(*d*))—In this position the plate is in a horizontal plane with the weld metal deposited from underneath.

4.6 *Horizontal Fixed Position* (Fig. 4(*e*))—In this position the pipe or cylindrical casting has its axis horizontal and the welding groove in a vertical plane. Welding shall be done without rotating the pipe or casting so that the weld metal is deposited from the flat, vertical, and overhead position.

4.7 *Qualification*— Qualification in the horizontal, vertical, or overhead position shall qualify also for the flat position. Qualification in the horizontal fixed position, or in the horizontal and vertical and overhead positions, shall qualify for all positions (Fig. 4(*f*)).

5. Preparation of Test Plate

5.1 Procedure qualification testing shall be performed on cast or wrought material having the same category number as the casting being welded. Test material shall be subjected to the same heat-treatment before and after welding as will be applied to the casting. If the castings are not to be postweld heat-treated, then the test material is not to be postweld heat-treated. Test plate material for performance qualification testing is covered in 12.2.

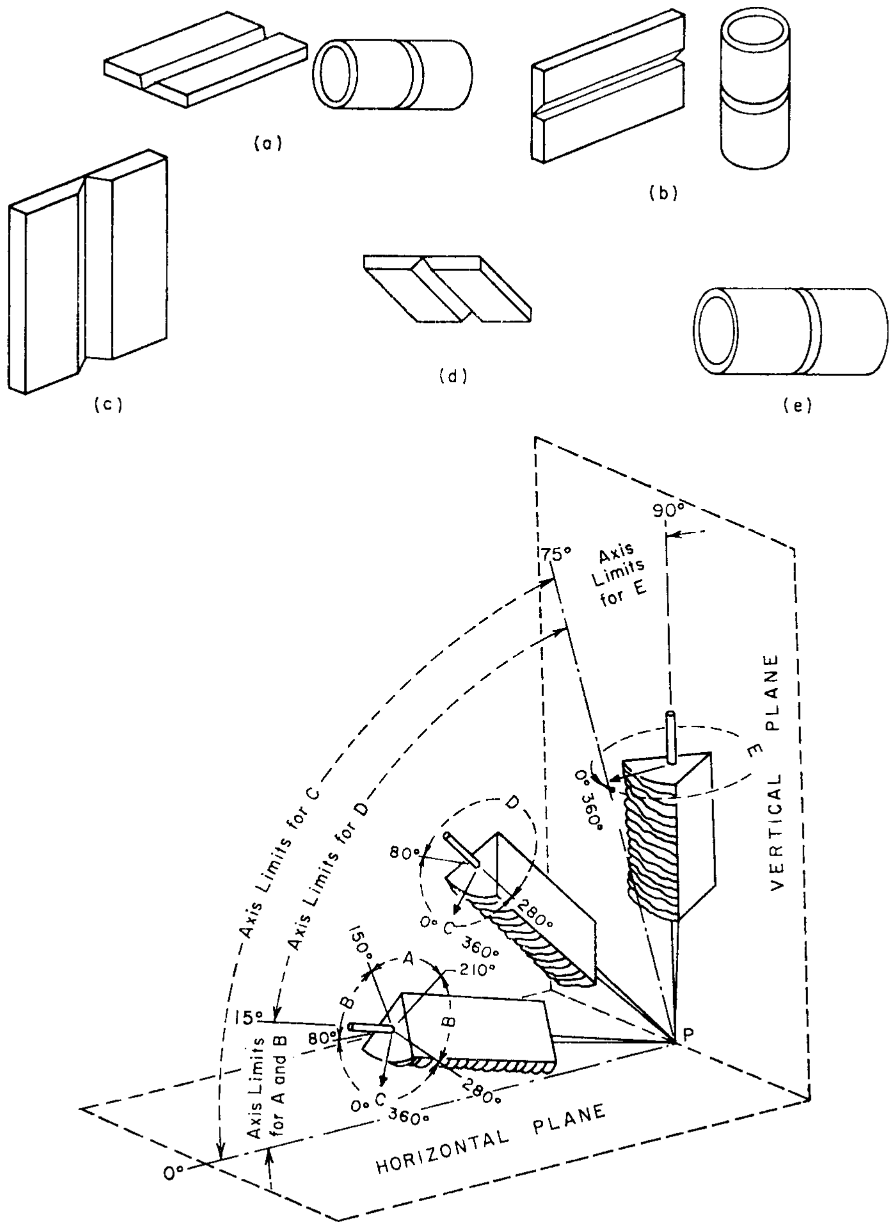
5.2 The dimensions of the test plate shall be such as to provide the required number of test specimens.

5.3 The test joint shall be welded using the type of welding groove proposed in the welding procedure. The dimensions of the welding groove are not essential variables of the welding procedure.

5.4 The thickness of the test plate shall depend on the range of thickness to be qualified as shown in Table 2 and Table 3.

5.5 The joint preparation shown in Fig. 5 shall qualify the supplier for all welding on steel castings.

5.6 Where pipe or a cylindrical casting is used for qualification, it is recommended that a minimum nominal diameter of 5 in. [125 mm] and a minimum thickness of ⅜ in. [10 mm] be used.



Tabulation of Positions of Groove Welds

Position	Diagram Reference	Inclination of Axis, °	Rotation of Face,°
Flat	A	0 to 15	150 to 210
Horizontal	B	0 to 15	80 to 150 210 to 280
Overhead	C	0 to 75	0 to 80 280 to 360
Vertical	D E	15 to 75 75 to 90	80 to 280 0 to 360

NOTE 1—(*a*) Flat Position; (*b*) Horizontal Position; (*c*) Vertical Position; (*d*) Overhead Position; (*e*) Horizontal Fixed Position; (*f*) Positions of Groove Welds

FIG. 4 Orientation of Welds

TABLE 2 Type and Number of Test Specimens and Range of Thicknesses Qualified—(Procedure)

Thickness, *t*, of Test Plate or Pipe as Welded, in. [mm]	Range of Thicknesses Qualified[A]		Type and Number of Tests Required[B]			
	min, in. [mm]	max	Reduced Section Tension	Side Bend	Face Bend	Root Bend
1⁄16 to 3⁄8 [1.6 to 9.5], incl	1⁄16 [1.6]	2*t*[C]	2	. . .	2	2
Over 3⁄8 [9.5], under 3⁄4 [19.0]	3⁄16 [4.8]	2*t*	2	. . .	2	2
3⁄4 [19.0] to under 1½ [38.1]	3⁄16 [4.8]	2*t*	2	4	. . .	. . .
1½ [38.1] and over	3⁄16 [4.8]	8 [203]	2	4	. . .	. . .

[A] For repair welding, the minimum thickness requirements do not apply.
[B] Either the face- and root-bend tests or the side-bend tests may be used for thicknesses from 3⁄8 to 3⁄4 in. [9.5 to 19.0 mm].
[C] The maximum thickness qualified with pipe smaller than 5 in. [127 mm] is two times the thickness of the pipe but not more than 3⁄4 in. [19.0 mm].

TABLE 3 Type and Number of Test Specimens and Thickness Limits Qualified—(Performance)

Thickness, *t*, of Test Plate or Pipe as Welded, in. [mm]	Thickness Qualified	Type and Number of Tests Required[A]		
		Side Bend	Face Bend	Root Bend
Up to 3⁄8 [9.5], incl	2*t*	. . .	1	1
Over 3⁄8 [9.5], under 3⁄4 [19.0][B]	2*t*	. . .	1	1
Over 3⁄8 [9.5], under 3⁄4 [19.0][B]	2*t*	2	. . .	. . .
3⁄4 [19.0], and over	max to be welded	2	. . .	. . .

[A] A total of four specimens are required to qualify for Position 1(e) of Fig. 4. Refer to Fig. 17 and Fig. 18.
[B] Either the face- and root-bend tests or the side-bend tests may be used for thicknesses from 3⁄8 to 3⁄4 in. [9.5 to 19.0 mm].

FIG. 5 Joint Preparation

6. Types of Tests

6.1 Four types of tests are used in the qualification procedure as follows:

6.1.1 *Tension Test*— Tests in direct tension are used in the procedure qualification to measure the strength of groove-weld joints.

6.1.2 *Bend Test*—Guided bend tests are used in the procedure and performance qualification tests to check the degree of soundness and ductility of groove-weld joints.

6.1.3 *Charpy Impact Test*—Charpy V-notch impact test specimens are used in the procedure qualification to determine the impact strength of weld metal deposited in groove-type joints.

6.1.4 *Radiographic Test*—Radiographic examination in accordance with 12.6 of a length of weld may be used to prove the ability of operators and welders to make sound welds.

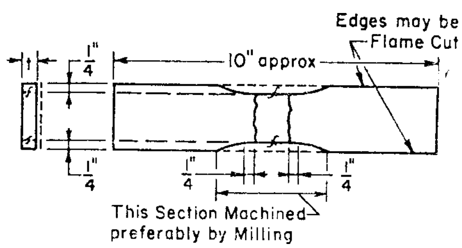
7. Tension Test

7.1 *Specimens*—Tension tests shall conform to the requirements of 7.1.1 or 7.1.2.

7.1.1 All thicknesses of plate may be tested using reduced-section specimens conforming to the requirements of Fig. 6. All thicknesses of pipe or cylindrical castings having an outside diameter greater than 3 in. [75 mm] may be tested using reduced-section specimens conforming to the requirements of Fig. 7.

7.1.1.1 A single specimen of full-plate or full-pipe thickness shall be used for thicknesses up to and including 1 in. [25 mm].

7.1.1.2 For plate or pipe thicknesses greater than 1 in. [25 mm], single or multiple specimens may be used.



Metric Equivalents

in.	1⁄4	10
[mm]	[6]	[255]

FIG. 6 Reduced-Section Tension Specimen for Plate

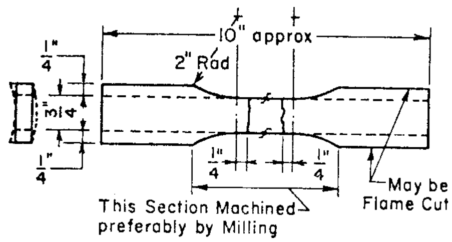
7.1.1.3 When multiple specimens are used, each set shall represent a single required tension test. Collectively, all of the specimens required to represent the full thickness of the weld at one location shall comprise a set.

7.1.1.4 When multiple specimens are necessary, the entire thickness shall be mechanically cut into a minimum number of approximately equal strips of a size that can be tested in the available equipment. Each specimen shall be tested and meet the requirements of 7.1.4.

7.1.2 Turned specimens conforming to the requirements of Fig. 8 may be used for tension tests.

7.1.2.1 For thicknesses up to and including 1 in. [25 mm], a single turned specimen may be used, which shall be a specimen of the largest diameter possible for the test coupon thickness.

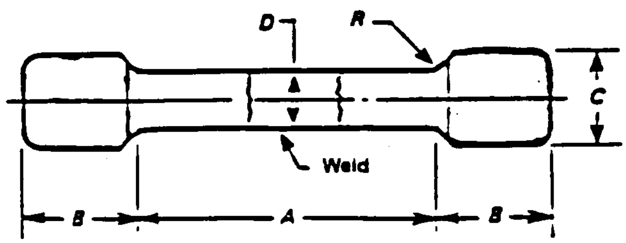
7.1.2.2 For thicknesses greater than 1 in. [25 mm], multiple



Metric Equivalents				
in.	¼	¾	2	10
[mm]	[6]	[20]	[50]	[255]

FIG. 7 Reduced-Section Tension Specimen for Pipe

NOTE 1—Reduced section *A* should not be less than width of weld plus 20.



	Standard Dimensions, in.			
	(a) 0.505 Specimen[A]	(b) 0.353 Specimen[B]	(c) 0.252 Specimen[C]	(d) 0.188 Specimen[D]
A—Length of reduced section	[Note]	[Note]	[Note]	[Note]
D—Diameter	0.500 ± 0.010	0.350 ± 0.007	0.250 ± 0.005	0.188 ± 0.003
R—Radius of fillet	⅜, min	¼, min	3⁄16, min	⅛, min
B—Length of end section	1⅜, approx.	1⅛, approx.	⅞, approx.	½, approx.
C—Diameter of endsection	¾	½	⅜	¼

[A] Use maximum diameter specimen (a), (b), (c), or (d) that can be cut from the section.
[B] Weld should be in center of reduced section.
[C] Where only a single coupon is required the center of the specimen should be midway between the surfaces.
[D] The ends may be threaded or shaped to fit the holders of the testing machine in such a way that the load is applied axially.

FIG. 8 Alternate Reduced-Section Tension Specimen

specimens shall be cut through the full thickness of the weld with their centers parallel to the metal surface and not over 1 in. [25 mm] apart. The centers of the specimens adjacent to the metal surfaces shall not exceed ⅝ in. [16 mm] from the surface.

7.1.2.3 When multiple specimens are used, each set shall represent a single required tension test. Collectively, all of the specimens required to represent the full thickness of the weld at one location shall comprise a set. Each specimen shall be tested and meet the requirements of 7.1.4.

7.1.3 The weld shall be in the center of the reduced section.

7.1.4 In order to meet the requirements of the tension test, specimens shall have a tensile strength not less than the specified tensile strength of the base material. If the specimen breaks in the base metal outside of the weld or fusion line, the test shall be accepted as meeting the requirements, provided the strength is not more than 5 % below the specified minimum tensile strength of the base metal.

7.2 *Tension Test*— Tension tests shall be conducted in accordance with Test Methods and Definitions A 370.

8. Guided Bend Test

8.1 *Specimens*—Guided bend test specimens shall be prepared by cutting the test plate or pipe to form specimens of approximately rectangular cross section. The cut surfaces shall be designated the sides of the specimen. The other two surfaces shall be called the face and root surfaces, the face surface having the greater width of weld. Guided bend test specimens are of three types depending on which surface (side, face, or root) is on the convex (outer) side of the bent specimen. (Fig. 9 and Fig. 10.)

8.1.1 *Side Bend*—The weld is transverse to the longitudinal axis of the specimen which is bent so that one of the side surfaces becomes the convex surface of the bent specimen.

8.1.2 *Face Bend*—The weld is transverse to the longitudinal axis of the specimen which is bent so that the face surface becomes the convex side of the bent specimen.

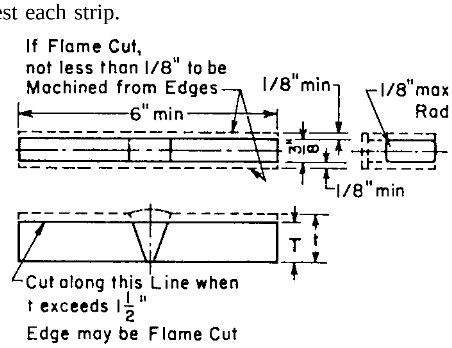
8.1.3 *Root Bend*—The weld is transverse to the longitudinal axis of the specimen which is bent so that the root surface becomes the convex side of the bent specimen.

8.2 *Guided Bend Tests*—Table 2 and Table 3 give the number and type of guided bend specimens that are to be used in the procedure and performance qualification tests.

8.2.1 Specimens of base metal thicknesses over 1.5 in. [38 mm] may be cut into approximately equal strips between ¾ in. [19 mm] and 1.5 in. [38 mm] wide for testing, or the specimens may be bent at full width. If multiple specimens are used, one complete set shall be made for each required test. Each specimen shall be tested and meet the requirements of 8.2.3.

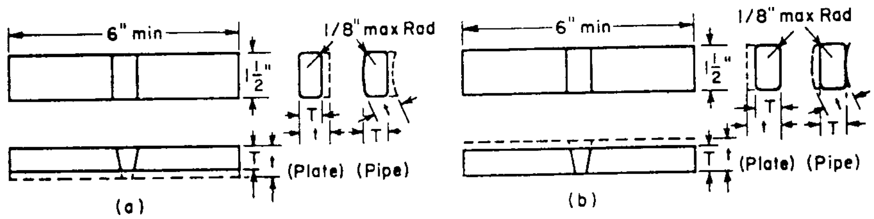
8.2.2 Guided bend specimens shall be bent in jigs that are in substantial accordance with Fig. 11, Fig. 12, and Fig. 13. The side of the specimen turned toward the gap of the jig shall be the face for face-bend specimens, the root for root-bend specimens, and the side with the greater number of defects, if any, for side-bend specimens. The specimen shall be forced into the die by applying load on the plunger until the curvature

NOTE 1—For plates over 1½ in. [38.1 mm] thick, cut specimen into approximately equal strips between ¾ in. [20 mm] and 1½ in. [40 mm] wide and test each strip.



Metric Equivalents				
in.	⅛	⅜	1½	6
[mm]	[3]	[10]	[40]	[155]

FIG. 9 Side-Bend Specimen



Metric Equivalents

in.	⅛	1½	6
[mm]	[3]	[40]	[155]

(*a*) Transverse Face-Bend Specimen—Plate and Pipe

t, in. [mm]	*T*, in. [mm] (all Ferrous Materials)
1⁄16 to ⅛ [1.6 to 3.2]	*t*
⅛ to ⅜ [3.2 to 9.5]	*t*
> ⅜ [9.5]	⅜[9.5]

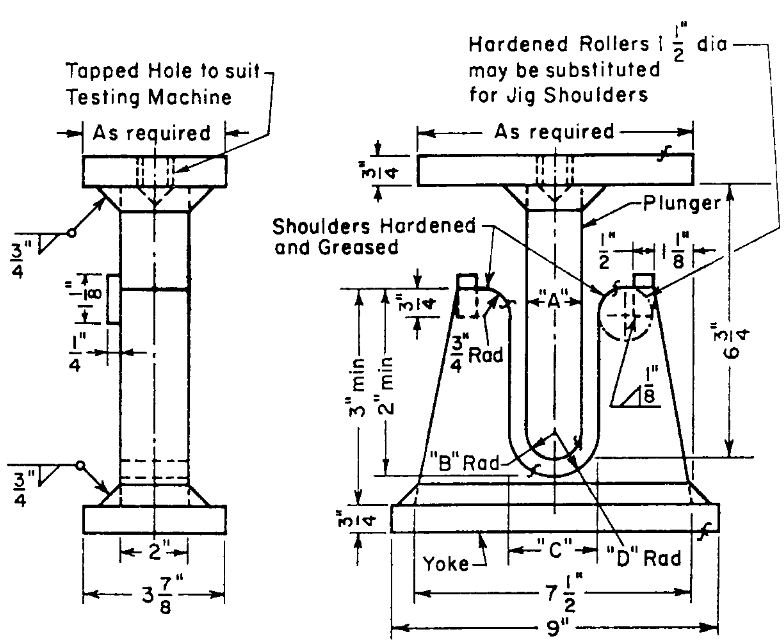
Metric Equivalents

in.	⅛	1½	6
[mm]	[3]	[40]	[155]

(*b*) Transverse Root-Bend Specimen—Plate and Pipe

Note—Weld reinforcement and backing strip or backing ring, if any, shall be removed flush with the surface of the specimen. If a recessed ring is used, this surface of the specimen may be machined to a depth not exceeding the depth of the recess to remove the ring, except that in such cases the thickness of the finished specimen shall be that specified above.

FIG. 10 Transverse Face- and Root-Bend Specimens, for Pipe and Plate



Metric Equivalents

in.	⅛	¼	½	¾	1⅛	1½	2	3	3⅞	6¾	7½	9
[mm]	[3]	[5]	[15]	[20]	[30]	[40]	[50]	[75]	[100]	[170]	[190]	[230]

Specimen Thickness, in. [mm]	*A*, in. [mm]	*B*, in. [mm]	*C*, in. [mm]	*D*, in. [mm]
⅜ [9.5]	1½ [38.1]	¾ [19.0]	2⅜ [60.3]	1 3⁄16 [30.2]
t	4*t*	2*t*	6*t* + ⅛ [3.2]	3*t* + 1⁄16 [1.6]

FIG. 11 Guided-Bend Test Jig

of the specimen is such that a ⅛-in. [3.2-mm] diameter wire cannot be inserted between the die and the specimen, or so that the specimen is bottom ejected if the alternate roller type jig is used. When using the wrap-around jig (Fig. 13), the side of the specimen turned toward the roller shall be the face for face-bend specimens, the root for root-bend specimens, and the side with the greater defects, if any, for side-bend specimens. When specimens wider than 1.5 in. [38.1 mm] are to be bent, the test jig mandrel must be at least 0.25 in. [6.4 mm] wider than the specimen width.

8.2.3 In order to meet the requirements of this test, the guided bend specimens shall have no cracks or other open defects exceeding ⅛ in. [3.2 mm] measured in any direction on the convex surface of the specimen after bending. However, cracks occurring on the corners of the specimen during testing shall not be considered unless there is definite evidence that

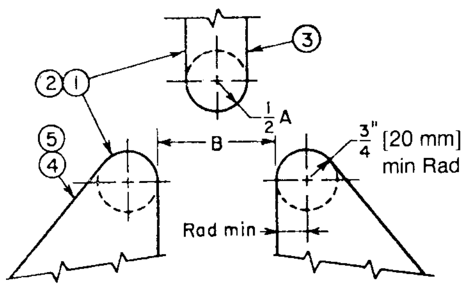


FIG. 12 Alternative Roller-Equipped Guided-Bend Test Jig

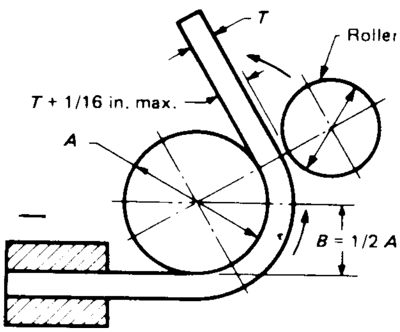


FIG. 13 Guided Bend Wrap-Around Jig

they result from slag inclusions or other internal defects.

8.2.4 Where the ductility of the parent metal is such as to render it incapable of meeting the bend test requirements of 8.2.2 and 8.2.3, the bend test shall be conducted in the following manner: A bend bar comprised of parent metal heat treated to the ductility and strength requirements of the applicable specification shall be bent to failure. The side-bend specimen shall then be capable of being bent to within 5° of the angle thus determined.

9. Charpy Impact Test

9.1 *Application*— Charpy V-notch impact tests of the weld metal and heat-affected zone shall be made when such tests are required for the parent metal by the material specification, or specified by the purchaser, and shall apply to the qualification of the welding procedure for fabrication and repair. When postweld heat treatment consists of a full reheat treatment of the welded part, thus eliminating the HAZ, impact testing of the HAZ shall not be required.

9.2 *Test Methods*— Test methods for Charpy V-notch impact tests shall be in accordance with Test Methods and Definitions A 370 and conducted at the same temperature as required for the parent metal.

9.2.1 *Test Specimens*— Each set of three weld metal impact specimens shall be taken across the weld with the notch in the weld metal. Each specimen shall be oriented so that the notch is normal to the surface of the material and one face of the specimen shall be within 1⁄16 in. [1.6 mm] of the surface of the metal. Heat-affected zone coupons for impact specimens shall be taken transverse to the weld and etched to define the heat-affected zone. The notch shall be cut normal to the material surface in the heat-affected zone to include as much heat-affected zone as possible in the resulting fracture (Fig. 14(*a*)). Where the material thickness permits, the axis of a heat-affected zone specimen may be inclined to allow the root of the notch to align parallel to the fusion line (Fig. 14(*b*)).

9.2.2 *Acceptance Criteria*—Acceptance criteria for the weld metal and heat-affected zone shall be the same as that required by the material specification for the parent metal.

10. Procedure Qualification

10.1 Each manufacturer or contractor shall record in detail the welding procedure used in qualifying under this practice. A suggested form (Fig. 1) is included with this practice.

10.2 The number of tests required to qualify a procedure for various thickness ranges shall be as shown in Table 2.

10.3 Test specimens shall be removed from the plate or pipe or cylindrical casting as shown in Fig. 15, Fig. 16, Fig. 17, and Fig. 18.

10.4 In order to qualify, test specimens shall meet the

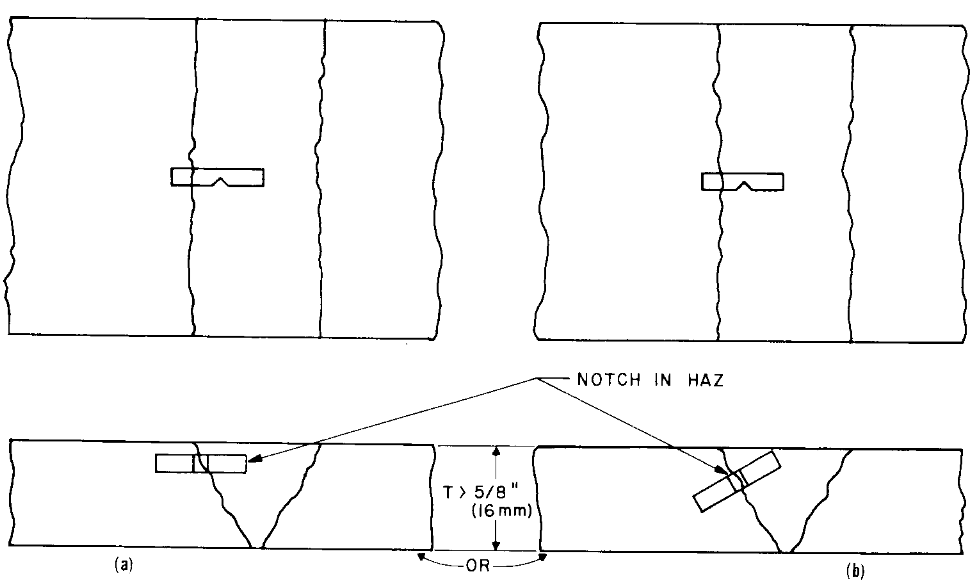


FIG. 14 Location of Notch in Charpy Specimens Shall Be In HAZ Midway Between Center and Surface

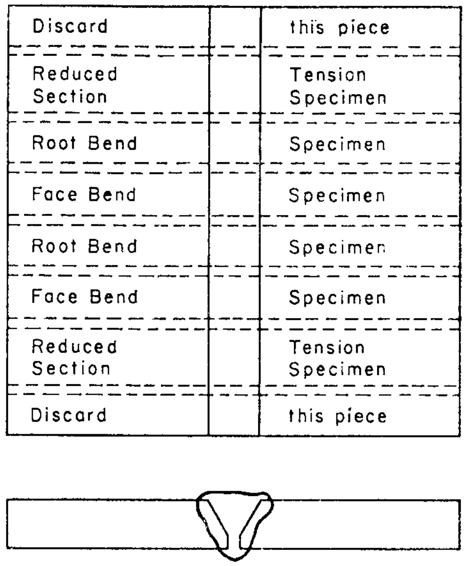


FIG. 15 Order of Removal of Test Specimens from Test Plate 1⁄16 to 3⁄4 in. [1.6 to 19.0 mm] Thick

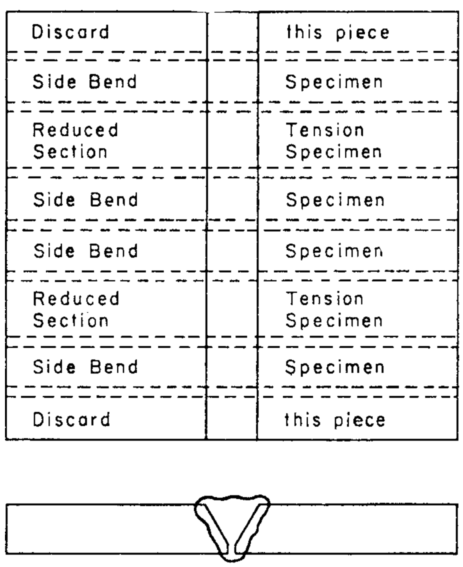


FIG. 16 Order of Removal of Test Specimens from Welded Test Plates over 3⁄4 in. [19.0 mm] Thick (May be Used for Thicknesses 3⁄8 to 3⁄4 in. [9.5 to 19.0 mm])

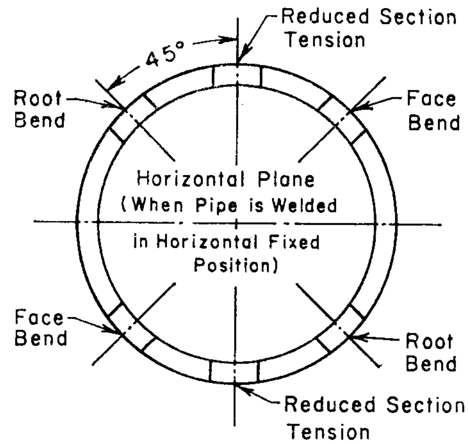


FIG. 17 Order of Removal of Test Specimens from Welded Pipe or Cylindrical Castings 1⁄16 to 3⁄4 in. [1.6 to 19.0 mm] Thick

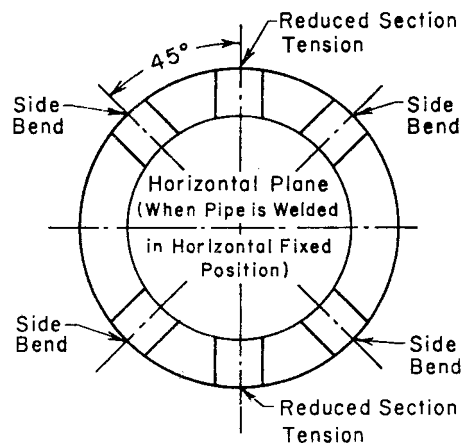


FIG. 18 Order of Removal of Test Specimens from Welded Pipe or Cylindrical Castings over 3⁄4 in. [19.0 mm] Thick (May be Used for Thicknesses 3⁄8 to 1⁄4 in. [9.5 to 19.0 mm])

requirements of 7.1.4, 8.2.3, or 8.2.4.

11. Requalification of a Procedure

11.1 A welding procedure must be set up as a new procedure and must be requalified when any of the changes in essential variables listed in 11.1.1 to 11.1.12, inclusive, are made. Changes other than those listed may be made without requalification, provided the procedure is revised to show these changes.

11.1.1 A change from a base material listed under one category number in Table 1 to a material listed under another category number. When two base materials having different category numbers are welded together, a procedure qualification must be performed for the combination.

11.1.2 A change in the weld-deposit analysis or electrode type will require requalification under any of the following conditions:

11.1.2.1 A change from one A number in Table 4 to any other A number. Qualification with A No. 1 shall qualify for A No. 2 and vice versa. In lieu of an A number designation, the nominal chemical composition of the weld deposit shall be indicated on the Welding Material Specification (Fig. 3). Designation of nominal chemical composition may also be by reference to the AWS classification (where such exists), the manufacturer's trade designation, or other established procurement documents.

11.1.2.2 A change from one F number in Table 5 to any other F number.

11.1.3 A decrease of 100°F [55°C] or more in the minimum specified preheat temperature.

11.1.4 A significant change in the post heat-treating temperature or time cycle.

11.1.5 A change in the method of backing up, or its omission if previously used.

11.1.6 A change in the welding process.

11.1.7 In submerged arc welding, where the alloy content of the weld metal is largely dependent upon the composition of the flux used, any change in any part of the welding procedure

TABLE 4 A Numbers—Classification of Weld Metal Analysis for Procedure Qualification

A No.	Types of Weld Deposit	Analysis[A]					
		C, %	Cr, %	MO, %	Ni, %	Mn, %	Si, %
1	Mild steel	0.15				1.60	1.00
2	Carbon-molybdenum	0.15	0.50	0.40 to 0.65		1.60	1.00
3	Chromium (0.4 to 2 %)—molybdenum	0.15	0.40 to 2.00	0.40 to 0.65		1.60	1.00
4	Chromium (2 to 6 %)—molybdenum	0.15	2.00 to 6.00	0.40 to 1.50		1.60	2.00
5	Chromium (6 to 10.5 %)—molybdenum	0.15	6.00 to 10.50	0.40 to 1.50		1.20	2.00
6	Chromium-martensitic	0.15	11.00 to 15.00	0.70		2.00	1.00
7	Chromium-ferritic	0.15	11.00 to 30.00	1.00		1.00	3.00
8	Chromium-nickel	0.15	14.50 to 30.00	4.00	7.50 to 15.00	2.50	1.00
9	Chromium-nickel	0.30	25.00 to 30.00	4.00	15.00 to 37.00	2.50	1.00
10	Nickel to 4 %	0.15		0.55	0.80 to 4.00	1.70	1.00
11	Manganese-molybdenum	0.17		0.25 to 0.75	0.85	1.25 to 2.25	1.00
12	Nickel-chromium-molybdenum	0.15	1.50	0.25 to 0.80	1.25 to 2.80	0.75 to 2.25	1.00

[A] Single values shown above are maximum.

that would result in the important alloying elements in the weld metal being outside of the specification range of chemistry given in the welding procedure specification.

11.1.8 In submerged arc welding a change in the nominal composition or type of flux used (requalification is not required for a change in flux particle size).

11.1.9 For submerged arc welding a change from a filler metal containing 1.75 to 2.25 % manganese to filler metal containing less than 1.00 % manganese or vice versa shall require requalification. The presence or absence of up to 0.5 % molybdenum in the filler metal analysis shall not require requalification.

11.1.10 For submerged arc welding a change in filler metal analysis in Table 4 from one A number to another.

11.1.11 In gas metal arc welding and gas tungsten arc welding.

11.1.11.1 A change from the qualified single gas to any other single gas or to a mixture of gases, or a change in specified percentage composition of gas mixture.

11.1.11.2 A decrease of 10 % or more in the rate of flow of shielding gas or mixture.

11.1.12 For gas metal arc welding a change in the consumable electrode from bare (solid) to flux cored, or vice versa.

11.1.13 Qualification of Category 10 base materials shall also qualify Category 9 base materials, and vice versa. Separate welding procedures are required for each category.

12. Performance Qualification of Welders or Operators

12.1 All welders and operators welding castings under this practice shall pass the welder qualification test. The welder or operator successfully performing the procedure qualification test is automatically qualified for performance.

12.1.1 Each welder or operator shall be qualified for each welding process (GTAW, GMAW, SMAW, FCAW, etc.) he uses. The welder or operator successfully qualified with one procedure for a process is qualified to weld with any other welding procedure using the same welding process, unless requalification is required by Section 13.

12.2 *Test Plate*—The test plate or pipe or cylindrical casting shall be the same as that used in the procedure qualification with respect to groove dimensions, filler metal, etc. Groove dimensions as shown in Fig. 5 may be used. The welding procedure shall conform to that given in the procedure qualification. For performance qualification, carbon steel plate, pipe, or cylindrical castings may be used for qualification of materials having a total alloy content of less than 6 %.

12.3 *Number of Tests*— The number and type of tests to qualify a performance shall be as shown in Table 3.

12.4 Test specimens shall be removed from the plate or pipe or cylindrical casting as shown in Fig. 15, Fig. 16, Fig. 17, and Fig. 18.

12.5 The guided bend test shall meet the requirements as specified in 8.2.3.

12.6 Alternative to the mechanical tests required in 12.3, 12.4, and 12.5, the qualification test plate for welders and operators making groove welds using SMAW, GTAW, FCAW, or GMAW (except the short circuiting mode of transfer) processes may be examined by radiography using a technique shown by penetrameters to equal or exceed 2 % sensitivity. The weld to be radiographed shall be at least 6 in. [150 mm] long for welders and operators, or alternatively, a 3-ft [0.9-m] length of the first production weld made by a welding operator may be examined by radiography.

12.6.1 Final acceptance of the welds shall be based on the radiographic requirements of Section IX of the ASME Boiler and Pressure Vessel Code.

12.6.2 If a production weld is selected for welder or operator qualification and it does not meet the radiographic standards, the welder or operator has failed the test. In the event the production weld requires welder or operator qualification, the entire production weld made by that welder or operator shall be radiographed and repaired by a qualified welder or operator. Alternatively, the entire weld shall be removed and replaced by a qualified welder or operator.

12.7 Each manufacturer or contractor shall maintain a record of the procedures, including essential variables, under which the welders and operators are examined. A suggested form for recording such information is shown in Fig. 2.

13. Requalification of Welders and Operators

13.1 A welder must be requalified when one of the changes in essential variables listed in 13.2 and 13.3 is made in the procedure, or as provided in 13.4 or 13.5.

13.2 A change in the weld deposit metal to a weld deposit metal having a different F number, or to a weld deposit metal not covered under Table 4. Qualification under any F number up to and including F4 shall qualify a welder for all lower F numbers.

13.3 A change in the method of backing up, or its omission if previously used.

13.4 When a welder has not used the specified process for three months or more.

13.5 When there is a reason to question his ability to make welds that meet this practice.

13.6 Requalification under 13.4 or 13.5 need only be made in a single thickness.

14. Retests

14.1 A welder or operator who fails to meet the requirements for one or more test specimens may be retested under the conditions described in 14.2 and 14.3.

14.2 When an immediate retest is made, the welder or operator shall make two test plates, each of which shall meet the requirements. If he fails these tests, he must undergo further training before a retest is permitted.

14.3 When a welder has had further training, a single retest is permitted.

15. Keywords

15.1 qualifications; steel castings; welding

TABLE 5 F Numbers—Grouping of Filler Metals for Qualification

F No.	ANSI/AWS Specification	ANSI/AWS Classification
1	SFA-5.1 & 5.5	EXX20, EXX22, EXX24, EXX27, EXX28
1	SFA-5.4	EXX25, EXX26
2	SFA-5.1 & 5.5	EXX12, EXX13, EXX14, EXX19
3	SFA-5.1 & 5.5	EXX10, EXX11
4	SFA-5.1 & 5.5	EXX15, EXX16, EXX18, EXX48
4	SFA-5.4 (other than austenitic and duplex)	EXX15, EXX16, EXX17
5	SFA-5.4 (austenitic and duplex)	EXX-15, EXX-16, EXX-17
6	SFA-5.2	RX
6	SFA-5.17	FXX-EXX, FXX-ECX
6	SFA-5.9	ERXX, ECXX, EQXX
6	SFA-5.18	ERXXS-X, EXXC-X, EXXC-XX
6	SFA-5.20	EXXT-X
6	SFA-5.22	EXXXT-X
6	SFA-5.23	FXX-EXXX-X, FXX-ECXXX-X, FXX-EXXX-XN, FXX-ECXXX-XN
6	SFA-5.25	FESXX-EXXXXX-EW
6	SFA-5.26	EGXXS-X, EGXXT-X
6	SFA-5.28	ERXXS-X, EXXC-X
6	SFA-5.29	EXXTX-X
6	SFA-5.30	INXXXX
41	SFA-5.11	ENi-1
41	SFA-5.14	ERNi-1
41	SFA-5.30	IN61
42	SFA-5.11	ENiCu-7
42	SFA-5.14	ERNiCu-7
42	SFA-5.14	ERNiCu-8
42	SFA-5.30	IN60
43	SFA-5.11	ENiCrFe-1
43	SFA-5.11	ENiCrFe-2
43	SFA-5.11	ENiCrFe-3
43	SFA-5.11	ENiCrFe-4
43	SFA-5.11	ENiCrFe-7
43	SFA-5.11	ENiCrFe-9
43	SFA-5.11	ENiCrFe-10
43	SFA-5.11	ENiCrCoMo-1
43	SFA-5.11	ENiCrMo-2
43	SFA-5.11	ENiCrMo-3
43	SFA-5.11	ENiCrMo-6
43	SFA-5.11	ENiCrMo-12
43	SFA-5.14	ERNiCr-3
43	SFA-5.14	ERNiCr-4
43	SFA-5.14	ERNiCr-6
43	SFA-5.14	ERNiCrFe-5
43	SFA-5.14	ERNiCrFe-6
43	SFA-5.14	ERNiCrFe-7
43	SFA-5.14	ERNiCrFe-8
43	SFA-5.14	ERNiCrFe-11
43	SFA-5.14	ERNiCrCoMo-1
43	SFA-5.14	ERNiCrMo-2
43	SFA-5.14	ERNiCrMo-3
43	SFA-5.30	IN82
43	SFA-5.30	IN62
43	SFA-5.30	IN62A
44	SFA-5.11	ENiMo-1
44	SFA-5.11	ENiMo-3
44	SFA-5.11	ENiMo-7

TABLE 5 *Continued*

F No.	ANSI/AWS Specification	ANSI/AWS Classification
44	SFA-5.11	ENiMo-8
44	SFA-5.11	ENiMo-9
44	SFA-5.11	ENiMo-10
44	SFA-5.11	ENiCrMo-4
44	SFA-5.11	ENiCrMo-5
44	SFA-5.11	ENiCrMo-7
44	SFA-5.11	ENiCrMo-10
44	SFA-5.11	ENiMo-13
44	SFA-5.11	ENiMo-14
44	SFA-5.14	ERNiMo-1
44	SFA-5.14	ERNiMo-2, ERNiMo-3
44	SFA-5.14	ERNiMo-7 (Alloy B-2)
44	SFA-5.14	ERNiMo-8
44	SFA-5.14	ERNiMo-9
44	SFA-5.14	ERNiMo-10
44	SFA-5.14	ERNiCrMo-4
44	SFA-5.14	ERNiCrMo-5
44	SFA-5.14	ERNiCrMo-7 (Alloy C-4)
44	SFA-5.14	ERNiCrMo-10
44	SFA-5.14	ERNiCrMo-13
44	SFA-5.14	ERNiCrMo-14
44	SFA-5.14	ERNiCrWMo-1
45	SFA-5.11	ENiCrMo-1
45	SFA-5.11	ENiCrMo-9
45	SFA-5.11	ENiCrMo-11
45	SFA-5.14	ERNiCrMo-1
45	SFA-5.14	ERNiFeCr-1
45	SFA-5.14	ERNiCrMo-8
45	SFA-5.14	ERNiCrMo-9
45	SFA-5.14	ERNiCrMo-11

APPENDIX

(Nonmandatory Information)

X1. PRACTICE A 488/A 488M CATEGORY NUMBER AND CORRESPONDING ASME P NUMBER

X1.1 Listed in Table X1.1 for information are the Practice A 488/A 488M categories of base metal casting specifications for welding qualifications and the corresponding P number designations from Section IX of the ASME Boiler and Pressure Vessel Code:

TABLE X1.1 ASTM Categories of Base Metal Casting Specifications and Corresponding P Number Designations

NOTE 1—The P numbers are under the jurisdiction of the ASME Boiler and Pressure Vessel Code and may be subject to change subsequent to the effective date of this specification.

ASTM			A 488/A 488M Category No.	ASME	
Specification	Grade	Class		P No.	Group No.
A 216/A 216M	WCA		1	1	1
	WCB		1	1	2
	WCC		2	1	2
A 217/A 217M	WC1		4	3	1
	WC4		4	4	1
	WC5		4	4	1
	WC6		4	4	1
	WC9		4	5A	1
	C5		5	5B	1
	C12		5	5B	1
	CA-15		8	6	3
A 351/A 351M	CF3		9	8	1
	CF3A		9	8	1
	CF8		10	8	1
	CF8A		10	8	1
	CF10		10	8	1
	CF10M		10	8	1
	CF3M		9	8	1
	CF8M		10	8	1
	CF8C		11	8	1
	CH8		10	8	2
	CH20		10	8	2
	CK20		11	8	2
	CN7M		11	45	. . .
	CG6MMN		10	8	3
	CG8M		10	8	1
	CD4MCU		12	10H	1
	CE8MN		10	10H	1
	CT15C		11	45	. . .
A 352/A 352M	CA6NM		8	6	4
	LCA		1	1	1
	LCB		1	1	1
	LCC		2	1	2
	LC1		4	3	1
	LC2		4/6	9A	1
	LC3		4/6	9B	1
	LC4		4/6	9C	1
	LC2-1		4/6	11A	5
A 487/A 487M	8	A	5	5B	1
	8B		6	5C	4
	8C		6	5C	4
	CA-15A		8	6	3
	CA-15B		8	6	3
	CA-15C		8	6	3
	CA-15D		8	6	3
	CA-15M	A	8	6	3
	CA 6NM	A	8	6	
	1	A	5	10A	1
	1	B	6	10A	1
	2	A	5	10F	1
	2	B	6	10F	1
	4	A	5	10F	1
	4	B	6	11A	3
	16	A	4	1	2
	4	E	6	11A	3

INTERNATIONAL

Designation: A 494/A 494M – 03a

Standard Specification for Castings, Nickel and Nickel Alloy[1]

This standard is issued under the fixed designation A 494/A 494M; 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 nickel, nickel-copper, nickel-copper-silicon, nickel-molybdenum, nickel-chromium, and nickel-molybdenum-chromium alloy castings for corrosion-resistant service.

1.2 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 must be used independently of the other. Combining values from the two systems may result in nonconformance with the specification. Inch-pound units are applicable for material ordered to Specification A 494 and SI units for material ordered to Specification A 494M.

2. Referenced Documents

2.1 *ASTM Standards:*

A 370 Test Methods and Definitions for Mechanical Testing of Steel Products[2]

[1] This specification is under the jurisdiction of ASTM Committee A01 on Steel, Stainless Steel, and Related Alloys and is the direct responsibility of Subcommittee A01.18 on Castings.

Current edition approved ~~May 10,~~ Oct. 1, 2003. Published ~~May~~ October 2003. Originally approved in 1958. Redesignated as A 494 in 1963. Last previous edition approved in 200~~1~~3 as A 494/A 494M – 0~~1a~~3.

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

A 488/A488M Practice for Steel Castings, Welding, Qualifications of Procedures and Personnel[3]
A 732/A732M Specification for Castings, Investment, Carbon and Low-Alloy Steel for General Application, and Cobalt Alloy for High Strength at Elevated Temperatures[3]
A 781/A781M Specification for Castings, Steel and Alloy, Common Requirements, for General Industrial Use[3]
E 8 Test Methods for Tension Testing of Metallic Materials[4]
E 29 Practice for Using Significant Digits in Test Data to Determine Conformance with Specifications[5]
E 30 Test Methods for Chemical Analysis of Steel, Cast Iron, Open-Hearth Iron, and Wrought Iron[6]
E 38 Methods for Chemical Analysis of Nickel-Chromium and Nickel-Chromium-Iron Alloys[7]
E 76 Test Methods for Chemical Analysis of Nickel-Copper Alloys[8]
E 354 Test Methods for Chemical Analysis of High-Temperature, Electrical, Magnetic, and Other Similar Iron, Nickel, and Cobalt Alloys[8]

3. Terminology

3.1 *Definitions:*

3.1.1 *master heat*—a single furnace charge of refined alloy which may either be poured directly into castings or into remelt alloy for individual melts.

3.1.2 *melts*—a single furnace charge poured into castings. When master heats are used to prepare melts, a melt analysis shall be reported.

4. General Conditions for Delivery

4.1 Material furnished to this specification shall conform to the requirements of Specification A 781/A 781M, including any supplementary requirements that are indicated in the purchase order. Failure to comply with the general requirements of Specification A 781/A 781M constitutes nonconformance with this specification. In case of conflict between the requirements of this specification and Specification A 781/A 781M, this specification shall prevail.

5. Ordering Information

5.1 Orders for castings to this specification should include the following information:
5.1.1 Quantity, in pieces, and
5.1.2 Grade designation (Table 1) and class (Table 2).
5.2 The purchaser shall specify any of the following information required to describe adequately the desired material:
5.2.1 Heat treat condition (see 6.1 and 6.2),
5.2.2 Repair welding (see 11)
5.2.3 Source inspection requirements, if any (see Specification A 781/A 781M),
5.2.4 Marking-for-identification requirements, if any (see 13.1), and
5.2.5 Supplementary requirements desired, including the standards of acceptance.

6. Heat Treatment

6.1 Castings shall be heat treated in accordance with the requirements in Table 2.

NOTE 1—Proper heat treatment of these alloys is usually necessary to enhance corrosion resistance and, in some cases, to meet mechanical properties. Minimum heat treat temperatures are specified; however, it is sometimes necessary to heat treat at higher temperatures, hold for some minimum time at temperature, and then rapidly cool the castings in order to enhance the corrosion resistance and meet mechanical properties.

6.2 When Class 1 is specified, grades CY40 and M25S shall be supplied in the as-cast condition. When Class 2 is specified, grades CY40 and M25S shall be supplied in the solution-treated condition. When Class 3 is specified, grade M25S shall be supplied in the age-hardened condition.

7. Chemical Composition

7.1 These alloys shall conform to the chemical composition requirements prescribed in Table 1.

7.2 An analysis of each master heat shall be made by the manufacturer to determine the percentages of the elements specified in Table 1. The analysis shall be made from a representative sample taken during the pouring of the master heat. Chemical composition shall be reported to the purchaser or his representative.

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[2] *Annual Book of ASTM Standards*, Vol 01.03.
[3] *Annual Book of ASTM Standards*, Vol 01.02.
[4] *Annual Book of ASTM Standards*, Vol 03.01.
[5] *Annual Book of ASTM Standards*, Vol 14.02.
[6] Discontinued. See 1994 *Annual Book of ASTM Standards* , Vol 03.05.
[7] Discontinued, see 1989 *Annual Book of ASTM Standards* , Vol 03.05.
[8] *Annual Book of ASTM Standards*, Vol 03.05.

TABLE 1 Chemical Requirements

NOTE—Values are maximum unless otherwise indicated.

Grade	CZ100	M35-1[A]	M35-2	M30H	M25S	M30C[A]	N12MV	N7M	CY40	CW12MW	CW6M	CW2M	CW6MC	CY5SnBiM	CX2MW	CU5MCuC	CX2M
UNS Numbers	J02100	J24135	J04020	J24030	J24025	J24130	J30012	J30007	J06040	J30002	J30107	J26455	J26625	J26055	N26022	N08826	N26059
	Composition, %																
C, max	1.00	0.35	0.35	0.30	0.25	0.30	0.12	0.07	0.40	0.12	0.07	0.02	0.06	0.05	0.02	0.050 max	0.02
~~Mn, max~~	~~1.50~~	~~1.50~~	~~1.50~~	~~1.50~~	~~1.50~~	~~1.50~~	~~1.00~~	~~1.00~~	~~1.50~~	~~1.00~~	~~1.00~~	~~1.00~~	~~1.00~~	~~1.5~~	~~1.00~~	~~1.0 max~~	
Mn, max	1.50	1.50	1.50	1.50	1.50	1.50	1.00	1.00	1.50	1.00	1.00	1.00	1.00	1.5	1.00	1.0 max	1.00
~~Si, max~~	~~2.00~~	~~1.25~~	~~2.00~~	~~2.7-3.7~~	~~3.5-4.5~~	~~1.0-2.0~~	~~1.00~~	~~1.00~~	~~3.00~~	~~1.00~~	~~1.00~~	~~0.80~~	~~1.00~~	~~0.5~~	~~0.80~~	~~1.0 max~~	
Si, max	2.00	1.25	2.00	2.7-3.7	3.5-4.5	1.0-2.0	1.00	1.00	3.00	1.00	1.00	0.80	1.00	0.5	0.80	1.0 max	0.50
P, max	0.03	0.03	0.03	0.03	0.03	0.03	0.040	0.040	0.03	0.040	0.040	0.03	0.015	0.03	0.025	0.030 max	0.020
S, max	0.03	0.03	0.03	0.03	0.03	0.03	0.030	0.030	0.03	0.030	0.030	0.03	0.015	0.03	0.025	0.030 max	0.020
~~Cu~~	~~1.25 max~~	~~26.0-33.0~~	~~26.0-33.0~~	~~27.0-33.0~~	~~27.0-33.0~~	~~26.0-33.0~~	~~. . .~~	~~. . .~~	~~. . .~~	~~. . .~~	~~. . .~~	~~. . .~~	~~. . .~~	~~. . .~~	~~. . .~~	~~1.50-3.50~~	
Cu	1.25 max	26.0-33.0	26.0-33.0	27.0-33.0	27.0-33.0	26.0-33.0	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	1.50-3.50	. . .
~~Mo~~	~~. . .~~	~~. . .~~	~~. . .~~	~~. . .~~	~~. . .~~	~~. . .~~	~~26.0-30.0~~	~~30.0-33.0~~	~~. . .~~	~~16.0-18.0~~	~~17.0-20.0~~	~~15.0-17.5~~	~~8.0-10.0~~	~~2.0-3.5~~	~~12.5-14.5~~	~~2.5-3.5~~	
Mo	. . .	. . .	. . .	. . .	. . .	. . .	26.0-30.0	30.0-33.0	. . .	16.0-18.0	17.0-20.0	15.0-17.5	8.0-10.0	2.0-3.5	12.5-14.5	2.5-3.5	15.0-16.5
~~Fe~~	~~3.00 max~~	~~3.50 max~~	~~3.50 max~~	~~3.50 max~~	~~3.50 max~~	~~3.50 max~~	~~4.0-6.0~~	~~3.00 max~~	~~11.0 max~~	~~4.5-7.5~~	~~3.0 max~~	~~2.0 max~~	~~5.0 max~~	~~2.0 max~~	~~2.0-6.0~~	~~balance~~	
Fe	3.00 max	3.50 max	3.50 max	3.50 max	3.50 max	3.50 max	4.0-6.0	3.00 max	11.0 max	4.5-7.5	3.0 max	2.0 max	5.0 max	2.0 max	2.0-6.0	balance	1.50 max
Ni	95.00 min	balance	balance	balance	balance	balance	balance	balance	balance	balance	balance	balance	balance	balance	balance	38.0-44.0	balance
Cr	. . .	. . .	. . .	. . .	. . .	. . .	1.00	1.0	14.0-17.0	15.5-17.5	17.0-20.0	15.0-17.5	20.0-23.0	11.0-14.0	20.0-22.5	19.5-23.5	22.0-24.0
~~Cb (Nb)~~	~~. . .~~	~~0.5 max~~	~~0.5 max~~	~~. . .~~	~~. . .~~	~~1.0-3.0~~	~~. . .~~	~~. . .~~	~~. . .~~	~~. . .~~	~~. . .~~	~~. . .~~	~~3.15-4.50~~	~~. . .~~	~~. . .~~	~~0.60-1.20~~	
Cb (Nb)	. . .	0.5 max	0.5 max	. . .	. . .	1.0-3.0	. . .	. . .	. . .	. . .	. . .	. . .	3.15-4.50	. . .	. . .	0.60-1.20	. . .
~~W~~	~~. . .~~	~~. . .~~	~~. . .~~	~~. . .~~	~~. . .~~	~~. . .~~	~~. . .~~	~~. . .~~	~~. . .~~	~~3.75-5.25~~	~~. . .~~	~~1.0 max~~	~~. . .~~	~~. . .~~	~~2.5-3.5~~	~~. . .~~	
W	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	3.75-5.25	. . .	1.0 max	. . .	. . .	2.5-3.5	. . .	. . .
~~V~~	~~. . .~~	~~. . .~~	~~. . .~~	~~. . .~~	~~. . .~~	~~. . .~~	~~0.20-0.60~~	~~. . .~~	~~. . .~~	~~0.20-0.40~~	~~. . .~~	~~. . .~~	~~. . .~~	~~. . .~~	~~0.35 max~~	~~. . .~~	
V	. . .	. . .	. . .	. . .	. . .	. . .	0.20-0.60	. . .	. . .	0.20-0.40	. . .	. . .	. . .	. . .	0.35 max	. . .	. . .
~~Bi~~	~~. . .~~	~~. . .~~	~~. . .~~	~~. . .~~	~~. . .~~	~~. . .~~	~~. . .~~	~~. . .~~	~~. . .~~	~~. . .~~	~~. . .~~	~~. . .~~	~~. . .~~	~~3.0-5.0~~	~~. . .~~	~~. . .~~	
Bi	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	3.0-5.0	. . .	. . .	. . .
~~Sn~~	~~. . .~~	~~. . .~~	~~. . .~~	~~. . .~~	~~. . .~~	~~. . .~~	~~. . .~~	~~. . .~~	~~. . .~~	~~. . .~~	~~. . .~~	~~. . .~~	~~. . .~~	~~3.0-5.0~~	~~. . .~~		~~. . .~~
Sn	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	3.0-5.0	. . .	. . .	. . .

[A] Order M35-1 or M30C when weldability is required.

TABLE 2 Heat Treat Requirements

Grade	Heat Treatment
CZ100, M35-1, M35-2, CY40 Class 1, M30H, M30C, M25S Class 1, CY5SnBiM	As cast
M25S, Class 2[A]	Load into furnace at 600°F [315°C] maximum. Heat to 1600°F [870°C] and hold for 1 h plus an additional 30 min for each ½ in. [13 mm] of cross section over 1 in.[B] Cool to 1300°F [705°C][C] and hold at temperature for 30 min then quench in oil to room temperature.
M25S, Class 3	Load into furnace at 600°F [315°C] maximum. Heat slowly to 1100°F [605°C] and hold to develop maximum hardness. Furnace or air cool to room temperature.
N12MV, N7M	Heat to 2000°F [1095°C] minimum, hold for sufficient time to heat castings to temperature, quench in water or rapid cool by other means.
CW12MW, CW6M, CW6MC, CW2M	Heat to 2150°F [1175°C] minimum, hold for sufficient time to heat castings to temperature, quench in water or rapid cool by other means.
CY40, Class 2	Heat to 1900°F [1040°C] minimum, hold for sufficient time to heat castings to temperature, quench in water or rapid cool by other means.
CX2MW	Heat to 2200°F [1205°C] minimum, hold for sufficient time to heat castings to temperature, quench in water or rapid air cool by other means.
CU5MCuC	Heat to 2100°F [1150°C] minimum, hold for sufficient time to heat castings to temperature, quench in water. Stabilize at 1725–1815°F [940–990°C], hold for sufficient time to heat castings to temperature, quench in water or rapid cool by other means.
CX2M	Heat to 2100°F [1150°C] minimum, hold for sufficient time to heat castings to temperature, quench in water or rapid air cool by other means.

[A] M25S, while machinable in the "as cast" condition, is capable of being solution treated for improved machinability. It may be subsequently age hardened to the hardness specified in Table 3 and finished machined or ground.
[B] For cross sections over 6 in. [125 mm] it may be necessary to increase the hold time if maximum softness is desired.
[C] For maximum softness and the least variation in hardness levels, castings should be transferred from an oven at 1600°F [870°C] to a second oven at 1300°F [705°C].

7.3 Test Methods E 76 or Test Methods E 354 shall be used for referee purposes. Test Methods E 30 or Methods E 38 shall be used if Test Methods E 76 or Test Methods E 354 do not include a method for some element present in the material.

8. Tensile Properties

8.1 One tension test shall be made from each master heat except for grades M25S and CY5SnBiM when the master heat is used to pour the castings. One tension test shall be made from each melt except for grades M25S and CY5SnBiM. Test results shall conform to the tensile requirements specified in Table 3. Test bars shall be poured in special blocks from the same heat as the castings represented.

8.2 The bar from which the test specimen is taken shall be heat treated in production furnaces to the same procedure as the castings it represents. If the castings are not heat treated, the bar used for the test specimen must not be heat treated.

8.3 Test specimens may be cut from castings, at the producer's option, instead of from test bars.

8.4 When castings are produced by methods other than investment process, tension test coupons shall be machined to the form and dimension shown in Fig. 8 of, and tested in accordance with, Test Methods E 8.

8.4.1 When castings are produced by the investment process, test specimens in accordance with Specification A 732/A 732M shall be used for measurement of tensile properties.

8.5 If any specimen shows defective machining or develops flaws, it may be discarded and another substituted from the same heats.

8.6 To determine conformance with the tension test requirements, an observed value or calculated value shall be rounded in accordance with Practice E 29 to the nearest 500 psi [3.5 MPa] for yield and tensile strength and to the nearest 1 % for elongation and reduction of area.

TABLE 3 Mechanical Properties

	CZ100	M35-1	M35-2	M30H	M25S	M30C	N12MV	N7M	CY40	CW12MW	CW6M	CW2M	CW6MC	CY5SnBiM	CX2MW	CU5MCuC	CX2M
~~Tensile strength, min, psi [MPa]~~	~~50 000 [345]~~	~~65 000 [450]~~	~~65 000 [450]~~	~~100 00 [690]~~	~~...~~	~~65 000 [450]~~	~~76 000 [525]~~	~~76 000 [525]~~	~~70 000 [485]~~	~~72 000 [495]~~	~~72 000 [495]~~	~~72 000 [495]~~	~~70 000 [485]~~	~~...~~	~~80 000 [550]~~	~~75 000 [520]~~	
Tensile strength, min, psi [MPa]	50 000 [345]	65 000 [450]	65 000 [450]	100 00 [690]	...	65 000 [450]	76 000 [525]	76 000 [525]	70 000 [485]	72 000 [495]	72 000 [495]	72 000 [495]	70 000 [485]	...	80 000 [550]	75 000 [520]	72000 [495]
~~Yield strength, min, psi [MPa]~~	~~18 000 [125]~~	~~25 000 [170]~~	~~30 000 [205]~~	~~60 000 [415]~~	~~...~~	~~32 500 [225]~~	~~40 000 [275]~~	~~40 000 [275]~~	~~28 000 [195]~~	~~40 000 [275]~~	~~40 000 [275]~~	~~40 000 [275]~~	~~40 000 [275]~~	~~...~~	~~45 000 [310]~~	~~35 000 [240]~~	
Yield strength, min, psi [MPa]	18 000 [125]	25 000 [170]	30 000 [205]	60 000 [415]	...	32 500 [225]	40 000 [275]	40 000 [275]	28 000 [195]	40 000 [275]	40 000 [275]	40 000 [275]	40 000 [275]	...	45 000 [310]	35 000 [240]	39000 [270]
~~Elongation in 2 in. [50 mm],[A] min, %~~	~~10.0~~	~~25.0~~	~~25.0~~	~~10.0~~	~~...~~	~~25.0~~	~~6.0~~	~~20.0~~	~~30.0~~	~~4.0~~	~~25.0~~	~~20.0~~	~~25.0~~	~~...~~	~~30.0~~	~~20.0~~	
Elongation in 2 in. [50 mm],[A] min, %	10.0	25.0	25.0	10.0	...	25.0	6.0	20.0	30.0	4.0	25.0	20.0	25.0	...	30.0	20.0	40
~~Hardness HB~~	~~...~~	~~...~~	~~...~~	~~...~~	[B]	~~...~~	~~...~~	~~...~~	~~...~~	~~...~~	~~...~~	~~...~~	~~...~~	~~...~~	~~...~~	~~...~~	
Hardness HB	...	...	...	...	[B]	...	...	...	...	...	...	...	...	...	...	...	...

[A] When ICI test bars are used in tensile testing as provided for in Specification A 732/A 732M, the gage length to reduced section diameter ratio shall be 4 to 1.
[B] 300 HB minimum for the age hardened condition.

9. Workmanship, Finish, and Appearance

9.1 Critical surfaces of all castings intended for corrosion-resistant service shall be cleaned. Cleaning may be accomplished by blasting with clean sand or metallic corrosion-resistant shot or by other approved methods.

10. Quality

10.1 The castings shall not be peened, plugged or impregnated to stop leaks.

10.2 Internal chills and chaplets may be used in the manufacture of castings. However, the chills, chaplets and affected cast material must be completely removed.

11. Repair by Welding

11.1 Repairs shall be made by using a welding procedure and operators capable of producing sound welds. The composition of deposited weld metal shall be similar to that of the castings.

11.2 Weld repairs shall be considered major in the case of a casting that has leaked on hydrostatic test or when the depth of the cavity after preparation for repair exceeds 20 % of the actual wall thickness, or 1 in. [25 mm], whichever is smaller, or when the extent of the cavity exceeds approximately 10 in.^{2} [65 cm^2]. All other weld repairs shall be considered minor. Major and minor weld repairs shall be subject to the same quality standards as are used to inspect the castings.

11.3 Castings of M30H, M25S, and CY5SnBiM may not be weld repaired.

11.4 Grades N12MV, N7M, CW12MW, CW6M, CW2M, CX2MW, and CX2M~~W~~ may require post weld heat treatment after major weld repairs. If post weld heat treatment is required, it must be specified along with the grade. If required, it shall be performed in accordance with Section 6.

11.5 For grade CU5MCuC, the composition of the deposited weld metal shall be similar to that of AWS A5.14 ER NiCrMo3 or AWS A5.11 E NiCrMo3.

12. Rejection and Rehearing

12.1 Samples that represent rejected material shall be preserved for two weeks from the date of transmission of the rejection report. In case of dissatisfaction with the results of the tests, the manufacturer may make claim for a rehearing within that time.

13. Product Marking

13.1 Castings shall be marked for the material identification with the ASTM specification designation (A 494/A 494M) and grade symbol, that is, CY40. The manufacturer's name or identification mark and the pattern number shall be cast or stamped on all castings except those of such small size as to make such marking impractical. To minimize small defects caused by dislodged particles of molding sand, the number of cast identification marks shall be minimized. The marking of heat numbers on individual castings shall be agreed upon by the manufacturer and the purchaser. Markings shall be in such position as not to injure the usefulness of the casting.

13.1.1 When the castings are too small to mark individually, a symbol traceable to the heat shall be placed on the castings and the required identification then placed on a tag affixed to the container in which these castings are shipped.

14. Keywords

14.1 corrosion resistant applications; nickel; nickel alloy castings; nickel alloys; nickel castings

SUPPLEMENTARY REQUIREMENTS

The following supplementary requirements shall not apply unless specified in the purchase order. A list of standard supplementary requirements for use at the option of the purchaser is included in Specification A 781/A 781M. Those which are ordinarily considered for use with this specification are given below; others enumerated in Specification A 781/A 781M may be used with this specification upon agreement between the manufacturer and the purchaser.

S2. Radiographic Examination

S3. Liquid Penetrant Examination

S6. Certification

S10. Hardness Tests

S10.1 When composition M25S material is ordered with a hardness maximum or range in the as-cast or solution treated condition, hardness tests shall be made in accordance with Test Methods and Definitions A 370. The test location, number of tests, and hardness values shall be agreed upon between the manufacturer and purchaser.

S10.1.1 If castings are ordered in the as-cast condition, hardness determinations shall be made on two different representative areas of each casting or coupon selected for test.

S10.1.1.1 By agreement between purchaser and producer, those as-cast castings which fail to meet the required hardness may be accepted in the solution annealed and hardened condition if the hardness thus developed meets the hardness requirement of the specification.

S10.1.2 If castings ordered are in the solution-treated condition, two sample castings or two coupons representing the lot shall be heat treated for tests (see S10.1.1). Hardness determinations shall be made on two different representative areas of each casting or coupon.

S10.1.3 When hardness tests are made, the specimens shall be at least ¼ in. [6 mm] in thickness and the area to be tested shall be ground clean before the hardness tests are made.

S22. Weldability Test

S22.1 If weldability tests are specified for M30C or M35-1, prepare a coupon obtained from a test bar shown in Fig. 1 or Fig. 2 for each lot of composition M30C or M35-1 castings. The weld test to be used shall be agreed upon between the purchaser and manufacturer.

S22.1.1 Prepare and weld the test bar cast in accordance with Fig. 1 and in accordance with Fig. 3.

S22.1.1.1 Machine the cast skin and unsound metal from two adjacent faces of the as-cast specimen, exclude the riser face, and cut the specimen into approximately 6-in. [150-mm] lengths.

S22.1.1.2 Clamp the two 6-in. [150 mm] lengths together to form a double V-joint and weld two passes at a time on alternate sides of the specimen using ⅛-in. [3-mm] diameter electrodes that will deposit metal of similar composition of the test pieces.

S22.1.1.3 Allow the specimen to cool to room temperature between passes, remove all flux, and examine visually for cracks.

S22.1.1.4 The clamps may be removed from the specimen after the first two weld passes have been completed.

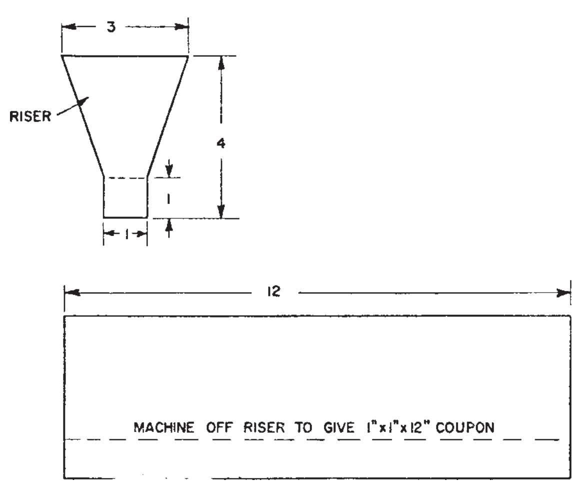
S22.1.1.5 Deposit alternate series of passes until the double V-groove has been completely filled. After the second series (number 4 pass) a 5⁄32-in. [4-mm] diameter electrode may be used if desired.

S22.1.1.6 During welding allow each pass to cool, clean, and examine visually for cracks. The presence of cracks shall be cause for rejection.

S22.1.1.7 Upon completion of the welding, cut one section approximately ¾ in. [19 mm] long transverse to the weld from each end and discard.

S22.1.1.8 Polish each end of the remaining center section on a 100/200-grit wheel and etch with concentrated HNO_3 or with Lepito's etchant. Prepare Lepito's etchant as follows: (*a*) 15 g of $(NH_4)_2SO_4$ dissolved in 75 cm^3 of water; (*b*) 250 g of $FeCl_3$(powdered) dissolved in 100 cm^3 of HCl; (*c*) mix solutions (*a*) and (*b*) and add 30 cm^3 of HNO_3.

S22.1.1.9 Examine the etched section under low magnification (5 to 10×). The lot represented by the test specimen shall be accepted if it complies with the following crack requirements: (*a*) Three cracks maximum in linear inch of base metal and (*b*) The length of any crack in the base metal does not exceed 0.20 in. [5 mm].

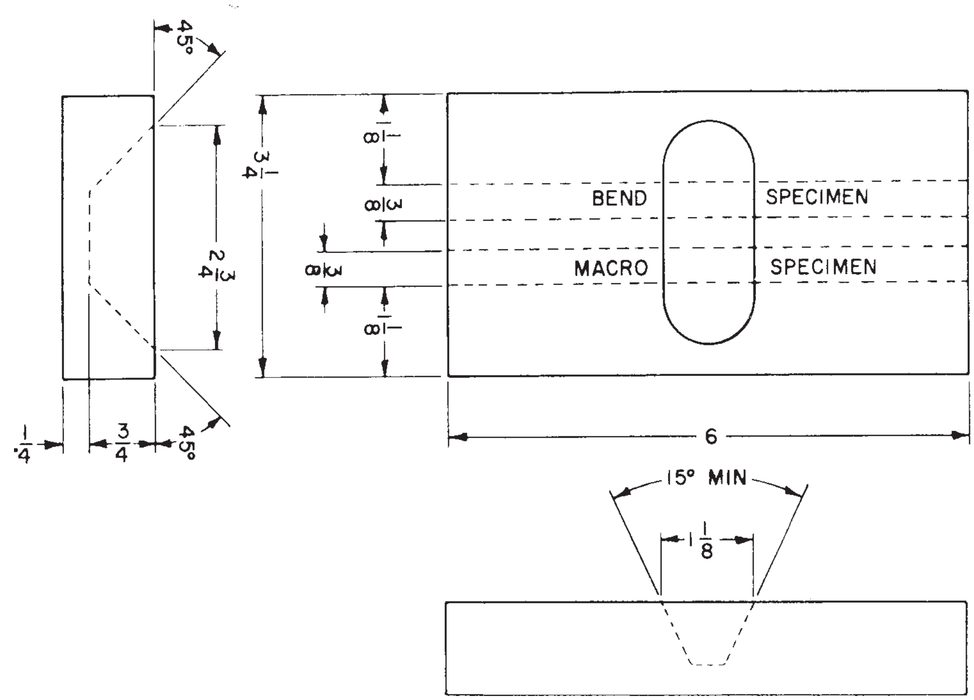


Metric Equivalents

in.	1	3	4	12
[mm]	[25]	[75]	[100]	[305]

NOTE—Riser shall be machined off and 1 in. [25 mm] square by 12 in. [305 mm] coupon shall be used for x-weld test. See Fig. 3.

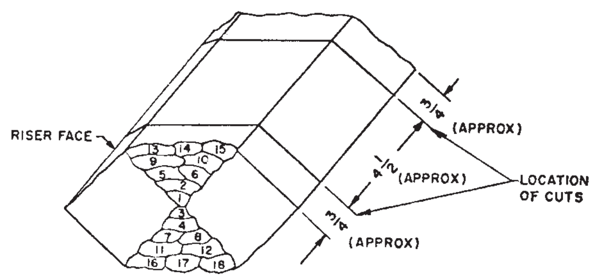
FIG. 1 Weld Test Bar (As Cast)



Metric Equivalents

in.	¼	⅜	¾	1⅛	2¾	3¼	6
[mm]	[5]	[10]	[20]	[30]	[70]	[85]	[155]

FIG. 2 Weld Test Bar (As Cast)



Metric Equivalents

in.	¾	4½
[mm]	[20]	[115]

FIG. 3 X-Weld Test

S22.1.1.10 Cracks observed in the weld metal during the low-magnification examination shall not be cause for rejection.

S22.1.1.11 Failure of welded test bars to comply with any of the requirements S22.1 through S22.1.1.10 shall result in rejection of the lot represented.

S22.1.2 Prepare and weld the test bar cast in accordance with Fig. 2 as follows:

S22.1.2.1 Fill the groove in the block completely with weld deposit using manual metallic arc process with ⅛-in. [3.2–mm] or 5⁄32-in. [4-mm] diameter electrodes that will deposit metal of similar composition of the test piece.

S22.1.2.2 Remove one ⅜-in. [10-mm] thick bend coupon longitudinally from the welded block by machining, sawing, abrasive cutting, or other suitable means. Make a transverse side bend test of the welded joint in accordance with Practice A 488/A 488M.

S22.1.2.3 Remove a transverse weld macro-specimen from the welded plate and visually examine for cracks. This specimen may be the same one to be used for the bend specimen.

S22.1.3 *Acceptance:*

S22.1.3.1 Cracks as tears in the casting in the fusion zone or heat-affected zone of the macro-specimen shall be cause for rejection. Cracks originating at the weld bead undercuts, at weld slag inclusions, or at casting defects shall not be cause for rejection.

S22.1.3.2 Cracks or other open defects exceeding ⅛-in. [3.2 mm] measured in any direction on the convex surface of the bent specimens shall be cause for rejection, except that cracks occurring on the corners while testing and cracks originating at weld bead undercuts shall not be considered.

SUMMARY OF CHANGES

Committee A01 has identified the location of selected changes to this standard since the last issue (A 494/A 494M – 03) that may impact the use of this standard. (Approved Oct. 1, 2003)

(1) Added new alloy CX2M.

Committee A01 has identified the location of selected changes to this standard since the last issue (A 494/A 494M – 01a $^{\epsilon 1}$) that may impact the use of this standard. (Approved May 10, 2003)

(1) Added UNS numbers to Table 1 and deleted them elsewhere in the standard.
(2) Deleted the dashes in the alloy designations.

Standard Specification for Calcium-Silicon Alloys[1]

This standard is issued under the fixed designation A 495; 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 a standard grade of calcium-silicon, a standard grade of calcium-manganese-silicon, a standard grade of calcium-silicon-barium and a standard grade of ferro-calcium-silicon.

2. Referenced Documents

2.1 *ASTM Standards:*

E 29 Practice for Using Significant Digits in Test Data to Determine Conformance with Specifications[2]

E 31 Methods for Chemical Analysis of Ferroalloys[3]

E 32 Practices for Sampling Ferroalloys and Steel Additives for Determination of Chemical Composition[3]

3. Ordering Information

3.1 Orders for material under this specification shall include the following information:

3.1.1 Quantity,

3.1.2 Name of material,

3.1.3 ASTM designation,

3.1.4 Size, and

3.1.5 Special requirements for packaging, analysis reports, etc., as appropriate.

3.2 The customary basis of payment for calcium-silicon and for calcium-manganese-silicon is per pound of ferroalloy, rather than per pound of contained elements.

4. Chemical Requirements

4.1 The material shall conform to the requirements as to chemical composition specified in Table 1 and Table 2.

4.2 *Calcium-Silicon*—The manufacturer shall furnish an analysis of each shipment showing the calcium, silicon, and aluminum content.

4.3 *Calcium-Manganese-Silicon*—The manufacturer shall furnish an analysis of each shipment showing the calcium, manganese, and silicon content.

TABLE 1 Chemical Requirements

Element	Composition, %			
	CaSi	CaSiMn	CaSiBa	FeCaSi
Calcium	28.0 to 32.0	16.0 to 20.0	14.0 to 20.0	14.0 to 18.0
Silicon	60.0 to 65.0	53.0 to 59.0	55.0 to 60.0	53.0 to 59.0
Manganese	. . .	14.0 to 18.0	. . .	. . .
Barium	. . .	. . .	14.0 to 18.0	. . .
Iron	5.0 max	10.0 max	5.0 max	14.0 to 18.0

4.4 . *Calcium-Silicon-Barium*—The manufacturer shall furnish an analysis of each shipment showing the calcium, silicon and barium contents.

4.5 *Ferro-Calcium-Silicon*—The manufacturer shall furnish an analysis of each shipment showing the calcium, silicon and iron contents.

4.6 The values shown in Table 2 are expected maximums. Upon request of the purchaser, the manufacturer shall furnish an analysis for any of the elements on a cumulative basis over a period mutually agreed upon by the manufacturer and the purchaser.

5. Size

5.1 Calcium-silicon alloys are available in sizes as listed in Table 3.

5.2 The sizes listed in Table 3 are typical as shipped from the manufacturer's plant. These alloys are friable and some attrition can be expected in transit, storage, and handling. The friability rating for these alloys is Code No. 6, the most friable rating on the scale.

TABLE 2 Supplemental Chemical Requirements[A]

Element	Composition, Max %			
	CaSi	CaSiMn	CaSiBa	FeCaSi
Carbon	1.00	1.00	1.0	1.0
Sulfur	0.070	0.025	0.050	0.050
Phosphorus	0.050	0.035	0.050	0.050
Titanium	0.20	0.20	0.20	0.20
Aluminum	1.5	1.5	1.5	1.5

[A]The composition of calcium-silicon alloys shall be within these limits; however, an analysis of each lot is not required. The manufacturer shall supply upon request the results of an analysis for these elements on a cumulative basis over a period mutually agreed upon by the manufacturer and the purchaser.

[1] This specification is under the jurisdiction of ASTM Committee A-1 on Steel, Stainless Steel, and Related Alloys and is the direct responsibility of Subcommittee A01.18 on Castings.

Current edition approved Aug. 15, 1994. Published October 1994. Originally published as A 495 – 63 T. Last previous edition A 495 – 76 (1992).

[2] *Annual Book of ASTM Standards*, Vol 14.02.

[3] *Annual Book of ASTM Standards*, Vol 03.05.

TABLE 3 Standard Sizes and Tolerances

Product	Standard Size	Tolerance	
Calcium-silicon	6 × 2 in. (152 × 50.8 mm)	25 lb lump max	10 % max, passing 2 in. (50 mm) sieve
	3 in. (76.2 mm) × down	10 % max, retained on 3 in. (75 mm) sieve	15 % max, passing ¼ in. (6.3 mm) sieve
	2 in. (50.8 mm) × down	10 % max, retained on 2 in. (50 mm) sieve	15 % max, passing No. 8 (2.36 mm) sieve
	1 in. (25.4 mm) × down	5 % max, retained on 1 in. (25.0 mm) sieve	25 % max, passing No. 8 (2.36 mm) sieve
	8 × 100 mesh (2.38 × 150 mm) sieve	5 % max, retained on No. 8 (2.36 mm) sieve	3 % max, passing No. 100 (150 µm) sieve
	8 mesh (2.38 mm) × down	5 % max, retained on No. 8 (2.36 mm) sieve	
	30 × 325 mesh (0.59 mm × 0.044 mm) sieve	5 % max, retained on 30 mesh	10 % max, passing 325 mesh (0.044 mm)
Calcium-manganese-silicon and	6 × 2 in. (152 × 50.8 mm)	25 lb lump max	10 % max, passing 2 in. (50 mm) sieve
	2 in. (50.8 mm) × down	10 % max, retained on 2 in. (50 mm) sieve	25 % max, passing No. 8 (2.36 mm) sieve
Calcium-silicon-barium	1 in. (25.4 mm) × down	5 % max,, retained on 1 in. (25.0 mm) sieve	25 % max, passing No. 8 (2.36 mm) sieve
	8 mesh (2.38 mm) × down	5 % max, retained on No. 8 (2.36 mm) sieve	
	30 × 325 mesh (0.59 mm × 0.044 mm) sieve	5 % max, retained on 30 mesh (0.59 mm) sieve	10 % max, passing 326 mesh (60.044 mm) sieve
Calcium-silicon-iron	6 × 2 in. (152 × 50.8 mm)	25 lb lump max	10 % max, passing 2 in. (50 mm) sieve
	3 in. (26.2 mm) × down	10 % max, retained on 2 in. (50 mm) sieve	15 % max, passing ¼ in. (6.3 mm) sieve
	2 in. (50.8 mm) × down	10 % max, retained on 2 in. (50 mm) sieve	15 % max, passing No. 8 (2.36 mm) sieve
	1 in. (25.4 mm) × down	5 % max, retained on No. 8 (2.36 mm) sieve	3 % max, passing No. 100 (0.149 mm) sieve
	8 mesh (2.38 mm) sieve × down	5 % max, retained on No. 8 (2.36 mm) sieve	

6. Sampling

6.1 The material shall be sampled in accordance with Practices E 32.

6.2 Other methods of sampling mutually agreed upon by the manufacturer and the purchaser may be used; however, in case of discrepancy, Practices E 32 shall be used for referee.

7. Chemical Analysis

7.1 The chemical analysis of the material shall be made in accordance with the procedures for calcium-silicon alloys as described in Methods E 31 or alternative methods that will yield equivalent results.

7.2 If alternative methods of analysis are used, in case of discrepancy, procedures described in Methods E 31 shall be used for referee.

7.3 Where no procedure is given in Methods E 31 for the analysis for a particular element, the analysis shall be made in accordance with a procedure agreed upon by the manufacturer and the purchaser.

7.4 For purposes of determining conformance with this specification, the reported analysis shall be rounded to the nearest unit in the last right-hand place of figures used in expressing the limiting value, in accordance with the rounding method of Practice E 29.

8. Inspection

8.1 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 the specification.

9. Rejection

9.1 Any claims or rejections shall be made to the manufacturer within 45 days from receipt of material by the purchaser.

10. Packaging

10.1 Calcium-silicon alloys shall be packaged in sound containers, or shipped in bulk, in such manner that none of the product is lost or contaminated in shipment.

Designation: A 518/A 518M – 99 (Reapproved 2003)

Standard Specification for Corrosion-Resistant High-Silicon Iron Castings[1]

This standard is issued under the fixed designation A 518/A 518M; 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 high-silicon cast iron castings intended for corrosion-resistant service.

1.2 This specification covers three grades as shown in Table 1. Selection of grade depends on the corrosive service to be experienced by the casting. All three grades are suited for application in severe corrosive environments. However, Grade 2 is particularly suited for application in strong chloride environments, and Grade 3 is recommended for impressed current anodes.

1.3 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.

1.4 The following safety hazards caveat pertains 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:* [2]

A 438 Test Method for Transverse Testing of Gray Cast Iron

E 350 Test Methods for Chemical Analysis of Carbon Steel, Low-Alloy Steel, Silicon Electrical Steel, Ingot Iron, and Wrought Iron

E 351 Test Methods for Chemical Analysis of Cast Iron—All Types

TABLE 1 Chemical Composition

Element	Composition, Weight %		
	Grade 1	Grade 2	Grade 3
Carbon	0.65–1.10	0.75–1.15	0.70–1.10
Manganese	1.50, max	1.50, max	1.50, max
Silicon	14.20–14.75	14.20–14.75	14.20–14.75
Chromium	0.50, max	3.25–5.00	3.25–5.00
Molybdenum	0.50, max	0.40–0.60	0.20, max
Copper	0.50, max	0.50, max	0.50, max

3. Ordering Information

3.1 Orders for material under this specification shall include the following information:

3.1.1 ASTM designation and year of issue.

3.1.2 Grade of high-silicon cast iron (see Section 5).

3.1.3 Number of castings.

3.1.4 Approximate weight of the casting.

3.1.5 Drawing showing the size, shape, dimensions, and finishing details. The drawing should indicate any critical dimensions and should give the allowable tolerances on all dimensions and on the accumulation of dimensions. If the purchaser supplies the pattern, the dimensions of the casting shall conform to those predicted by the pattern.

3.1.6 Options in this specification, including:

3.1.6.1 The status of the heat treatment of the castings when shipped by the manufacturer (see Section 7).

3.1.6.2 If the chemical analysis and mechanical test results are to be reported to the purchaser (see Section 14).

3.1.6.3 If a transverse test is required (see 8.1).

3.1.6.4 If hydraulic testing is required, and, if required, the test pressure and the leakage permitted (see 8.2).

3.1.6.5 Any special packing, markings, etc.

4. Method of Manufacture

4.1 The alloy may be produced by any melting and casting process, or combination of processes, capable of meeting the chemical composition and mechanical properties specified.

[1] This specification is under the jurisdiction of ASTM Committee A04 on Iron Castings and is the direct responsibility of Subcommittee A04.01 on Grey and White Iron Castings.

Current edition approved Oct. 10, 1999. Published December 1999. Originally approved in 1964. Last previous edition approved in 1999 as A 518 – 99.

[2] 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.

5. Chemical Composition

5.1 High-silicon iron castings are produced in one of three grades, as given in Table 1 of this specification.

6. Chemical Analysis

6.1 *Heat Analysis*—Chemical analysis of each heat (or each tap, if from a continuous melting operation) shall be made by the manufacturer to determine the percentages of the elements specified in Table 1. The analysis shall be made from a test sample cast during the pouring of the heat (or tap). The chemical composition thus determined shall conform to the requirements specified for that grade in Table 1.

6.2 *Product Analysis*—A product analysis may be made by the purchaser from material representing each heat, lot, or casting. The sample for such analysis shall be taken as desired by the purchaser. The chemical composition thus determined shall meet the requirements for the grade specified.

6.3 *Routine Analysis Methods*—Spectrometric and other instrumental methods or wet chemical laboratory methods are acceptable for routine and control determinations, but shall be standardized against and give essentially the same results as the methods specified in 6.4.

6.4 *Reference Analysis Methods*:

6.4.1 *Silicon*:

6.4.1.1 Analyze samples soluble when processed in accordance with Test Methods E 350, by that method, except as follows:

(a) (a) The sample weight shall be 0.3 g with a weight tolerance of ±0.1 mg.

(b) (b) Pulverize one or more pieces of the sample until the entire material in the piece or pieces passes through a 100-mesh screen.

(c) (c) Dissolve the sample in 25 mL of perchloric acid.

6.4.1.2 Analyze samples that are not soluble when processed in accordance with 6.4.1.1 in accordance with Annex A1.

6.4.2 *Molybdenum*:

6.4.2.1 Mill, lathe, or pulverize the sample to pass through a 100-mesh sieve. If the sample is soluble when processed in accordance with Test Methods E 350, use this method.

6.4.2.2 If the sample is not acid-soluble when processed in accordance with 6.4.2.1, proceed as follows:

(a) (a) Use the appropriate weight of sample in accordance with 6.4.2.1 instead of the weight given in A1.2.3 of Annex A1.

(b) (b) Fuse the sample in accordance with A1.2.1 and A1.2.2 and A1.2.4-A1.2.12 of Annex A1.

(c) (c) Add the amount of dissolving acid(s), specified in the sections in Molybdenum by the Photometric Method in Test Methods E 350, heat to fumes of perchloric acid. Proceed in accordance with Test Methods E 350.

6.4.3 *Carbon*—Determine carbon in accordance with sections on Carbon, Total, by the Combustion Gravimetric Method, in Test Methods E 350.

6.4.4 *Manganese*:

6.4.4.1 Mill, lathe, or pulverize the sample to pass through a 100-mesh sieve.

6.4.4.2 Determine manganese in accordance with the sections on Manganese by the Peroxydisulfate-Arsenite Titrimetric Method in Test Methods E 350. Add hydrofluoric acid as required for complete solution of the (HF) sample.

6.4.5 *Chromium*:

6.4.5.1 Mill, lathe, or pulverize the sample to pass through a 100-mesh sieve.

6.4.5.2 Determine chromium in accordance with the sections on Chromium by the Peroxydisulfate-Oxidation Titrimetric Method in Test Methods E 350, except dissolve the sample as follows:

(a) (a) Place the appropriate amount of weighed sample into a 600-mL Griffin beaker or 500-mL volumetric flask. Add 20 mL of nitric acid (HNO_3) and carefully add HF, dropwise, until the reaction ceases. A TFE-fluorocarbon beaker may be used if desired.

(b) (b) Add 30 mL of 1 + 1 sulfuric acid (H_2SO_4), 5 mL of phosphoric acid (H_3PO_4), and boil until light fumes of H_2SO_4 are present and the sample is completely dissolved.

(c) (c) Cool the solution, add 150 mL of water, heat to dissolve if necessary, and continue as in Test Methods E 350.

6.4.6 *Copper*:

6.4.6.1 Mill, lathe, or pulverize the sample to pass through a 100-mesh sieve.

6.4.6.2 Determine the copper in accordance with the sections on Copper by the Sulfide Precipitation-Electrodeposition Gravimetric Method in Test Methods E 350, or

6.4.6.3 Determine the copper in accordance with the sections on Copper by the Neocuproine Photometric Method, in Test Methods E 350. Add HF as required for complete solution of the sample.

7. Heat Treatment

7.1 High-silicon iron castings are generally used in the heat-treated (stress-relieved) condition. Small castings of simple configuration not conducive to high-residual stresses may be used in the as-cast condition. If the castings are to be supplied in the stress-relieved condition, the purchaser must so specify.

7.2 At its option, the foundry may heat treat the castings to remove stresses without the purchaser so specifying.

7.3 If used, the stress-relieving heat treatment shall be as follows:

7.3.1 Heat at a rate that will not crack the castings.

7.3.2 Hold the castings at a minimum temperature of 1600°F [870°C] for a minimum period of 1 h/in. [mm] of maximum section thickness, except that in no case shall the holding period be less than 2 h.

7.3.3 Cool the castings to 400°F [205°C] maximum at a rate not faster than 100°F [55°C]/15 min.

7.3.4 From 400°F [205°C] to ambient temperature, the castings may be cooled in still ambient air.

8. Mechanical Requirements

8.1 *Transverse Bend Test*:

8.1.1 When specified by the purchaser, the silicon-iron alloy shall be given a transverse bend test. The specimen tested shall meet the test requirements prescribed in Table 2.

TABLE 2 Transverse Bend Test Minimum Requirements

NOTE 1—Test bars are to be tested on supports 12 in. [3.5 mm] apart.

Load at center, min, lbf [N]	930 [4090]
Deflection at center, min, in. [mm]	0.026 [0.66]

8.1.2 When transverse bend tests are specified, test bars shall be made and tested from each heat (or ladle in the case of continuous melting) from which the castings are poured.

8.1.3 The test bars shall be heat treated in the production furnaces to the same procedure as the castings.

8.1.4 Each test bar shall be permanently marked with the heat or ladle number from which it was poured. Marking shall be accomplished with cast digits, with a vibratory marking tool, or with a felt-point pen using indelible ink.

8.2 *Hydrostatic Test*—When specified by the purchaser, subject the castings for critical applications involving pressure or vacuum conditions to a hydrostatic pressure test at a minimum of 40 psig [275 kPa]. Any leak revealed by this test shall be cause for rejection of the casting.

9. Transverse Bend Test Method

9.1 When a requirement for transverse bend tests has been agreed upon between the purchaser and the manufacturer, the manufacturer shall test transverse bend bar(s) from each heat.

9.2 Conduct the transverse bend test in accordance with Method A 438, except as follows:

9.2.1 Do not machine the specimen.

9.2.2 The specimen shall be sufficiently smooth, round, and straight to permit testing without machining.

9.2.3 Produce the specimen in accordance with Fig. 1.

9.2.4 The specimen shall conform to the dimensions shown in Fig. 2.

9.2.5 Report the actual breaking load without use of a correction factor. The requirements of Table 2 allow for deviation due to variations in test bar diameter. In the same sense, measure and report the deflection at fracture without correction.

9.2.6 Apply the load at a rate such that a 0.025-in. [0.65-mm] deflection is produced in 50 to 70 s. Continue loading at the same head-movement rate until the specimen fractures.

10. Workmanship, Finish, and Appearance

10.1 The workmanship and finish shall be as agreed upon between the manufacturer and the purchaser.

11. Number of Tests and Retests

11.1 If a valid test specimen fails to conform to this specification, two retests shall be made. If either retest fails to

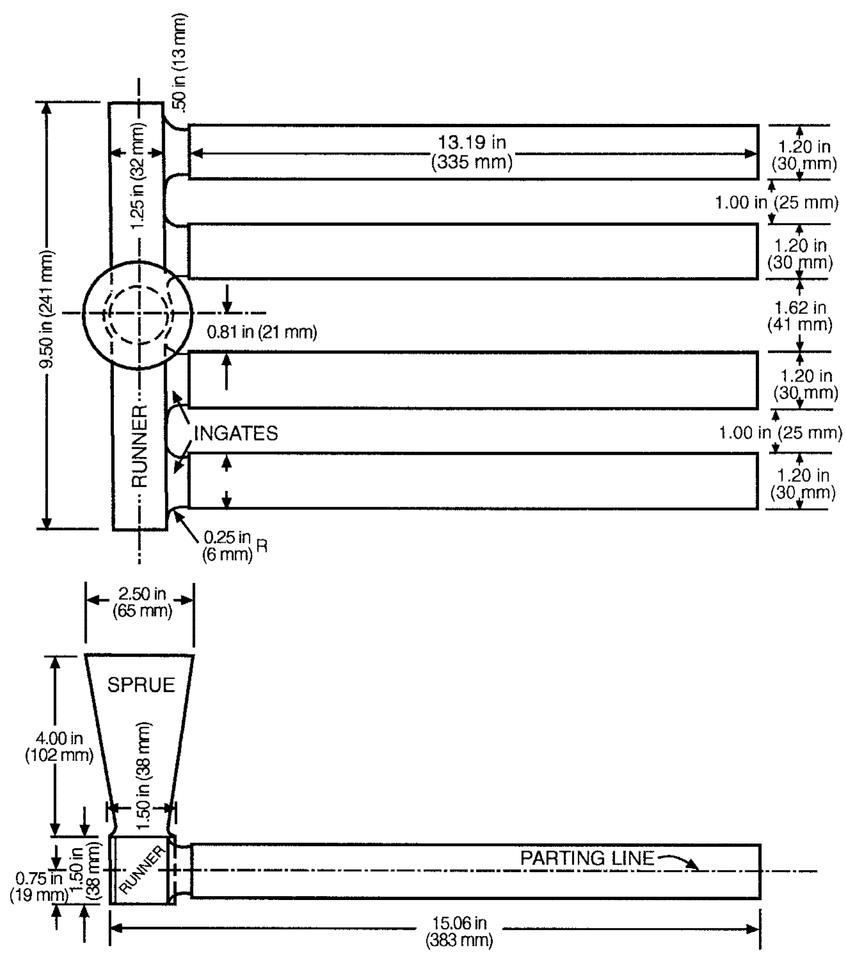
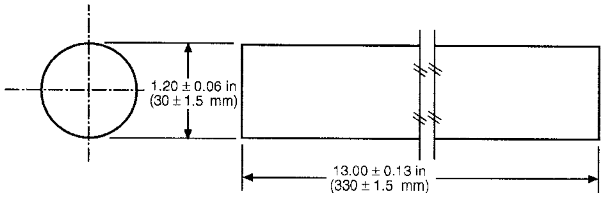


FIG. 1 Suggested Pattern for Transverse Bend Test Bar, Cast Horizontally, 1.20 in. [30.5 mm] in Diameter



NOTE 1—It is recommended that the casting be mold-cooled to below 1000°F [540°C] before shakeout, and that the test bars be stress-relieved before transverse testing.

FIG. 2 Transverse Bend Test Bar Dimensions

conform to this specification, the castings represented by these test bars shall be rejected.

11.2 If after testing, a test specimen shows evidence of a defect, the results of the test may be regarded as invalid and another test made.

11.3 In the absence of further separately cast test bars, the manufacturer shall have the option of submitting test bars sectioned from an agreed-upon position in the castings.

11.4 If reheat treatment is required to meet the specification, castings and their representative test bars shall be reheat treated together. Testing will then proceed as in 11.1, 11.2, and 11.3.

12. Inspection

12.1 When specified in the purchase order, the inspector representing the purchaser shall have access to the material subject to inspection for the purpose of witnessing the selection of the samples, the preparation of the test pieces, and the performance of the test(s). For such tests, the inspector shall have the right to indicate the pieces from which the samples will be taken in accordance with the provisions of this specification.

12.2 The manufacturer shall inspect the material covered by this specification prior to shipment and, upon request, shall furnish the purchaser with a certification of test(s).

13. Rejection and Rehearing

13.1 *Rejection*—Any rejection based on test reports shall be reported to the manufacturer within 30 days from the receipt of the test report by the purchaser. The manufacturer shall be advised within one week of purchaser's discovery of material that contains injurious defects. The purchaser shall hold the material a minimum of 30 days pending action by the manufacturer.

13.2 *Rehearing*—Samples tested in accordance with this specification that represent rejected material shall be preserved for two weeks from the date of the test report. In case of dissatisfaction with the results of the test, the manufacturer may make a claim for a rehearing within that time.

14. Certification

14.1 When specified by the purchaser, the manufacturer shall provide the purchaser with a certification stating that the castings meet the specified requirements. The certification shall include the results of any chemical analyses and mechanical tests.

15. Product Marking

15.1 The trademark of the manufacturer shall be legibly cast on each casting.

ANNEX

(Mandatory Information)

A1. SILICON BY THE FUSION-HYDROCHLORIC ACID DEHYDRATION METHOD

A1.1 This method may be used for the referee determination of silicon in high-silicon cast irons. All reagents are to be reagent grade. All water is to be deionized or triple-distilled.

A1.2 *Procedure*:

A1.2.1 *Preparation of Sample*—Pulverize a representative portion of the sample until the entire portion will pass a No. 100 sieve.

A1.2.2 Weigh 8 g of anhydrous sodium carbonate into a 50-mL nickel crucible.

A1.2.3 Weigh 0.5 g of pulverized sample and place on top of the sodium carbonate in the nickel crucible.

A1.2.4 Weigh 4 g of sodium peroxide and place on top of the sample in the nickel crucible.

A1.2.5 Stir carefully with a glass rod until the mixture is homogeneous.

NOTE A1.1—If a delay of 5 min or more is required before fusion of the sample, place the crucible and mixture in a desiccator or on a warm (122°F) hot plate.

A1.2.6 Fuse the mixture carefully over a flame from a Meker burner as follows: Grasp the crucible with a pair of tongs, and slowly revolve the crucible around the outer edge of the flame until the contents have melted down quietly. Increase the temperature of the flame by increasing the air pressure (decreasing the fuel-to-air ratio). Gradually, to avoid spattering, raise the temperature of the flame by passing the crucible in and out of the hotter flame. As the contents become molten, rotate the crucible to stir up any unattacked particles of sample adhering to the bottom or sides. Finally, hold the crucible in the flame (continue to rotate it) until the crucible is bright red for 1 min. Use eye and skin protection for this procedure.

A1.2.6.1 *Caution*:

A1.2.7 Allow the crucible to air cool to room temperature. Invert the crucible over an 800-mL beaker and tap the sides of the crucible gently with the crucible tongs. Finally, tap the bottom of the crucible firmly several times until the cake falls into the beaker. Cover the beaker with a watch glass.

A1.2.8 Fill the crucible with hot (50°C) water. Carefully, in small increments, add the rinse to the beaker. Keep the beaker partially covered, because the fusion cake effervesce as the water contacts it. Rinse the crucible with a stream of hot water (~5 mL) from a wash bottle, transferring particles of fusion cake to the beaker.

A1.2.9 Fill the crucible to above the cake line with HCl (1 + 3) and warm on the hot plate at about 70°C until all particles adhering to the crucible have loosened or dissolved. Transfer the rinse solution to the beaker, again guarding against excessive effervescence. Wash the crucible twice more with 5-mL portions of hot water from a wash bottle and add the rinsings to the beaker.

A1.2.10 Add 100 mL of HCl (1 + 1) to the 800-mL beaker. Cover with a ribbed watch glass and heat gently until all of the melt has dissolved (about 30 min). If undissolved sample remains, as indicated by effervescing particles, the fusion must be repeated.

A1.2.11 Add 2 mL of nitric acid (HNO_3) and evaporate the solution to dryness. As the volume is reduced, lower the temperature to approximately 70°C to avoid spattering.

A1.2.12 Cool the beaker and dry the residue to room temperature. Add 20 mL of HCl and warm gently (~70°C). Break up hard lumps with a glass rod. Add 200 mL of hot water and digest 3 to 5 min until salts have dissolved.

A1.2.13 Filter the solution into a 12.5-cm quantitative ashless general-purpose filter paper containing paper pulp. Collect the filtrate in an 800-mL beaker. Transfer the precipitate to the filter, and scrub the beaker thoroughly with a rubber policeman. With a stream of hot (50°C) water from a wash bottle, rinse the sides of the beaker and wash any remaining precipitate into the filter paper. Wash the precipitate alternately with 5-mL portions of hot HCl (1 + 19) and hot water, ten times each. Finally, wash three times with 5-mL portions of hot water. Reserve the precipitate and the filtrate.

A1.2.14 Stir the filtrate and again evaporate to dryness. When dry, continue to heat the residue for 30 min at a temperature not exceeding 110°C. Prolonged heating or heating at higher temperatures may result in insoluble oxides of iron.

A1.2.15 Cool the beaker to room temperature. Add 20 mL HCl and warm gently in accordance with A1.2.12. Break up lumps, add 200 mL hot water, and digest 3 to 5 min until salts have dissolved.

A1.2.16 Filter through an 11-cm quantitative ashless general-purpose filter paper containing paper pulp. Scrub the beaker thoroughly with a rubber policeman, then wash traces of precipitate into filter with a stream of hot water from a wash bottle. Wash the filter and precipitate alternately with 5-mL portions of hot HCl (1 + 19) and hot water, ten times each. Finally, wash the paper three times with hot water. Discard the filtrate (or reserve for determination of other elements).

A1.2.17 Transfer the 11-cm filter paper and precipitate into the 12.5-cm paper. Fold the two papers together and transfer to a platinum crucible.

A1.2.18 Char the papers at approximately 250°C in a muffle furnace. Gradually increase the temperature to 600°C, completely charring the paper without flaming. Heat at 600°C until all of the black carbon is removed. (This may require 3 h or more.) Ignite at 1100 to 1150°C for at least 50 min, or to constant weight. Cool in a desiccator and weigh to the nearest 0.1 mg.

A1.2.19 Moisten the precipitate with 1 to 2 ml of sulfuric acid (H_2SO_4) (1 + 1) and add 3 to 5 mL of HF. Heat gently until silica is dissolved and the solution is evaporated to dryness. Increase the temperature until fumes of H_2SO_4 are removed. Ignite at 1100 to 1150°C for 15 min. Cool in a desiccator and weigh to the nearest 0.1 mg.

A1.3 *Calculations*:

A1.3.1 Calculate the percentage of silicon as follows:

$$\text{Silicon, \%} = \frac{(A - B) \times 0.4675 \times 100}{C} \quad \text{(A1.1)}$$

where:
A = initial weight of crucible and impure silica, g,
B = final weight of crucible and residue, g, and
C = grams of sample used.

Designation: A 532/A 532M – 93a (Reapproved 2003)

Standard Specification for Abrasion-Resistant Cast Irons[1]

This standard is issued under the fixed designation A 532/A 532M; 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 a group of white cast irons that have been alloyed to secure high resistance to abrasive wear in the applications of the mining, milling, earth-handling, and manufacturing industries.

1.2 Simple and low-alloy white cast irons that consist essentially of iron carbides and pearlite are specifically excluded from this specification.

1.3 The values stated in inch-pound units or SI units are to be regarded separately as the standard. Within the text, 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 the specification.

2. Referenced Documents

2.1 *ASTM Standards:* [2]

E 10 Test Method for Brinell Hardness of Metallic Materials

E 18 Test Methods for Rockwell Hardness and Rockwell Superficial Hardness of Metallic Materials

E 92 Test Method for Vickers Hardness of Metallic Materials

E 350 Test Methods for Chemical Analysis of Carbon Steel, Low-Alloy Steel, Silicon Electrical Steel, Ingot Iron, and Wrought Iron

E 351 Test Methods for Chemical Analysis of Cast Iron—All Types

3. Ordering Information

3.1 Orders for material in this specification should include the following information:

3.1.1 Quantity,

3.1.2 Specification number, class, and type,

3.1.3 Description of the casting, pattern number, or drawing,

3.1.4 Chilling of the casting, if required (see 4.2),

3.1.5 Heat treat condition (see 5.1),

3.1.6 Hardness level, if supplied hardened or hardened and stress relieved, and

3.1.7 Hardness method, Brinell, Rockwell, Vickers (see Section 9). If the hardness method is not specified, it shall be at the manufacturer's option.

4. Method of Manufacture

4.1 These alloys may be made by any suitable melting process.

4.2 If the casting is to be chilled or otherwise specially treated on any portion, the inquiries and the purchase order shall so state and a properly marked drawing of the casting will accompany both the inquiry and the purchase order.

5. Heat Treatment

5.1 The casting will be supplied in one of the following conditions:

5.1.1 As-cast,

5.1.2 As-cast and stress relieved,

5.1.3 Hardened,

5.1.4 Hardened and stress relieved, or

5.1.5 Softened for machining.

5.2 Unless otherwise specified by the purchaser, the manufacturer shall supply the castings in the heat treatment he deems best for the application.

5.3 If the heat treatment specified for delivered condition is not that of final use, it shall be the responsibility of the purchaser to provide the additional heat treatment.

5.4 Class II and Class III alloys are frequently ordered in the annealed condition with a maximum hardness of 400 HB. After machining operations are performed the castings may then be hardened. If both annealing and machining are to be performed by the manufacturer, as specified in the inquiry, contract, or order, the purchaser may then specify delivery in the hardened condition. If the purchaser specifies delivery in the annealed condition, subsequent hardening (and stress-relief, if it is desired) is the responsibility of the purchaser.

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[1] This specification is under the jurisdiction of ASTM Committee A04 on Iron Castings and is the direct responsibility of Subcommittee A04.01 on Grey and White Iron Castings.

Current edition approved Jan. 15, 1993 and April 15, 1993. Published November 1993. Originally approved in 1965. Last previous edition approved in 1999 as A 532–93a (1999)$^{\epsilon 1}$.

[2] 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.

6. Chemical Composition

6.1 The composition of the metal of a class and type produced under this specification shall fall within the ranges prescribed in Table 1 for that class and type.

6.2 Spectrographic, X-ray, or wet chemical laboratory techniques are acceptable for routine and control determinations, but shall be standardized against, and give essentially the same results as, the umpire methods specified in 6.3 of this specification.

6.3 In case of dispute, umpire determinations of the chemical analysis of the metal shall be made using ASTM standard methods detailed as follows:

6.3.1 The following is in accordance with Test Methods E 351:

6.3.1.1 Carbon, Total by the Combustion Gravimetric Method.

6.3.1.2 Chromium by the Poroxydisulfate-Oxidation Titrimetric Method.

6.3.1.3 Copper by the Sulfide Precipitation-Electrodeposition Gravimetric Method.

6.3.1.4 Manganese by the Peroxydisulfate-Arsenite Titrimetric Method.

6.3.1.5 Nickel by the Dimethylglyoxime Gravimetric Method.

6.3.1.6 Phosphorus by the Molybdenum Blue Photometric Method.

6.3.1.7 Sulfur by the Combustion-Iodate Titration Method.

6.3.2 The following is in accordance with Test Methods E 350:

6.3.2.1 Molybdenum by the Photometric Method.

7. Microstructure

7.1 The alloys covered by this specification are expected to have microstructures that consist essentially of carbides, martensite, bainite, austenite; and in exceptional cases minor amounts of graphite or pearlite.

7.2 The microstructure will not be routinely determined nor reported except in accordance with special agreement between the manufacturer and the purchaser, or in cases of dispute.

8. Hardness Requirements

8.1 The castings shall conform to the hardness requirements specified in Table 2.

8.2 The hardness test shall be performed on the original surface of the casting or up to ⅛ in. (3 mm) below that surface.

9. Hardness Method

9.1 Perform the hardness test in accordance with one of the following methods to be specified by the purchaser:

9.1.1 Test Method E 10 (Brinell) using a tungsten carbide ball and 3000 kgf load,

9.1.2 Test Method E 18 (Rockwell) using a diamond cone penetrator, 150 kgf load, and the Rockwell C Scale, or

9.1.3 Test Method E 92 (Vickers).

10. Keywords

10.1 abrasion resistant; alloyed cast iron; cast iron; white cast iron

TABLE 1 Chemical Requirements, Weight %

Class	Type	Designation	Carbon	Manganese	Silicon	Nickel	Chromium	Molybdenum	Copper	Phosphorus	Sulfur
I	A	Ni-Cr-Hc	2.8–3.6	2.0 max	0.8 max	3.3–5.0	1.4–4.0	1.0 max	. . .	0.3 max	0.15 max
I	B	Ni-Cr-Lc	2.4–3.0	2.0 max	0.8 max	3.3–5.0	1.4–4.0	1.0 max	. . .	0.3 max	0.15 max
I	C	Ni-Cr-GB	2.5–3.7	2.0 max	0.8 max	4.0 max	1.0–2.5	1.0 max	. . .	0.3 max	0.15 max
I	D	Ni-HiCr	2.5–3.6	2.0 max	2.0 max	4.5-7.0	7.0–11.0	1.5 max	. . .	0.10 max	0.15 max
II	A	12 % Cr	2.0–3.3	2.0 max	1.5 max	2.5 max	11.0–14.0	3.0 max	1.2 max	0.10 max	0.06 max
II	B	15 % Cr-Mo	2.0–3.3	2.0 max	1.5 max	2.5 max	14.0–18.0	3.0 max	1.2 max	0.10 max	0.06 max
II	D	20 % Cr-Mo	2.0–3.3	2.0 max	1.0–2.2	2.5 max	18.0–23.0	3.0 max	1.2 max	0.10 max	0.06 max
III	A	25 % Cr	2.0–3.3	2.0 max	1.5 max	2.5 max	23.0–30.0	3.0 max	1.2 max	0.10 max	0.06 max

TABLE 2 Hardness Requirements

Class	Type	Designation	Hardness Value-HB															Typical Section Thickness
			Sand Cast, min[A]									Chill Cast, min[B]			Softened, max			
			As Cast or As Cast and Stress Relieved			Hardened or Hardened and Stress Relieved												
						Level 1			Level 2									
			HB	HRC	HV	HB	HRC	HV	HB	HRC	HV	HB	HRC	HV	HB	HRC	HV	
I	A	Ni-Cr-HiC	550	53	600	600	56	660	650	59	715	600	56	660	. . .	. . .	. . .	. . .
I	B	Ni-Cr-LoC	550	53	600	600	56	660	650	59	715	600	56	660	. . .	. . .	. . .	. . .
I	C	Ni-Cr-GB	550	53	600	600	56	660	650	59	715	600	56	660	400	41	430	. . .
I	D	Ni-HiCr	500	50	540	600	56	660	650	59	715	550	53	600	. . .	. . .	. . .	. . .
II	A	12 % Cr	550	53	600	600	56	660	650	59	715	550	53	600	400	41	430	. . .
II	B	15 % Cr-Mo	450	46	485	600	56	660	650	59	715	. . .	. . .	. . .	400	41	430	. . .
II	D	20 % Cr-Mo	450	46	485	600	56	660	650	59	715	. . .	. . .	. . .	400	41	430	. . .
III	A	25 % Cr	450	46	485	600	56	660	650	59	715	. . .	. . .	. . .	400	41	430	. . .

[A] 90 % of the minimum surface hardness level shall be maintained to a depth of 40 % of the casting section, with any softer material being at the thermal center of the casting. A sampling procedure should be established by agreement between the supplier and the purchaser.

[B] Non-chilled areas of casting shall meet minimum hardness or sand cast requirements.

Designation: A 536 – 84 (Reapproved 1999)$^{\epsilon 1}$

Standard Specification for Ductile Iron Castings[1]

This standard is issued under the fixed designation A 536; 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.

ϵ^1 NOTE—Keywords were added editorially in October 1999.

1. Scope

1.1 This specification covers castings made of ductile iron, also known as spheroidal or nodular iron, that is described as cast iron with the graphite substantially spheroidal in shape and essentially free of other forms of graphite, as defined in Definitions A 644.

1.2 The values stated in inch-pound units are to be regarded as the standard.

1.3 No precise quantitative relationship can be stated between the properties of the iron in various locations of the same casting or between the properties of castings and those of a test specimen cast from the same iron (see Appendix X1).

2. Referenced Documents

2.1 *ASTM Standards:*

A 370 Test Methods and Definitions for Mechanical Testing of Steel Products[2]

A 644 Terminology Relating to Iron Castings[3]

A 732/A 732M Specification for Castings, Investment, Carbon and Low–Alloy Steel for General Application, and Cobalt Alloy for High Strength at Elevated Temperatures[3]

E 8 Test Methods for Tension Testing of Metallic Materials[4]

2.2 *Military Standard:*

MIL-STD-129 Marking for Shipment and Storage[5]

3. Ordering Information

3.1 Orders for material to this specification shall include the following information:

3.1.1 ASTM designation,

3.1.2 Grade of ductile iron required (see Table 1, and Sections 4 and 9),

3.1.3 Special properties, if required (see Section 7),

3.1.4 If a different number of samples are required (see Section 10),

3.1.5 Certification, if required (see Section 14), and

3.1.6 Special preparation for delivery, if required (see Section 15).

4. Tensile Requirements

4.1 The iron represented by the test specimens shall conform to the requirements as to tensile properties presented in Table 1 and Table 2. The irons listed in Table 1 cover those in general use while those listed in Table 2 are used for special applications (such as pipes, fittings, etc.).

4.2 The yield strength shall be determined at 0.2 % offset by the offset method (see Test Methods E 8). Other methods may be used by mutual consent of the manufacturer and purchaser.

5. Heat Treatment

5.1 The 60-40-18 grade will normally require a full ferritizing anneal. The 120-90-02 and the 100-70-03 grades generally require a quench and temper or a normalize and temper, or an isothermal heat treatment. The other two grades can be met either as-cast or by heat treatment. Ductile iron, that is heat treated by quenching to martensite and tempering, may have substantially lower fatigue strength than as cast material of the same hardness.

6. Test Coupons

6.1 The separately cast test coupons from which the tension test specimens are machined shall be cast to the size and shape shown in Fig. 1 or Fig. 2. A modified keel block cast from the mold shown in Fig. 3 may be substituted for the 1-in. Y-block or the 1-in. keel block. The test coupons shall be cast in open molds made of suitable core sand having a minimum wall thickness of 1½ in. (38-mm) for the ½-in. (12.5 mm) and 1-in. (25-mm) sizes and 3-in. (75-mm) for the 3-in. size. The coupons shall be left in the mold until they have cooled to a black color (approximately 900°F (482°C) or less). The size of coupon cast to represent the casting shall be at the option of the purchaser. In case no option is expressed, the manufacturer shall make the choice.

[1] This specification is under the jurisdiction of the ASTM Committee A-4 on Castings and is the direct responsibility of Subcommittee A04.02 on Malleable and Ductile Iron Castings.

Current edition approved June 15, 1984. Published December 1984. Originally published as A 536 – 65T. Last previous edition A 536 – 80.

[2] *Annual Book of ASTM Standards*, Vol 01.03.

[3] *Annual Book of ASTM Standards*, Vol 01.02.

[4] *Annual Book of ASTM Standards*, Vol 03.01.

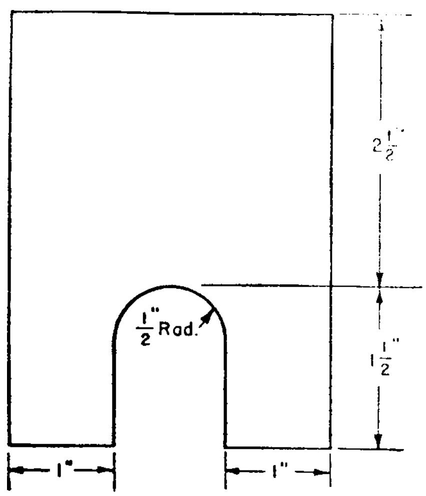
[5] Available from Standardization Documents Order Desk, Bldg. 4 Section D, 700 Robbins Ave., Philadelphia, PA 19111-5094, Attn: NPODS.

TABLE 1 Tensile Requirements

	Grade 60-40-18	Grade 65-45-12	Grade 80-55-06	Grade 100-70-03	Grade 120-90-02
Tensile strength, min, psi	60 000	65 000	80 000	100 000	120 000
Tensile strength, min, MPa	414	448	552	689	827
Yield strength, min, psi	40 000	45 000	55 000	70 000	90 000
Yield strength, min, MPa	276	310	379	483	621
Elongation in 2 in. or 50 mm, min, %	18	12	6.0	3.0	2.0

TABLE 2 Tensile Requirements for Special Applications

	Grade 60-42-10	Grade 70-50-05	Grade 80-60-03
Tensile strength, min, psi	60 000	70 000	80 000
Tensile strength, min, MPa	415	485	555
Yield strength, min, psi	42 000	50 000	60 000
Yield strength, min, MPa	290	345	415
Elongation in 2 in. or 50 mm, min, %	10	5	3

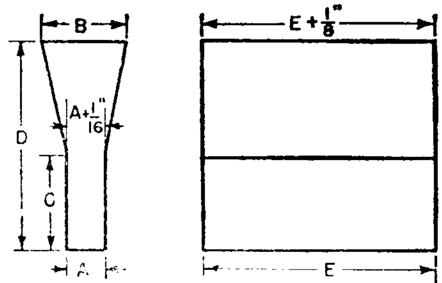


Metric Equivalents

in.	mm	in.	mm
½	12.7	1½	38.1
1	25.4	2½	63.5

NOTE—The length of the keel block shall be 6 in. (152 mm).

FIG. 1 Keel Block for Test Coupons



Dimensions	"Y" Block Size: For Castings of Thickness Less Than ½ in. (13 mm), in.	mm	For Castings of Thickness ½ in. (13 mm) to 1½ in. (38 mm), in.	mm	For Castings of Thickness of 1½ in. (38 mm) and Over, in.	mm
A	½	13	1	25	3	75
B	1⅝	40	2⅛	54	5	125
C	2	50	3	75	4	100
D	4	100	6	150	8	200
E	7 approx	175 approx	7 approx	175 approx	7 approx	175 approx

FIG. 2 Y-Blocks for Test Coupons

6.2 When investment castings are made to this specification, the manufacturer may use test specimens cast to size incorporated in the mold with the castings, or separately cast to size using the same type of mold and the same thermal conditions that are used to produce the castings. These test specimens shall be made to the dimensions shown in Fig. 1 of Specification A 732 or Figs. 5 and 6 of Methods and Definitions A 370.

6.3 The manufacturer may use separately cast test coupons or test specimens cut from castings when castings made to this specification are nodularized or inoculated in the mold. Separately cast test coupons shall have a chemistry that is representative of castings produced from the ladle poured and a cooling rate equivalent to that obtained with the test molds shown in Figs. 1 and 2, Figs. 4-6, or Appendix X2. The size (cooling rate) of the coupon chosen to represent the casting should be decided by the purchaser. If test coupon size is not specified, the manufacturer shall make the choice. When test bars will be cut from castings, test bar location shall be agreed on by the purchaser and manufacturer and indicated on the casting drawing. The manufacturer shall maintain sufficient controls and control documentation to assure the purchaser that properties determined from test coupons or test bars are representative of castings shipped.

6.4 The test coupons shall be poured from the same ladle or heat as the castings they represent.

6.5 Test coupons shall be subjected to the same thermal treatment as the castings they represent.

7. Special Requirements

7.1 When specified in the contract or purchase order, castings shall meet special requirements as to hardness, chemical composition, microstructure, pressure tightness, radiographic soundness, magnetic particle inspection dimensions, and surface finish.

8. Workmanship, Finish, and Appearance

8.1 The castings shall be smooth, free of injurious defects, and shall conform substantially to the dimensions of the drawing or pattern supplied by the purchaser.

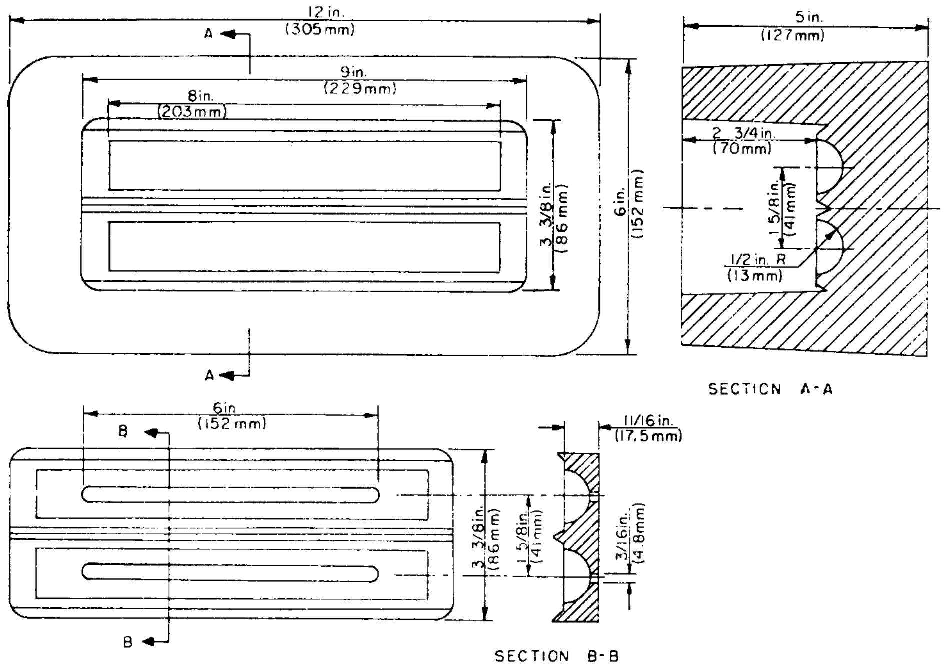


FIG. 3 Mold for Modified Keel Block

8.2 Castings shall not have chilled corners or center chill in areas to be machined.

9. Chemical Requirements

9.1 It is the intent of this specification to subordinate chemical composition to mechanical properties; however, any chemical requirements may be specified by agreement between the manufacturer and the purchaser.

10. Number of Tests and Retests

10.1 The number of representative coupons poured and tested shall be established by the manufacturer, unless otherwise agreed upon with the purchaser.

10.2 In the case of the Y-block, the section shall be cut from the block as shown in Fig. 4. If any tension test specimen shows obvious defects, another may be cut from the same test block or from another test block representing the same metal.

11. Tension Test Specimen

11.1 The standard round tension test specimen with a 2-in. or 50-mm gage length shown in Fig. 5 shall be used, except when the ½-in. (12.7-mm) Y-block coupon is used. In this case, either of the test specimens shown in Fig. 6 shall be satisfactory.

12. Responsibility for Inspection

12.1 Unless otherwise specified in the contract or purchase order, the supplier is responsible for the performance of all inspection requirements as specified herein. Except as otherwise specified in the contract or order, the supplier may use his own or any other facilities suitable for the performance of the inspection requirements specified herein, unless disapproved by the purchaser. The purchaser reserves the right to perform any of the inspections set forth in the specification where such inspections are deemed necessary to assure supplies and services conform to prescribed requirements.

13. Identification Marking

13.1 When size permits, each casting shall be identified by the part or pattern number in raised numerals. Location of marking shall be as shown on the applicable drawing.

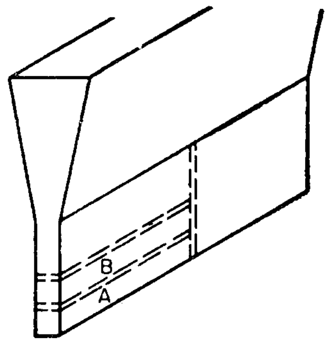
14. Certification

14.1 When agreed upon in writing by the purchaser and the seller, a certification shall be made the basis of acceptance of the material. This shall consist of a copy of the manufacturer's test report or a statement by the seller, accompanied by a copy of the test results, that the material has been sampled, tested, and inspected in accordance with provisions of this specification. Each certification so furnished shall be signed by an authorized agent of the seller or manufacturer.

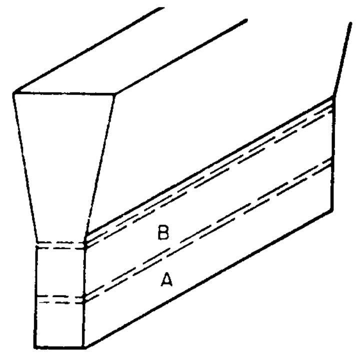
15. Preparation for Delivery

15.1 Unless otherwise specified in the contract or purchase order, cleaning, drying, preservation, and packaging of casting shall be in accordance with manufacturer's commercial practice. Packing and marking shall also be adequate to ensure acceptance and safe delivery by the carrier for the mode of transportation employed.

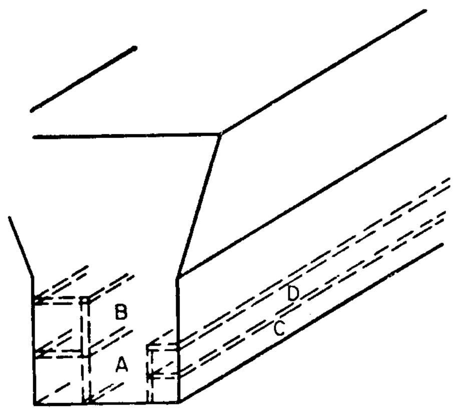
15.2 *Government Procurement*—When specified in the contract or purchase order marking for shipment shall be in accordance with the requirements of MIL-STD-129.



(*a*) ½-*in.* (*12.7-mm*) *Y-block*—Two blanks for 0.252-in. (6.40-mm) diameter test specimens.

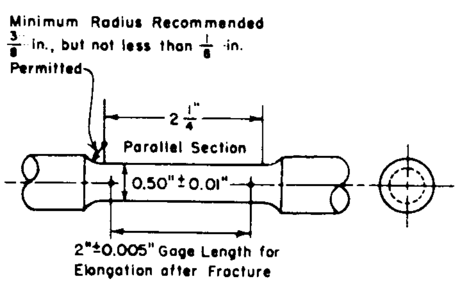


(*b*) *1-in.* (*25.4-mm*) *Y-Block*—Two blanks for 0.50-in. (12.7-mm) diameter tension test specimens.



(*c*) *3-in.* (*76.2-mm*) *Y-Block*—Two blanks for 0.50-in. (12.7-mm) diameter tension test specimens.

FIG. 4 Sectioning Procedure for Y-Blocks

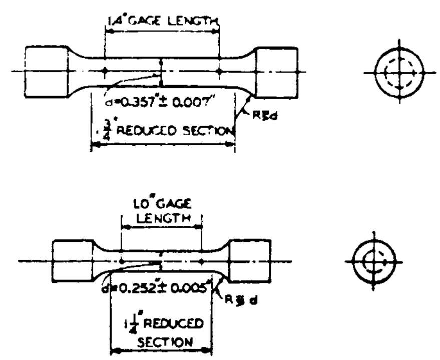


Metric Equivalents

in.	mm	in.	mm
0.005	0.13	0.50	12.7
0.10	2.5	2	50.8
⅛	3.2		
⅜	9.5	2¼	57.2

NOTE—The gage length and fillets shall be as shown but the ends may be of any shape to fit the holders of the testing machine in such a way that the load shall be axial. The reduced section shall have a gradual taper from the ends toward the center, with the ends 0.003 to 0.005 in. (0.08 to 0.13 mm) larger in diameter than the center.

FIG. 5 Standard Round Tension Test Specimen with 2-in. or 50-mm Gage Length



Metric Equivalents

in.	mm	in.	mm
0.005	0.13	1.0	25.4
0.007	0.18	1¼	31.8
0.252	6.40	1.4	35.6
0.357	9.07	1¾	44.4

NOTE—If desired, the length of the reduced section may be increased to accommodate an extensometer.

FIG. 6 Examples of Small-Size Specimens Proportional to Standard ½-in. (12.7-mm) Round Specimen

16. Keywords

16.1 casting; ductile iron; modular iron; spheroidal graphite

APPENDIXES

(Nonmandatory Information)

X1. MECHANICAL PROPERTIES OF CASTINGS

X1.1 The mechanical properties of iron castings are influenced by the cooling rate during and after solidification, by chemical composition, by heat treatment, by the design and nature of the mold, by the location and effectiveness of gates and risers, and by certain other factors.

X1.2 The cooling rate in the mold and, therefore, the properties developed in any particular section are influenced by the presence of cores, chills and chaplets, changes in section thickness, and the existence of bosses, projections, and intersections, such as junctions of ribs and bosses. Because of the interactions of these factors, no precise quantitative relationship can be stated between the properties of the iron in various locations of the same casting or between the properties of a casting and those of a test specimen cast from the same iron. When such a relationship is important and must be known for a specific application, it may be more closely ascertained by appropriate experimentation.

X1.3 When reliable information is unavailable on the relationship between properties in a casting and those in a separately cast test specimen, and where experimentation would be unfeasible, the size of the test casting should be so selected as to approximate the cooling rate of the main or controlling section of the casting.

X2. Y-BLOCK SELECTION

X2.1 As a general guide for selection of the proper Y-block, the tabulation in Table X2.1, based on cooling rates, shows, for various test coupons, the equivalent geometric shapes with various dimensions.

TABLE X2.1 Equivalent Geometric Shapes Corresponding to Y-Blocks

Y-Block Size, in. (mm)	Infinite Plate Thickness, in. (mm)	Round Diameter, in. (mm)	Cube Edge, in. (mm)
½ (12.7)	0.5 (12.7)	1.2 (30.5)	1.75 (44.4)
1 (25.4)	0.9 (22.9)	1.75 (44.4)	2.75 (69.8)
3 (76.2)	1.6 (40.6)	3.1 (78.7)	4.8 (121.9)

Designation: A 550 – 78 (Reapproved 2000)

Standard Specification for Ferrocolumbium[1]

This standard is issued under the fixed designation A 550; 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 three grades of ferrocolumbium, designated Low-Alloy Steel Grade, Alloy and Stainless Steel Grade, and High-Purity Grade.

1.2 The values stated in inch-pound units are to be regarded as the standard.

2. Referenced Documents

2.1 *ASTM Standards:*

E 11 Specification for Wire-Cloth Sieves for Testing Purposes[2]

E 29 Practice for Using Significant Digits in Test Data to Determine Conformance with Specifications[2]

E 31 Methods for Chemical Analysis of Ferroalloys[3]

E 32 Practices for Sampling Ferroalloys and Steel Additives for Determination of Chemical Composition[3]

3. Ordering Information

3.1 Order for material to this specification shall include the following information:

3.1.1 Quantity,

3.1.2 Name of material,

3.1.3 ASTM designation and year of issue,

3.1.4 Grade (Section 1),

3.1.5 Size, if appropriate (Section 5), and

3.1.6 Special requirements for packing, inspection, analysis reports, etc., as appropriate.

NOTE 1—A typical ordering description is as follows: 100 000 lb ferrocolumbium, ASTM A 550, Low-Alloy Steel Grade, 2 in. (51 mm) by Down, packed in sealed containers.

3.2 Although ferrocolumbium is purchased by total net weight, the customary basis of payment is on the contained weight of columbium.

4. Chemical Composition

4.1 The various grades shall conform to the requirements as to chemical composition specified in Table 1 and Table 2.

4.2 *Chemical Analysis*—The chemical analysis of the material shall be made in accordance with Methods E 31. Where no method is given in Methods E 31 for the analysis for a particular element, the analysis shall be made in accordance with a procedure agreed upon by the manufacturer and purchaser.

5. Sizing

5.1 Ferrocolumbium is available in these sizes: 2 in. (50.8 mm) by down, ½ in. (12.7 mm) by down, ¼in. (6.35 mm) by down, 8 mesh (2.38 mm) by down and 20 mesh (0.841 mm) by down. Other sizes may be specified as agreed upon. The size shall be specified in the order.

5.2 Size tolerances as given in Table 3 shall apply.

6. Sampling

6.1 The material shall be sampled in accordance with Practices E 32.

6.2 Other methods of sampling which have been agreed upon by manufacturer and purchaser may be used. In case of discrepancy, Practices E 32 shall be used for referee.

7. Inspection

7.1 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.

8. Rejection

8.1 Any claims or rejections based upon check analysis shall be made to the manufacturer within 45 days from the receipt of the material by the purchasers.

9. Packaging and Package Marking

9.1 *Packaging*:

9.1.1 Ferrocolumbium shall be packed so that it will be protected from loss or damage during shipment.

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[1] This specification is under the jurisdiction of ASTM Committee A-1 on Steel, Stainless Steel, and Related Alloys and is the direct responsibility of Subcommittee A 01.18 on Castings.

Current edition approved April 28, 1978. Published June 1978. Originally published as A 550 – 65. Last previous edition A 550 – 73.

[2] *Annual Book of ASTM Standards*, Vol 14.02.

[3] *Annual Book of ASTM Standards*, Vol 03.05.

TABLE 1 Chemical Requirements[A]

NOTE—An analysis report on each lot is required.

Element	Composition, %		
	Low-Alloy Steel Grade	Alloy and Stainless Steel Grade	High-Purity Grade
Columbium[B]	60.0–70.0	60.0–70.0	60.0–70.0
Tantalum, max	5.0	2.0	0.50[C]
Carbon, max	0.5	0.3	0.10
Manganese, max	3.0	2.0	0.50
Silicon, max	4.0	2.5	0.40
Aluminum, max	3.0[D]	2.0[D]	2.0[E]
Tin, max	0.25	0.15	0.02
Phosphorus, max	0.10	0.05	0.02
Sulfur, max	0.10	0.05	0.02

[A] To determine conformance with this specification, the reported analysis shall be rounded to the nearest unit in the last right-hand place of figures used in expressing the limiting value, in accordance with the rounding method of Recommended Practice E 29.

[B] To determine the columbium content of any shipment, columbium shall be reported to the nearest 0.1 %, applying the same rounding procedure as prescribed in Footnote *A*.

[C] Or 0.25 % maximum as agreed between purchaser and seller.

[D] Or 1.50 % maximum as agreed between purchaser and seller.

[E] Or 1.0 maximum as agreed between purchaser and seller.

9.1.2 When shipment is required to be in containers under the provisions of Section 3, the containers shall be sound and capable of protecting the material from loss or damage during shipment and handling.

9.2 *Marking*:

9.2.1 When the shipment is made in bulk, it shall be accompanied by appropriate identification showing the material, the grade designation, the ASTM designation, the size, the lot number and the name, brand, or trademark of the manufacturer.

TABLE 2 Supplementary Chemical Requirements

NOTE—These are maximum limits allowable unless otherwise stated.[A]

Element	Composition, %		
	Low-Alloy Steel Grade	Alloy and Stainless Steel Grade	High-Purity Grade
Chromium	1.00	1.00	0.10
Tungsten	1.00	0.5	0.05
Titanium	1.00	1.0	0.10
Lead	0.25	0.01	0.01
Cobalt	0.25	0.05	0.05

[A] The composition of the ferrocolumbian shall be within these limits; however, an analysis of each lot is not required. Upon request, the manufacturer shall supply the results of an analysis for these elements on terms previously agreed upon by the manufacturer and purchaser.

TABLE 3 Standard Sizes and Tolerances

Standard Size	Tolerance[A]	Friability Rating
2 in. by down	10 % max retained on 2-in. (50-mm) sieve 10 % max passing No. 8 (2.36-mm) sieve	4
½ in. by down	10 % max retained on ½-in. (12.5-mm) sieve	4
¼ in. by down	10 % max retained on ¼-in. (6.3-mm) sieve	4
8 mesh by down	10 % max retained on No. 8 (2.36-mm) sieve	4
20 mesh by down	10 % max retained on No. 20 (850-ϵm) sieve	4

[A] Specifications of sieve sizes used to define tolerances herein are as listed in Specification E 11.

9.2.2 When the shipment is made in containers, each container shall be marked or a label or tag attached. The marking shall show the material, the grade designation, the ASTM designation, the size, the lot number, gross, tare and net weight, and the name, brand, or trademark of the manufacturer.

10. Keywords

10.1 columbium; ferrocolumbium; tantalum

Standard Specification for Castings, Chromium-Nickel Alloy[1]

This standard is issued under the fixed designation A 560/A 560M; 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 chromium-nickel alloy castings intended for heat-resisting and elevated-temperature corrosion applications such as structural members, containers, supports, hangers, spacers, and the like in corrosive environments up to 2000°F [1090°C].

1.2 The values stated in either inch-pound units or SI units are to be regarded separately as standard. Within the test, 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 the specification.

2. Referenced Documents

2.1 *ASTM Standards:*

A 370 Test Methods and Definitions for Mechanical Testing of Steel Products[2]

A 781/A 781M Specification for Castings, Steel and Alloy, Common Requirements, for General Industrial Use[3]

3. General Conditions for Delivery

3.1 Material furnished to this specification shall conform to the requirements of Specification A 781/A 781M, including any supplementary requirements that are indicated in the purchase order. Failure to comply with the general requirements of Specification A 781/A 781M constitutes nonconformance with this specification. In case of conflict between the requirements of this specification and Specification A 781/A 781M, this specification shall prevail.

4. Ordering Information

4.1 The purchaser should specify the alloy grade desired and whether tension tests are required, and shall include standards of acceptance where necessary.

5. Materials and Manufacture

5.1 *Process*—The alloy for the castings shall be made by the electric-arc or induction-furnace process unless otherwise agreed upon between the manufacturer and the purchaser. Castings may be poured in sand, shell, investment, or centrifugal molds.

5.2 *Heat Treatment*—Castings may be shipped in the as-cast condition. If heat treatment is required the treatment shall be established by mutual consent between the manufacturer and purchaser and shall be so specified in the inquiry, purchase order, or contract.

6. Chemical Composition

6.1 The castings shall conform to the requirements as to chemical composition prescribed in Table 1.

7. Tensile Properties

7.1 Tensile properties, if required, of the alloy used for the castings shall conform to the requirements prescribed in Table 2.

7.2 Tension tests, if required, shall be performed in accordance with Test Methods and Definitions A 370.

8. Test Specimens

8.1 Test specimens, if required, shall be prepared in accordance with Test Methods and Definitions A 370. Test bars shall be poured in special blocks from the same heat as the castings represented. Test bars, if required, shall be furnished in sufficient number to furnish specimens for the test required in Section 9.

8.2 The test coupons shall be cast from the same melt from which the castings they represent are poured, and shall represent the full melting practice. Chemical composition of the test coupons shall conform to the requirements prescribed in Table 1.

8.3 Tension test specimens shall be machined to the form and dimensions of the standard round 2-in. [50-mm] gage length specimen shown in Fig. 4 of Test Methods and Definitions A 370.

[1] This specification is under the jurisdiction of ASTM Committee A-1 on Steel, Stainless Steel, and Related Alloys and is the direct responsibility of Subcommittee A01.18 on Castings.

Current edition approved Dec. 15, 1993. Published February 1994. Originally published as A 560 – 66. Last previous edition A 560 – 89.

[2] *Annual Book of ASTM Standards*, Vol 01.03.

[3] *Annual Book of ASTM Standards*, Vol 01.02.

TABLE 1 Chemical Requirements[A]

Element	Composition, %		
	Grade		
	50 Cr-50 Ni	60 Cr-40 Ni	50 Cr-50 Ni-Cb (R20501)
Carbon, max	0.10	0.10	0.10
Manganese, max	0.30	0.30	0.30
Silicon, max	1.00	1.00	0.50
Sulfur, max	0.02	0.02	0.02
Phosphorus, max	0.02	0.02	0.02
Nitrogen, max	0.30	0.30	0.16
Nitrogen + Carbon, max	. . .	. . .	0.20
Iron, max	1.00	1.00	1.00
Titanium, max	0.50	0.50	0.50
Aluminum, max	0.25	0.25	0.25
Columbium	. . .	. . .	1.4–1.7
Chromium	48.0–52.0	58.0–62.0	47.0–52.0
Nickel	balance	balance	balance

[A] The total of the nickel, chromium, and columbium contents must exceed 97.5 %.

TABLE 2 Room Temperature Tensile and Charpy Requirements

	50 Cr-50 Ni	60 Cr-40 Ni	50 Cr-50 Ni-Cb (R20501)
Tensile strength, min, ksi [MPa]	80 [550]	110 [760]	80 [550]
Yield point, min, ksi [MPa]	50 [340]	85 [590]	50 [345]
Elongation in 2 in. [50 mm], min, %	5.0	. . .	5.0
Impact, unnotched, Charpy, min, ft·lbf [J]	50 [78]	10 [14]	. . .

8.4 Impact test specimens shall conform to the length and cross section dimensions of the specimens shown in Fig. 10 of Test Methods and Definitions A 370. The impact specimens are to be broken unnotched.

9. Number of Tests and Retests

9.1 *Tension Test*—One tension test, if required, shall be made from each melt.

9.2 *Impact Test*—One unnotched Charpy impact test, if required, shall be made from each melt.

9.3 *Retests*:

9.3.1 Retest of a duplicate specimen will be allowed if the results of the mechanical tests for any lot do not conform to the requirements specified in Table 2.

9.3.2 If the percentage of elongation of any tension test specimen is less than specified in Table 2 and any part of the fracture is more than ¾ in. [19.0 mm] from the center of the gage length, as indicated by scribe scratches marked on the specimen before testing, a retest shall be allowed.

10. Keywords

10.1 chromium-nickel alloys; corrosion; high temperature applications; steel castings

SUPPLEMENTARY REQUIREMENTS

The following supplementary requirements shall not apply unless specified in the purchase order. A list of standardized supplementary requirements for use at the option of the purchaser is included in Specification A 781/A 781M. Those which are ordinarily considered suitable for use with this specification are given below. Others enumerated in Specification A 781/A 781M may be used with this specification upon agreement between the manufacturer and the purchaser.

S2. Radiographic Examination

S3. Liquid Penetrant Examination

S8. Marking

Designation: A 571/A 571M – 01

Standard Specification for Austenitic Ductile Iron Castings for Pressure-Containing Parts Suitable for Low-Temperature Service[1]

This standard is issued under the fixed designation A 571/A 571M; 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[2] covers austenitic ductile iron, Type D-2M, Classes 1 and 2, for compressors, expanders, pumps, valves, and other pressure-containing parts intended primarily for low-temperature service.

1.2 These grades of austenitic ductile iron are characterized by having their graphite substantially in a spheroidal form and free of flake graphite. They are essentially free of carbides and contain sufficient alloy content to produce a stable austenitic matrix down to −423°F [−252°C] (liquid hydrogen).

1.3 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 shall be used independently of the other. Combining values from the two systems may result in nonconformance with the specification.

1.4 The following precautionary caveat pertains only to the test methods portion, Section 11, 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 941 Terminology Relating to Steel, Stainless Steel, Related Alloys, and Ferroalloys[3]

E 8 Test Methods for Tension Testing of Metallic Materials[4]

E 23 Test Methods for Notched Bar Impact Testing of Metallic Materials[4]

E 30 Test Methods for Chemical Analysis of Steel, Cast Iron, Open-Hearth Iron, and Wrought Iron[5]

E 59 Practice for Sampling Steel and Iron for Determination of Chemical Composition[6]

3. Ordering Information

3.1 Orders for material under this specification shall include the following information:

3.1.1 Quantity (weight or number of pieces),

3.1.2 ASTM designation and year of issue,

3.1.3 Material class (Table 1),

3.1.4 Impact test temperature requirement (Section 11),

3.1.5 Place of inspection (Section 13), and

3.1.6 Certification requirements (Section 14).

4. Materials and Manufacture

4.1 *Material*—The iron shall be made in the electric-arc furnace, induction furnace, cupola, or any other furnace which is capable of producing castings meeting the chemical compositions and mechanical properties in this specification.

4.2 *Heat Treatment*:

4.2.1 All castings shall be heat treated.

4.2.2 Heat treatment shall be performed before machining except in instances when reheat treating is necessary.

4.2.3 Heat treatment shall consist of annealing. The procedure for this type treatment shall consist of heating the casting to a minimum of 1600°F [870°C] but not greater than 1800°F [980°C] holding at that temperature not less than 1 h/in. [1 h/25 mm] of section and furnace cooling. (See Terminology A 941.)

5. Chemical Requirements

5.1 Drillings taken from test coupons, broken test specimens or castings shall conform to the requirements as to chemical composition prescribed in Table 2.

5.2 The chemical analysis for total carbon shall be made on either chilled cast pencil-type specimens or thin wafers approximately 1⁄32-in. [0.8-mm] thick cut from test coupons. Drillings shall not be used because of attendant loss of graphite.

6. Physical Property Requirements

6.1 *Tensile Properties*—The room temperature mechanical properties of the two classes of ductile iron used for the casting

[1] This specification is under the jurisdiction of the ASTM Committee A04 on Iron Castings and is the direct responsibility of Subcommittee A04.02 on Malleable and Ductile Iron Castings.

Current edition approved Nov. 10, 2001. Published January 2002. Originally published as A 571 – 66. Last previous edition A 571 – 84 (1997).

[2] For ASME Boiler and Pressure Vessel Code applications see related Specification SA-571 in Section II of that code.

[3] *Annual Book of ASTM Standards*, Vol 01.01.

[4] *Annual Book of ASTM Standards*, Vol 03.01.

[5] *Annual Book of ASTM Standards*, Vol 03.05.

[6] Discontinued. See 1995 *Annual Book of ASTM Standards*, Vol 03.05. (Replaced by E 1806, Vol 03.06.)

TABLE 1 Mechanical Property Requirements[A]

	Class 1	Class 2	Class 3	Class 4
Tensile Strength, min, ksi [mPa]	65	60	[450]	[415]
Yield Strength 0.2 % (offset), min, ksi [mPa][B]	30	25	[205]	[170]
Elongation, min, %	30	25	30	25
Brinell Hardness, 3000 kg [kgf]	121–171	111–171	121–171	111–171
Charpy V-notch, ft·lbf [J]				
min, average 3 tests	15	20	[20]	[27]
min, individual test[C]	12	15	[16]	[20]

[A] Heat-treated condition.
[B] Yield Strength shall be determined at 0.2 % offset by the offset method, see Test Methods E 8. Other methods may be agreed upon by mutual consent of manufacturer and purchaser.
[C] Not more than one test in a set of three may be below the minimum average required for the set of three.

TABLE 2 Chemical Requirements

Element	Composition, %
Total carbon	2.2–2.7[A]
Silicon	1.5–2.50
Manganese	3.75–4.5
Nickel	21.0–24.0
Chromium	0.20 max[B]
Phosphorus	0.08 max

[A] For castings with sections under ¼ in. [6 mm], it may be desirable to adjust the carbon upwards to a maximum of 2.90 %.
[B] Not intentionally added.

shall conform to the requirements for the heat-treated condition shown in Table 1.

6.2 *Impact Properties*—The notched-bar impact properties of the materials shall be determined by testing a set of three Charpy V-notch impact specimens to the energy absorption requirements shown in Table 1. The test temperature shall be agreed upon by the manufacturer and the purchaser. The energy absorption value shown in Table 1 are applicable at temperatures down to and including −320°F [−195°C].

6.3 *Brinell Hardness*—The room temperature hardness of test bars and castings shall conform to the requirements of Table 1.

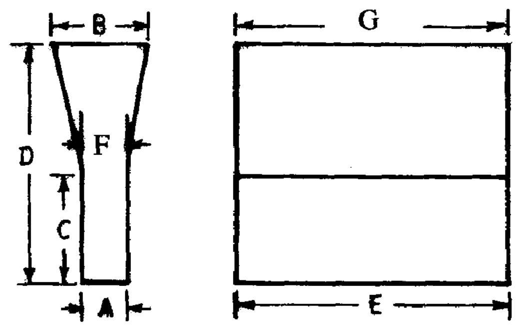
7. Workmanship, Finish, and Appearance

7.1 The castings shall conform to the dimensions and tolerances on the drawings furnished by the purchaser, or if no drawing has been provided, to the dimensions predicated by the pattern supplied by the purchaser. The castings shall be free from injurious defects. Surfaces of the castings shall be free of burnt-on sand and shall be reasonably smooth. Runners, risers, fins, and other useless cast-on pieces shall be removed. In other respects the castings shall conform to whatever points may be specifically agreed upon between the manufacturer and the purchaser.

8. Sampling

8.1 The standard test coupons shall be the 1-in. [25-mm] "Y" block and 1-in. [25-mm] keel block as shown in Fig. 1 and Fig. 2, respectively.

8.2 The separately cast test coupons from which the tension test specimens are machined shall be cast to the size and shape shown in Fig. 1 or Fig. 2. The size of coupon cast to represent the casting shall be at the option of the purchaser. In case no option is expressed, the manufacturer shall make the choice.



"Y" Block Size

Dimensions	For Castings of Thickness Less Than ½ in. [12.5 mm]	For Castings of Thickness ½ to 1½ in. [12.5 to 40 mm]	For Castings of Thickness of 1½ in. [40 mm] and Over
	in. [mm]	in. [mm]	in. [mm]
A	½ [12.5]	1 [25]	3 [75]
B	1 [25]	2⅛ [55]	5 [125]
C	2 [50]	3 [75]	4 [100]
D	4 [100]	6 [150]	8 [200]
E	7 [175] approx	7 [175] approx	7 [175] approx
F	9⁄16 [14]	1 1⁄16 [27]	3 1⁄16 [78]
G	7⅛ [180] approx	7⅛ [180] approx	7⅛ [180] approx

FIG. 1 "Y" Blocks for Test Coupons

8.3 Test coupons shall be poured immediately after the castings and from the same ladle of metal. Test coupons shall be left in the mold until they have cooled black. Test coupons shall be included in the same furnace load as the castings they represent (see Fig. 3).

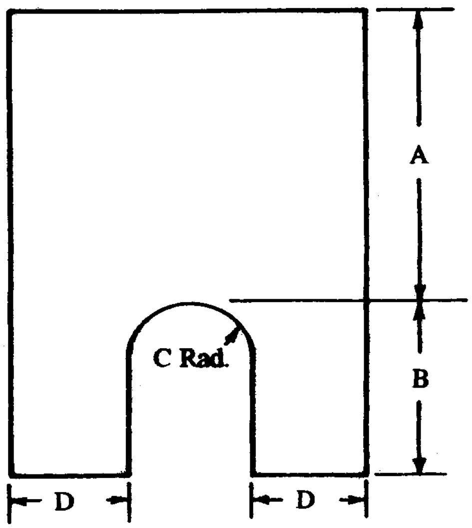
9. Number of Tests and Retests

9.1 Test coupons shall be poured from each ladle treated with nodulizing agent unless otherwise specified.

9.2 The number of representative coupons poured and tested shall be established by the manufacturer, unless otherwise agreed upon with the purchaser.

9.3 One tension test at room temperature and three impact tests at the required temperature shall be performed from each ladle treated with nodulizing agent unless otherwise specified.

9.4 If any test specimens (tension or impact) show obvious foundry defects, another specimen may be cut from the same test coupon or from another test coupon representing the same

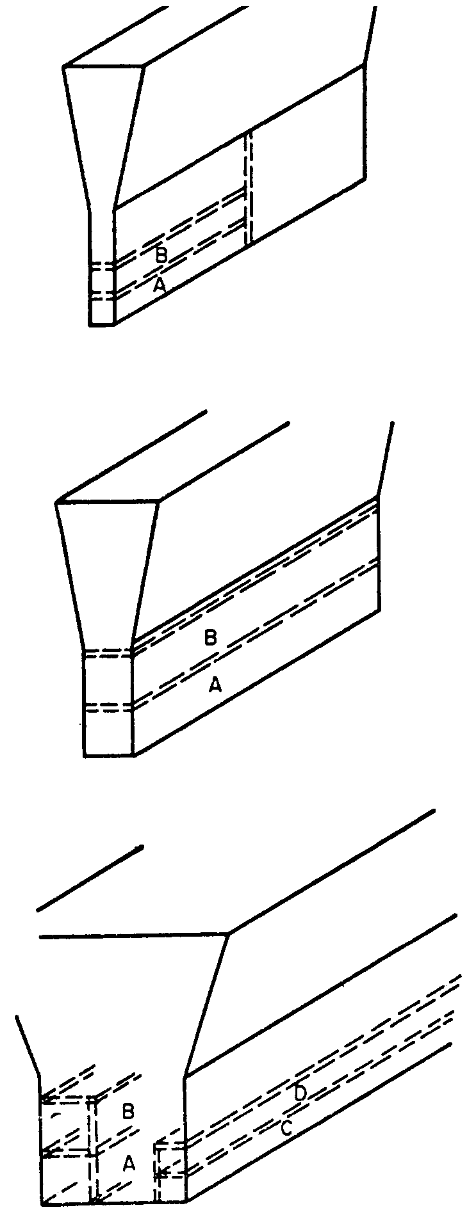


NOTE—The length of the keel block shall be 6 in. [150 mm].

Keel Block Dimensions

Dimensions	in.	[mm]
A	2½	60
B	1½	40
C	½	13
D	1	25

FIG. 2 Keel Block for Test Coupons



(*a*) ½-in. [12.5-mm] "Y"-Block—Two blanks for 0.252-in. [6.5-mm] diameter tension test specimens.
(*b*) 1-in. [25-mm] "Y"-Block—Two blanks for 0.50-in. [12.5-mm] diameter tension test specimens or impact specimens.
(*c*) 3-in. [75-mm] "Y"-Block—Two blanks for 0.50-in. [12.5-mm] diameter tension test specimens and two blanks for impact specimens.

FIG. 3 Sectioning Procedure for "Y" Blocks

metal. The manufacturer may reheat treat castings, but only once without requiring approval of the purchaser, if the test results do not conform to the requirements specified.

9.5 Failure of the retest specimen to conform to this specification shall be cause for rejection of the castings that they represent.

10. Specimen Preparation

10.1 Tension test specimens shall be the standard round specimen with 2-in. [50-mm] gage length (Fig. 4) except when the ½-in. [12.5-mm] "Y" block is being used. In this case, either of the test specimens shown in Fig. 5 shall be satisfactory.

10.2 Impact test specimens shall be machined to the form shown for Type A in Test Methods E 23.

11. Test Methods

11.1 *Chemical Analysis*—All chemical analyses shall be made in accordance with the following methods: Practice E 59, and Test Methods E 30, or by spectrographic methods. Should a dispute arise concerning the chemical composition when spectrographic techniques are used, the methods specified in Practice E 59 and Test Methods E 30 shall be used as umpire methods.

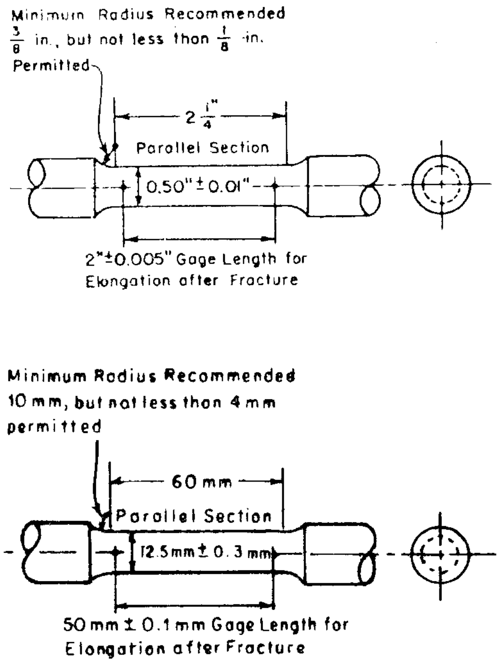
11.2 *Impact Test*:

11.2.1 The notched-bar impact test shall be made in accordance with the procedure for the simple beam Type A Charpy test described in Test Methods E 23.

11.2.2 In particular, impact tests at these low temperatures should be made with the following precautions: The impact test specimens as well as the handling tongs shall be cooled a sufficient time in a suitable container so that both reach the desired temperature. The temperature shall be measured with thermocouples, thermometers, or any other suitable devices and shall be controlled within ±10°F [6°C]. The specimens shall be quickly transferred from the cooling device to the anvil of the Charpy impact testing machine and broken with a time lapse of not more than 5 s.

12. Special Tests

12.1 *Hydrostatic Pressure Tests*:



NOTE—The gage length fillets shall be as shown but the ends may be of any shape to fit the holders of the testing machine in such a way that the load shall be axial. The reduced section shall have a gradual taper from the ends toward the center, with the ends 0.003 to 0.005 in. [0.08 to 0.13 mm] larger in diameter than the center.

FIG. 4 Standard Round Tension Test Specimen with 2-in. [50-mm] Gage Length

12.1.1 Each pressure-containing casting, where practicable, shall be tested after machining to the test pressure specified by any applicable code and shall show no leaks. Castings ordered under this specification not covered by any pertinent specification and castings ordered for special service applications shall be tested to such pressures as may be established by the purchaser.

12.1.2 Although the foundry cannot always perform the required pressure testing on unmachined castings, they shall be responsible for the satisfactory performance of the castings under the final tests required in 12.1.1.

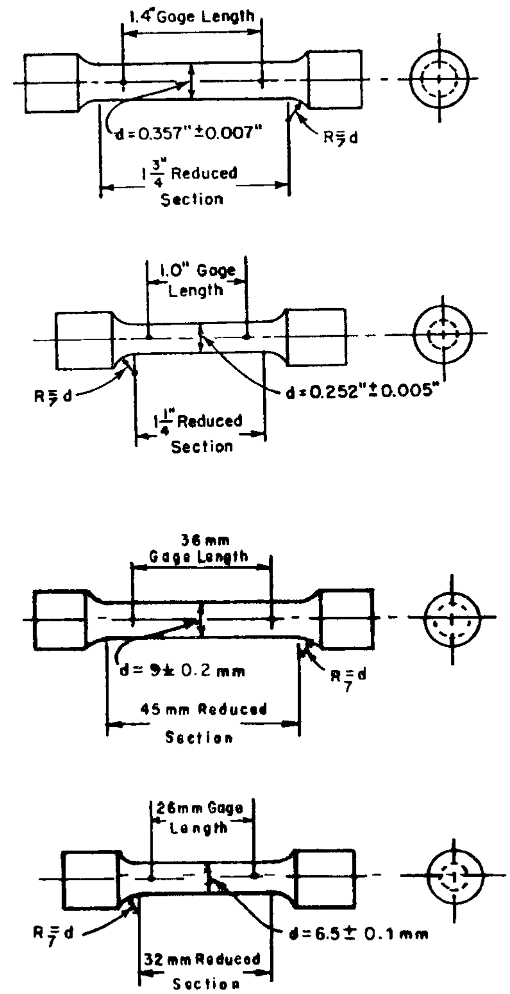
12.2 *Additional Tests*:

12.2.1 Radiographic standards, fracture tests, microstructure standards, liquid penetrant tests, or any other special tests may be required when so specified in the inquiry, contract or order and when mutually agreed upon by the manufacturer and purchaser.

12.2.2 Due to the very low magnetic permeability of this material, the magnetic particle inspection test is not an acceptable method of qualification.

13. Inspection

13.1 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



NOTE—If desired, the length of the reduced section may be increased to accommodate an extensometer.

FIG. 5 Examples of Small-Size Specimens Proportional to Standard ½-in. [12.5-mm] Round Specimen

which concern the manufacture of the materials ordered. The manufacturer 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 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.

14. Certification

14.1 When agreed upon in writing by the purchaser and the seller, a certification shall be made the basis of acceptance of the material. This shall consist of a copy of the manufacturer's test report or a statement by the seller, accompanied by a copy of the test results, that the material has been tested and inspected in accordance with the provisions of this specification. Each certification so furnished shall be signed by an authorized agent of the seller or manufacturer.

APPENDIX

(Nonmandatory Information)

X1. Y-BLOCK SELECTION

X1.1 As a general guide for selection of the proper Y-block, the tabulation in Table X1.1, based on coolingrates, shows, for various test coupons, the equivalent geometric shapes with various dimensions.

TABLE X1.1 Equivalent Geometric Shapes Corresponding to Y-blocks

Y-Block Size, in. [mm]	Infinite Plate, Thickness, in. [mm]	Round, Diameter, in. [mm]	Cube Edge, in. [mm]
½ [12.5]	0.5 [12.5]	1.2 [30]	1.75 [44]
1 [25]	0.9 [22.5]	1.75 [44]	2.75 [69]
3 [75]	1.6 [40]	3.1 [78]	4.8 [120]

Designation: A 601 – 96 (Reapproved 2000)

Standard Specification for Electrolytic Manganese Metal[1]

This standard is issued under the fixed designation A 601; 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 six grades of electrolytic manganese designated as follows:

	Grade
Regular	A
Intermediate Hydrogen	B
Low Hydrogen	C
4.5 % Nitrogen Bearing	D
6 % Nitrogen Bearing	E
Weld Grade Powder	F

2. Referenced Documents

2.1 *ASTM Standards:*

E 11 Specification for Wire-Cloth Sieves for Testing Purposes[2]

E 29 Practice for Using Significant Digits in Test Data to Determine Conformance With Specifications[2]

E 32 Practices for Sampling Ferroalloys and Steel Additives for Determination of Chemical Composition[3]

3. Ordering Information

3.1 Orders for material to this specification shall include the following information:

3.1.1 Quality,

3.1.2 Name of material,

3.1.3 ASTM designation and year of issue,

3.1.4 Grade (see 1.1),

3.1.5 Sizing, if appropriate (Section 6), and

3.1.6 Special requirements for packaging, inspection, analysis reports, etc., as appropriate.

4. Chemical Requirements

4.1 The various grades shall conform to the requirements as to chemical composition specified in Table 1 and Table 2.

4.2 The manufacturer shall furnish an analysis of each shipment showing the elements specified in the applicable table.

5. Size

5.1 The various grades are available in the sizes listed in Table 3.

5.2 The sizes listed in Table 3 are typical as shipped from the manufacturer's plant. These alloys exhibit varying degrees of friability; therefore, some attrition may be expected in transit, storage, and handling (see 5.3).

5.3 *Friability Ratings* (see Appendix):

Grades A, B, C	No. 6
Grades D, E	No. 5

6. Sampling

6.1 The material shall be sampled in accordance with Practices E 32.

6.2 Other methods of sampling that have been agreed upon between the manufacturer and the purchaser may be used. In case of discrepancy, Practices E 32 shall be used for referee.

7. Chemical Analysis

7.1 Chemical procedures for analysis of ferroalloy components are not standardized. The chemical content procedures must be mutually agreed upon between the purchaser and the manufacturer if there are differences in results.

7.2 *Special Analysis Requirements*—Analysis for additional elements other than those listed in Table 1 and Table 2 shall be agreed upon between the purchaser and the manufacturer. Such elements in trace quantities shall be reported as less than "<" the limit of analytical equipment. This shall be mutually agreed upon between the purchaser and the manufacturer.

7.3 For purposes of determining conformance with this specification, the reported analysis shall be rounded to the nearest unit in the last right-hand place of figures used in expressing the limiting value, in accordance with the rounding method of Practice E 29.

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[1] This specification is under the jurisdiction of ASTM Committee A-1 on Steel, Stainless Steel, and Related Alloys and is the direct responsibility of Subcommittee A01.18 on Castings.

Current edition approved May 10, 1996. Published June 1996. Originally published as A 601 – 69. Last previous edition A 601 – 69 (1990) $^{\epsilon 1}$.

[2] *Annual Book of ASTM Standards*, Vol 14.02.

[3] *Annual Book of ASTM Standards*, Vol 03.05.

TABLE 1 Chemical Requirements

Element	Composition, %					
	Regular A	Intermediate Hydrogen B	Low Hydrogen C	4.5 % Nitrogen Bearing D	6 % Nitrogen Bearing E	Weld Grade Powder F
Manganese, total	99.5 min	99.5 min	99.5 min	94–95[A]	93–94[A]	99.5 min
Manganese,[B] metallic	99.9 min[A]	99.9 min[A]	99.9 min[A]	[C]	[C]	99.9 min
Sulfur	0.030 max[A]	0.030 max	0.030 max	0.035 max	0.035 max	0.035 max
Hydrogen	0.015 max	0.005 max[A]	0.0010 max[A]	[C]	[C]	0.0030 max[A]
Nitrogen	[C]	[C]	[C]	4.0–5.4[A]	5.5–6.5[A]	[C]

[A] Analysis required with each lot.
[B] Percentage of total as metallic manganese.
[C] No requirement.

TABLE 2 Supplemental Chemical Requirements

Element, max	Composition, max, %					
	Regular A	Intermediate Hydrogen B	Low Hydrogen C	4.5 % Nitrogen Bearing D	6 % Nitrogen Bearing E	Weld Grade Powder F
Iron	0.005	0.005	0.005	0.005	0.005	0.08
Carbon	0.005	0.005	0.005	0.040	0.040	0.010
Phosphorus	0.001	0.001	0.001	0.001	0.001	0.001
Silicon	0.001	0.001	0.001	0.001	0.001	0.001
Aluminum	0.001	0.001	0.001	0.001	0.001	0.001

8. Inspection

8.1 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.

9. Rejection

9.1 Any claims of rejections based upon check analysis shall be made to the manufacturer within 45 days from the receipt of the material by the purchasers.

10. Packaging

10.1 When a shipment is made in bulk, it shall be accompanied by appropriate identification showing the name of the material, the grade designation, the ASTM designation, the lot number, and the name, brand, or trademark of the manufacturer.

10.2 When shipment is made in containers, each container shall be marked or a label or tag attached. The marking shall show the material, lot number, net weight, name, and brand or trademark of the manufacturer.

10.3 Color coding shall be used when shipment is made in containers. The color coding may be used in lieu of grade designation, if agreed upon between the purchaser and the manufacturer. The following colors shall be used to designate the grades:

Color	Designation	Grade
Blue	Regular	A
Purple	Intermediate Hydrogen	B
White	Low Hydrogen	C
Red	4.5 % Nitrogen Bearing	D
Yellow	6 % Nitrogen Bearing	E
No color	Weld Grade Powder	F

11. Packaging and Package Marking

11.1 The material shall be packed so that it will be protected from loss or damage during shipment.

11.2 When shipment is required to be in containers under the provision of Section 3, the containers shall be sound and capable of protecting the material from loss or damage during shipment and handling.

12. Keywords

12.1 electrolytic manganese; electrolytic manganese powder; intermediate hydrogen electrolytic manganese; low hydrogen electrolytic manganese; manganese metal; nitrogen bearing manganese; weld grade electrolytic manganese powder; weld grade powdered electrolytic manganese

TABLE 3 Standard Sizes and Tolerances

Grade	Standard Sizes	Tolerances[A]
Regular		15 % max retained on 2-in. (50.8-mm) sieve
Intermediate Hydrogen	Plate 2 in. (51 mm) by down	10 % max passing No. 8 (2.36-mm) sieve
Low Hydrogen		
4.5 % Nitrogen Bearing	Plate 2 in. (51 mm) by down	10 % max retained on 2-in. (50.8-mm) sieve
6 % Nitrogen Bearing		10 % max passing No. 10 (2.00-mm) sieve

[A] Specification of sieve sizes used to define tolerances herein are as listed in Specification E 11.

APPENDIX

(Nonmandatory Information)

X1. FRIABILITY RATINGS OF FERROALLOYS

X1.1 Descriptions of material of each friability rating are as follows:

Friability Code No.	Description
1	Very tough materials which are susceptible to little, if any, breakage during shipment or handling.
2	Some breakage of large pieces probable in shipping and handling. No appreciable fines produced from either lump or crushed sizes.
3	Appreciable reduction in size of large pieces possible in shipping and handling. No appreciable production of fines in handling of crushed sizes.
4	Appreciable reduction in size of large pieces upon repeated handling. Some fines produced upon repeated handling of crushed sizes.
5	Appreciable reduction in size in repeated handling of large pieces. Appreciable fines may be produced in the handling of crushed sizes.
6	This category represents the most friable alloys.

Standard Specification for Automotive Malleable Iron Castings[1]

This standard is issued under the fixed designation A 602; 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 castings of ferritic, pearlitic, tempered pearlitic, and tempered martensitic grades of malleable iron used in the products of the automotive and allied industries. Castings shall be heat treated to meet this specification.

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:* [2]

E 10 Test Method for Brinell Hardness of Metallic Materials

3. Grades

3.1 The specified grades with required hardness range and final heat treatment are shown in Table 1.

3.2 The foundry may also produce Grades M4504 and M5003 by liquid quenching and tempering or alloying, or both.

4. Hardness

4.1 The foundry shall exercise the necessary controls and inspection procedures to ensure compliance with the specified hardness range. Hardness readings shall be taken in accordance with Test Method E 10 after sufficient material has been removed from the casting surface to ensure representative hardness readings. The area or areas on the casting where hardness is to be checked shall be established by agreement between supplier and purchaser and shown on the drawing.

5. Microstructure Requirements

5.1 *Grade M3210 Ferritic Malleable Iron*:

TABLE 1 Grades of Malleable Iron

Grade	Casting Hardness Range	Heat Treatment
M3210	156 HB max 4.8 BID[A] min	annealed
M4504	163–217 HB 4.7–4.1 BID[A]	air quenched and tempered
M5003	187–241 HB 4.4–3.9 BID[A]	air quenched and tempered
M5503	187–241 HB 4.4–3.9 BID[A]	liquid quenched and tempered
M7002	229–269 HB 4.0–3.7 BID[A]	liquid quenched and tempered
M8501	269–302 HB 3.7–3.5 BID[A]	liquid quenched and tempered

[A] Brinell impression diameter (BID) is the diameter in millimetres of the impression of a 10-mm ball at 3000-kg load.

5.1.1 The microstructure of Grade M3210 malleable iron shall consist of temper-carbon nodules distributed in a matrix of ferrite.

5.1.2 Because of reaction with the annealing furnace atmosphere, some depletion of carbon and silicon occurs at the surface of the castings. This usually results in a rim which can consist of coarse lamellar pearlite underlying a graphite-free ferritic surface layer. If the pearlite layer is excessive, it can result in poor machinability. The rim, therefore, shall not exceed a depth greater than 0.050 in. (1.27 mm) as measured from the casting surface.

5.1.3 The area below the rim can contain some pearlite; however, it shall not exceed the amount shown in Fig. 1.

5.2 *Grades M4504, M5003, M7002, and M8501*:

5.2.1 The microstructure of these other grades of malleable iron shall consist of temper-carbon nodules distributed in a matrix of ferrite and lamellar pearlite or tempered pearlite in air-quenched castings or a matrix of tempered martensite in the case of liquid-quenched castings.

5.2.2 Because of reaction with the annealing furnace atmosphere, some depletion of carbon and silicon occurs at the surface of the castings. This usually results in a rim which can consist of a graphite-free layer sometimes containing more or less combined carbon than the underlying material.

5.3 All grades shall be free of primary graphite.

5.4 All grades shall not exceed 2 % spheroidal primary carbides in the microstructure.

[1] This specification is under the jurisdiction of ASTM Committee A04 on Iron Castings and is the direct responsibility of Subcommittee A04.02 on Malleable and Ductile Iron Castings.

Current edition approved May 1, 2004. Published May 2004. Originally approved in 1970. Last previous edition approved in 1998 as A 602 – 94 (1998).

[2] 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.

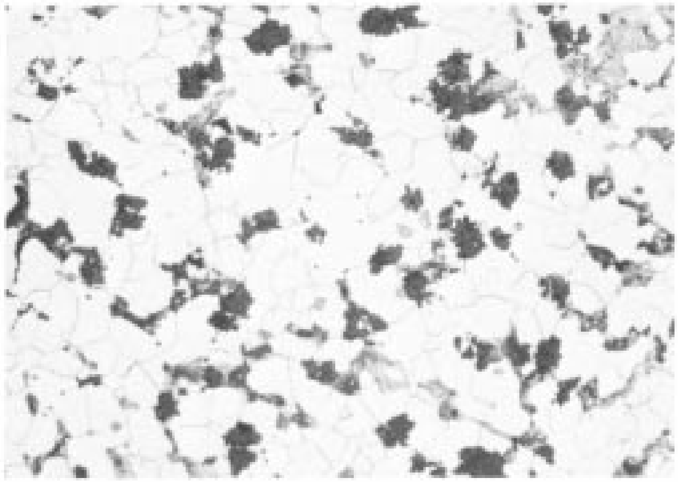


FIG. 1 Reference Photomicrograph Showing Allowable Pearlite in Grade M3210 Iron (100 ×; 2 % Nital Etch)

5.5 The maximum surface ferrite layer and denodularized zone shall be measured after polishing, etching in nital, and viewing at 100×.

6. Quality Assurance

6.1 Sampling plans are a matter of agreement between supplier and purchaser. The supplier shall employ adequate equipment and controls to ensure that parts conform to the agreed upon requirements.

7. General

7.1 Castings furnished to this specification shall be representative of good foundry practice and shall conform to dimensions and tolerances specified on the casting drawing.

7.2 Minor imperfections usually not associated with the structural function may occur in castings. These imperfections often are repairable; however, repairs shall be made only in areas allowed by the purchaser and only by approved methods.

7.3 Additional casting requirements may be agreed upon between the purchaser and supplier. These should appear as additional product requirements on the casting drawing.

8. Keywords

8.1 casting; ferrite; malleable iron; mechanical properties; pearlite; temper carbon nodules; tensile strength; yield strength

APPENDIX

(Nonmandatory Information)

X1. MATERIAL DESCRIPTION OF MALLEABLE IRON

X1.1 Definition and Classification

X1.1.1 *malleable iron*—a cast iron in which the graphite is present as temper-carbon nodules instead of flakes, as in gray iron, or small spherulites, as in ductile iron.

X1.1.2 The term malleable iron includes all grades of malleable iron, including those with a ferritic, pearlitic, tempered pearlite, or tempered martensite matrix.

X1.2 Chemical Composition

X1.2.1 The chemical composition of malleable iron generally conforms to the following range:

Element	Composition, %
Total carbon	2.20–2.90
Silicon	0.90–1.90
Manganese	0.15–1.25
Sulfur	0.02–0.20
Phosphorus	0.02–0.15

X1.2.2 Individual foundries will produce to narrower ranges than those shown above. The composition is controlled such that the molten iron solidifies with all the carbon in the combined form producing a "white iron'' structure free of graphite, which is heat treated to specifications.

X1.3 Microstructure

X1.3.1 The microstructure of malleable iron consists of a matrix of ferrite, pearlite, tempered pearlite, or tempered martensite or combinations of these containing temper carbon nodules (see Figs. X1.1-X1.6). The structure of the matrix is controlled by heat treatment or composition, or both.

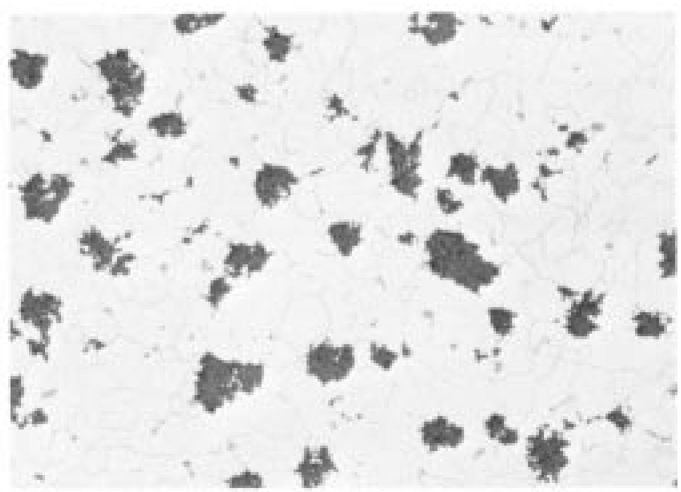


FIG. X1.1 Grade M3210, Approximately HB 143 (100×)

X1.3.2 The matrix of the M3210 grade of malleable iron is essentially free of combined carbon but a small amount of pearlite is permitted.

X1.3.3 The matrices of the other grades of malleable iron contain combined carbon as pearlite, tempered pearlite, or tempered martensite.

X1.3.4 Because of reaction with the annealing furnace atmosphere, some depletion of carbon and silicon occurs at the surface of the castings. This usually results in a rim, which if

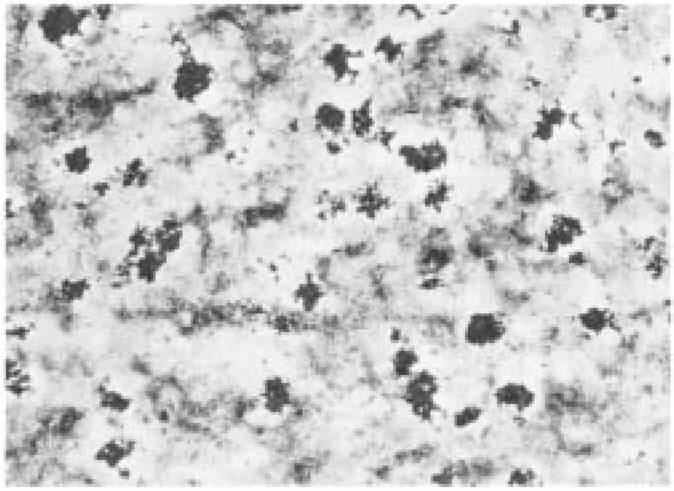


FIG. X1.2 Grade M4504, Approximately HB 207 (100×)

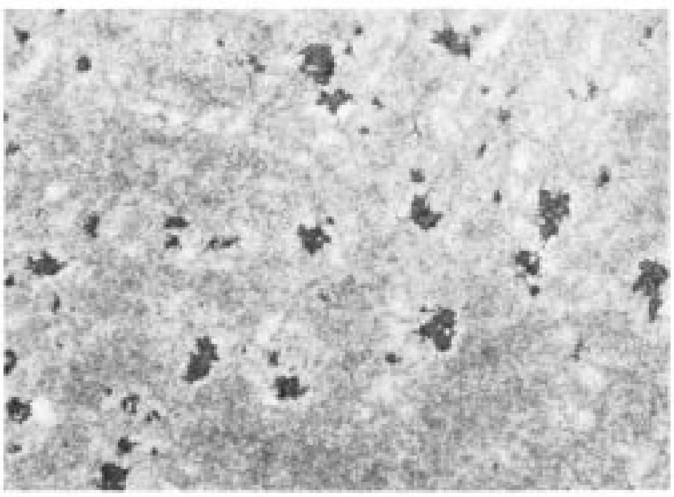


FIG. X1.3 Grade M5003, Approximately HB 229 (100×)

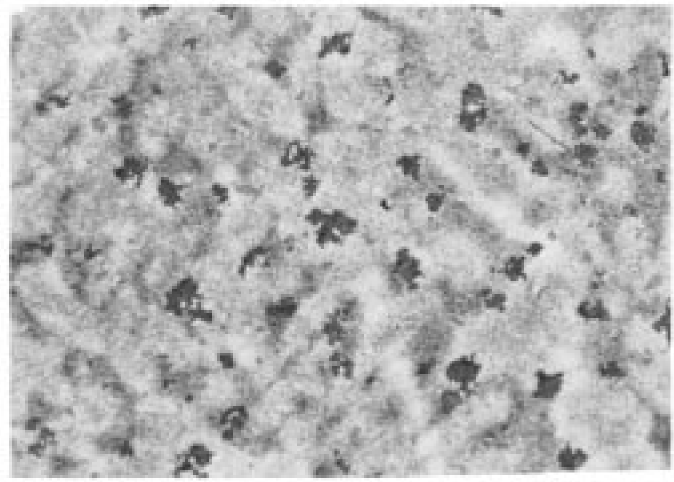


FIG. X1.4 Grade M5503, Approximately HB 229 (100×)

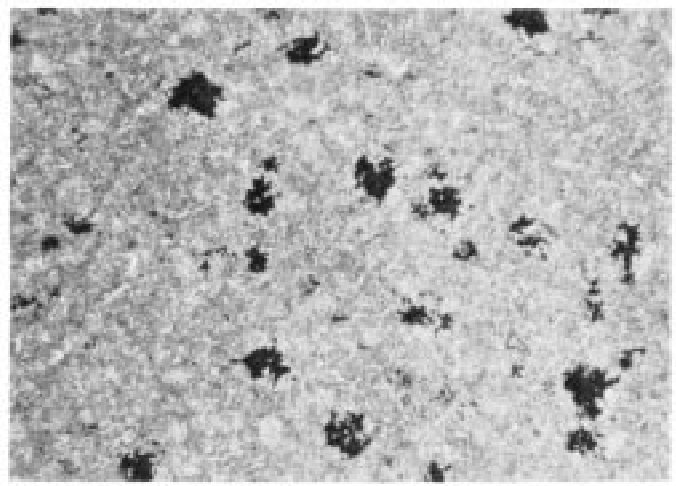


FIG. X1.5 Grade M7002, Approximately HB 262 (100×)

excessive, can result in poor machinability. The rim on M3210 malleable iron can consist of coarse pearlite underlying a graphite-free ferritic surface layer. The rim on the other grades can consist of a graphite-free layer sometimes containing more or less combined carbon than the underlying material.

X1.4 Mechanical Properties

X1.4.1 The mechanical properties listed in Table X1.1 can be used for design purposes but the suitability of a particular grade for an intended use is best determined by laboratory or service tests.

X1.4.2 The mechanical properties vary with microstructure and hardness. For optimum mechanical properties, especially in the liquid-quenched and tempered grades, section size should be limited to ¾ in. (19.05 mm) to ensure a uniform structure.

X1.5 Typical Applications

X1.5.1 Grade M3210 is used in less highly stressed parts where good machinability is important such as steering gear housings, carriers, and mounting brackets.

X1.5.2 Grade M4504 is used where slightly higher strength and hardness is required such as certain compressor crank-shafts and hubs.

X1.5.3 Grade M5003 is used where moderate strength or selective hardening, or both, are required for parts such as planet carriers, certain transmission gears, and differential cases.

X1.5.4 Grade M5503 is used where better machinability or improved response to induction hardening, or both, are necessary for parts requiring moderate strength.

X1.5.5 Grade M7002 is used for parts where high strength is required such as connecting rods and universal joint yokes.

X1.5.6 Grade M8501 is used where high strength and wear resistance are required, such as certain gears.

X1.6 Additional Information

X1.6.1 Additional information on malleable iron may be found in Refs. **1-6**.[3]

[3] The boldface numbers refer to the list of references at the end of this standard.

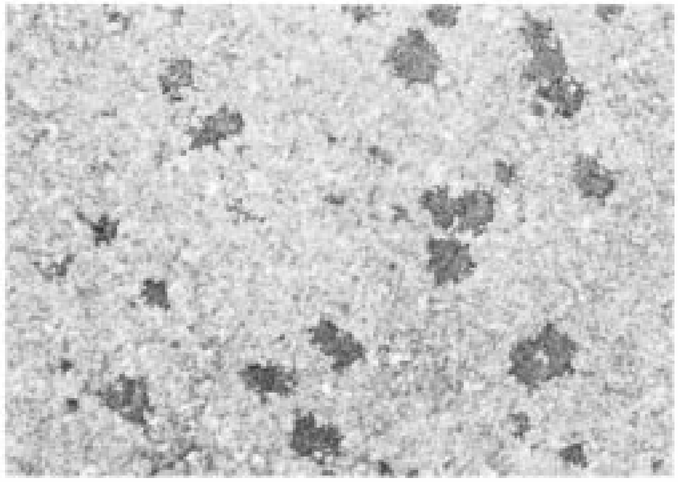


FIG. X1.6 Grade M8501 Approximately HB 285 (100×)

TABLE X1.1 Typical Mechanical Properties for Design Purposes

Grade	Hardness Range	Heat Treatment	Tensile Strength, psi (MPa)	Yield Strength, psi (0.2 percent offset) (MPa)	Percent Elongation in 2 in. or 50 mm	Modulus of Elasticity, Million psi (GPa)
M3210	156 HB max 4.8 BID[A] min	annealed	50 000 (345)	32 000 (221)	10	25 (172)
M4504	163–217 HB 4.7–4.1 BID[A]	air or liquid quenched and tempered	65 000 (448)	45 000 (310)	4	26 (179)
M5003	187–241 HB 4.4–3.9 BID[A]	air or liquid quenched and tempered	75 000 (517)	50 000 (345)	3	26 (179)
M5503	187–241 HB 4.4–3.9 BID[A]	liquid quenched and tempered	75 000 (517)	55 000 (379)	3	26 (179)
M7002	229–269 HB 4.0–3.7 BID[A]	liquid quenched and tempered	90 000 (621)	70 000 (483)	2	26 (179)
M8501	269–302 HB 3.7–3.5 BID[A]	liquid quenched and tempered	10 000 (724)	85 000 (586)	1	26 (179)

[A] Brinell impression diameter (BID) is the diameter in millimetres of the impression of a 10-mm ball at 3000-kg load.

REFERENCES

(**1**) *Cast Metals Handbook*, American Foundrymen’s Society, Des Plaines, IL.

(**2**) *Malleable Iron Castings*, Malleable Founders Society, Cleveland, OH.

(**3**) *Metals Handbook*, Vol 1, 2, and 5, 8th Edition, American Society for Metals, Metals Park, OH.

(**4**) *Modern Pearlitic Malleable Castings Handbook*, Malleable Research and Development Foundation, Dayton, OH.

(**5**) Angus, H. D., *Physical and Engineering Properties of Cast Iron*, British Cast Iron Research Association, Alvechurch, Birmingham, Eng., 1960.

(**6**) Gilbert, G. N. J., *Engineering Data on Cast Irons*, British Cast Iron Research Assoc., 1968.

Designation: A 609/A 609M – 91 (Reapproved 2002)

Standard Practice for Castings, Carbon, Low-Alloy, and Martensitic Stainless Steel, Ultrasonic Examination Thereof[1]

This standard is issued under the fixed designation A 609/A 609M; 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 practice[2] covers the standards and procedures for the pulse-echo ultrasonic examination of heat-treated carbon, low-alloy, and martensitic stainless steel castings by the longitudinal-beam technique.

1.2 This practice is to be used whenever the inquiry, contract, order, or specification states that castings are to be subjected to ultrasonic examination in accordance with Practice A 609/A 609M.

1.3 This practice contains two procedures for ultrasonic inspection of carbon, low-alloy, and martensitic stainless steel castings; that is, Procedure A and Procedure B. Procedure A is the original A 609/A 609M practice and requires calibration using a series of test blocks containing flat bottomed holes. It also provides supplementary requirements for angle beam testing. Procedure B requires calibration using a back wall reflection from a series of solid calibration blocks.

NOTE 1—Ultrasonic examination and radiography are not directly comparable. This examination technique is intended to complement Guide E 94 in the detection of discontinuities.

1.4 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 must be used independently of the other. Combining values from the two systems may result in nonconformance with this practice.

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 217/A217M Specification for Steel Castings, Martensitic Stainless and Alloy, for Pressure-Containing Parts, Suitable for High-Temperature Service[3]

E 94 Guide for Radiographic Examination[4]

E 317 Practice for Evaluating Performance Characteristics of Ultrasonic Pulse-Echo Examination Instruments and Systems Without the Use of Electronic Measurement Instruments[4]

2.2 *Other Document:*

SNT-TC-1A Recommended Practice for Non-Destructive Testing Personnel Qualification and Certification[5]

3. Ordering Information

3.1 The inquiry and order should specify which procedure is to be used. If a procedure is not specified, Procedure A shall be used.

3.2 *Procedure A—Flat-Bottomed Hole Calibration Procedure*:

3.2.1 When this practice is to be applied to an inquiry, contract, or order, the purchaser shall furnish the following information:

3.2.1.1 Quality levels for the entire casting or portions thereof,

3.2.1.2 Sections of castings requiring longitudinal-beam examination,

3.2.1.3 Sections of castings requiring dual element examination,

3.2.1.4 Sections of castings requiring supplementary examination, using the angle-beam procedure described in Supplementary Requirement S1 in order to achieve more complete examination, and

3.2.1.5 Any requirements additional to the provisions of this practice.

3.3 *Procedure B: Back-Wall Reflection Calibration Procedure*—When this procedure is to be applied to an inquiry, contract, or order, the purchaser shall designate the quality levels for the entire casting or applicable portions.

[1] This practice is under the jurisdiction of ASTM Committee A01 on Steel, Stainless Steel, and Related Alloys and is the direct responsibility of Subcommittee A01.18 on Castings.

Current edition approved Dec. 15, 1991. Published July 1992. Originally published as A 609 – 70. Last previous edition A 609/A 609M – 90.

[2] For ASME Boiler and Pressure Vessel Code applications, see related Specification SA-609 of Section II of that Code.

[3] *Annual Book of ASTM Standards*, Vol 01.02.

[4] *Annual Book of ASTM Standards*, Vol 03.03.

[5] Available from American Society for Nondestructive Testing, P.O. Box 28518, 1711 Arlingate Ln., Columbus, OH 43228-0518.

PROCEDURE A—FLAT-BOTTOMED HOLE CALIBRATION PROCEDURE

4. Apparatus

4.1 *Electronic Apparatus*:

4.1.1 An ultrasonic, pulsed, reflection type of instrument that is capable of generating, receiving, and amplifying frequencies of at least 1 to 5 MHz.

4.1.2 The ultrasonic instrument shall provide linear presentation (within ±5 %) for at least 75 % of the screen height (sweep line to top of screen). Linearity shall be determined in accordance with Practice E 317 or equivalent electronic means.

4.1.3 The electronic apparatus shall contain a signal attenuator or calibrated gain control that shall be accurate over its useful range to ±10 % of the nominal attenuation or gain ratio to allow measurement of signals beyond the linear range of the instrument.

4.2 *Search Units*:

4.2.1 *Longitudinal Wave*, internally grounded, having a ½ to 1⅛ in. [13 to 28 mm] diameter or 1-in. [25-mm] square piezo-electric elements. Based on the signals-to-noise ratio of the response pattern of the casting, a frequency in the range from 1 to 5 MHz shall be used. The background noise shall not exceed 25 % of the distance amplitude correction curve (DAC). Transducers shall be utilized at their rated frequencies.

4.2.2 *Dual-Element*, 5-MHz, ½ by 1-in. [13 by 25-mm], 12° included angle search units are recommended for sections 1 in. [25 mm] and under.

4.2.3 Other frequencies and sizes of search units may be used for evaluating and pinpointing indications.

4.3 *Reference Blocks*:

4.3.1 Reference blocks containing flat-bottom holes shall be used to establish test sensitivity in accordance with 8.2.

4.3.2 Reference blocks shall be made from cast steels that give an acoustic response similar to the castings being examined.

4.3.3 The design of reference blocks shall be in accordance with Fig. 1, and the basic set shall consist of those blocks listed in Table 1. When section thicknesses over 15 in. [380-mm] are to be inspected, an additional block of the maximum test thickness shall be made to supplement the basic set.

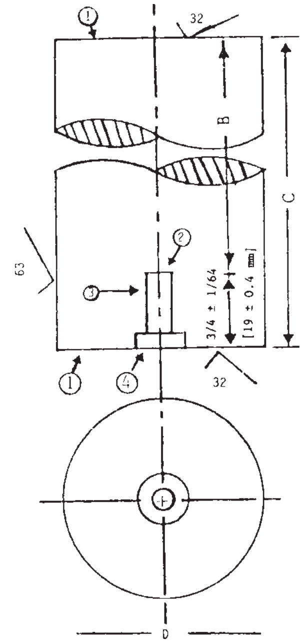
4.3.4 Machined blocks with 3⁄32-in. [2.4-mm] diameter flat-bottom holes at depths from the entry surface of ⅛ in. [3 mm], ½ in. [13 mm], or ½ *t* and ¾ in. [19 mm], or ¾ *t* (where *t* = thickness of the block) shall be used to establish the DAC for the dual-element search units (see Fig. 2).

4.3.5 Each reference block shall be permanently identified along the side of the block indicating the material and the block identification.

4.4 *Couplant*—A suitable couplant having good wetting characteristics shall be used between the search unit and examination surface. The same couplant shall be used for calibrations and examinations.

5. Personnel Requirements

5.1 The manufacturer shall be responsible for assigning qualified personnel to perform ultrasonic examination in conformance with the requirements of this practice.



NOTE 1—Opposite ends of reference block shall be flat and parallel within 0.001 in. [0.025 mm].

NOTE 2—Bottom of flat-bottom hole shall be flat within 0.002-in. [0.051 mm] and the finished diameter shall be ¼ + 0.002 in. [6.4 + 0.050].

NOTE 3—Hole shall be straight and perpendicular to entry surface within 0°, 30 min and located within 1⁄32 in. [0.80 mm] of longitudinal axis.

NOTE 4—Counter bore shall be ½ in. [15.0 mm] diameter by ⅛ in. [5 mm] deep.

FIG. 1 Ultrasonic Standard Reference Block

TABLE 1 Dimensions and Identification of Reference Blocks in the Basic Set (See Fig. 1)

Hole Diameter in 1⁄64ths, in. [mm]	Metal Distance (*B*), in.^{A} [mm]	Overall Length (*C*), in. [mm]	Width or Diameter (*D*), min, in. [mm]	Block Identification Number
16 [6.4]	1 [25]	1¾ [45]	2 [50]	16-0100
16 [6.4]	2 [50]	2¾ [70]	2 [50]	16-0200
16 [6.4]	3 [75]	3¾ [95]	2 [50]	16-0300
16 [6.4]	6 [150]	6¾ [170]	3 [75]	16-0600
16 [6.4]	10 [255]	10¾ [275]	4 [100]	16-1000
16 [6.4]	B	B + ¾ [B + 20]	5 [125]	16-B00^{B}

^{A} Tolerance ±⅛ in. [3 mm].

^{B} Additional supplemental blocks for testing thickness greater than 10 in. [250 mm], see 4.3.3.

5.2 Personnel performing ultrasonic examinations in accordance with this practice shall be familiar with the following:

5.2.1 Ultrasonic terminology,

5.2.2 Instrument calibration,

5.2.3 Effect of transducer material, size, frequency, and mode on test results,

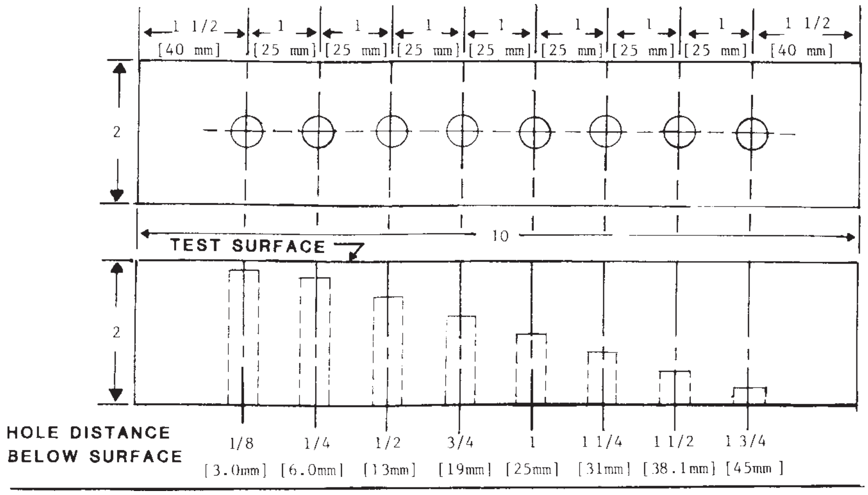
5.2.4 Effect of material structure (grain size, cleanliness, etc.) on test results,

5.2.5 Effect of test distance on test results,

5.2.6 Effect of nonlinearity on test results,

5.2.7 Effect of thickness and orientation of discontinuities on test results, and

5.2.8 Effect of surface roughness on test results.



NOTE 1—Entrant surface shall be 250 µin. [6.3 µm] or finer.

NOTE 2— The 3⁄32-in. [2.4 mm] flat-bottom hole must be flat within 0.002 in. [0.05 mm]. Diameter must be within +0.005 in. [0.13 mm] of the required diameter. Hole axis must be perpendicular to the block and within an angle of 0°, 30 min.

NOTE 3—Hole shall be plugged following checking for ultrasonic response.

in.	[mm]	in.	[mm]
1⁄8	[3]	1 1⁄4	[32]
1⁄4	[6]	1 1⁄2	[38]
1⁄2	[13]	1 3⁄4	[44]
3⁄4	[19.0]	2	[50]
1	[25]	10	[254]

FIG. 2 Ultrasonic Standard Reference Block for Dual-Search Unit Calibration

5.3 A qualification record (see Note 2) of personnel considered suitable by the manufacturer to perform examinations in accordance with this practice shall be available upon request.

NOTE 2—SNT-TC-1A, Ultrasonic Testing Method, provides a recommended procedure for qualifying personnel. Other personnel qualification requirement documents may by used when agreed upon between the purchaser and the supplier.

6. Casting Conditions

6.1 Castings shall receive at least an austenitizing heat treatment before being ultrasonically examined.

6.2 Test surfaces of castings shall be free of material that will interfere with the ultrasonic examination. They may be as cast, blasted, ground, or machined.

6.3 The ultrasonic examination shall be conducted prior to machining that prevents an effective examination of the casting.

7. Test Conditions

7.1 To assure complete coverage of the specified casting section, each pass of the search unit shall overlap by at least 10 % of the width of the transducer.

7.2 The rate of scanning shall not exceed 6 in./s [150 mm/s].

7.3 The ultrasonic beam shall be introduced perpendicular to the examination surface.

8. Procedure

8.1 Adjust the instrument controls to position the first back reflection for the thickness to be tested at least one half of the distance across the cathode ray tube.

8.2 Using the set of reference blocks spanning the thickness of the casting being inspected, mark the flat-bottom hole indication height for each of the applicable blocks on the cathode ray tube shield. Draw a curve through these marks on the screen or on suitable graph paper. The maximum signal amplitude for the test blocks used shall peak at approximately three-fourths of the screen height above the sweep by use of the attenuator. This curve shall be referred to as the 100 % distance amplitude correction (DAC) curve. If the attenuation of ultrasound in the casting thickness being examined is such that the system's dynamic range is exceeded, segmented DAC curves are permitted.

8.3 The casting examination surface will normally be rougher than that of the test blocks; consequently, employ a transfer mechanism to provide approximate compensation. In order to accomplish this, first select a region of the casting that has parallel walls and a surface condition representative of the rest of the casting as a transfer point. Next, select the test block whose overall length, *C* (Fig. 1), most closely matches the reflection amplitude through the block length. Place the search unit on the casting at the transfer point and adjust the instrument gain until the back reflection amplitude through the casting matches that through the test block. Using this transfer technique, the examination sensitivity in the casting may be expected to be within ±30 % or less of that given by the test blocks.

8.4 Do not change those instrument controls and the test frequency set during calibration, except the attenuator, or calibrated gain control, during acceptance examination of a given thickness of the casting. Make a periodic calibration during the inspection by checking the amplitude of response from the ¼-in. [6.4-mm] diameter flat-bottom hole in the test block utilized for the transfer.

NOTE 3—The attenuator or calibrated gain control may be used to change the signal amplitude during examination to permit small amplitude signals to be more readily detected. Signal evaluation is made by returning the attenuator or calibrated gain control to its original setting.

8.5 During examination of areas of the casting having parallel walls, recheck areas showing 75 % or greater loss of back reflection to determine whether loss of back reflection is due to poor contact, insufficient couplant, misoriented discontinuity, etc. If the reason for loss of back reflection is not evident, consider the area questionable and further investigate.

9. Report

9.1 The manufacturer's report of final ultrasonic examination shall contain the following data and shall be furnished to the purchaser:

9.1.1 The total number, location, amplitude, and area when possible to delineate boundaries by monitoring the movement of the center of the search unit of all indications equal to or greater than 100 % of the DAC,

9.1.2 Questionable areas from 8.5 that, upon further investigation, are determined to be caused by discontinuities,

9.1.3 The examination frequency, type of instrument, types of search units employed, couplant, manufacturer's identifying numbers, purchaser's order number, and data and authorized signature, and

9.1.4 A sketch showing the physical outline of the casting, including dimensions of all areas not inspected due to geometric configuration, with the location and sizes of all indications in accordance with 9.1.1 and 9.1.2.

10. Acceptance Standards

10.1 This practice is intended for application to castings with a wide variety of sizes, shapes, compositions, melting processes, foundry practices, and applications. Therefore, it is impractical to specify an ultrasonic quality level that would be universally applicable to such a diversity of products. Ultrasonic acceptance or rejection criteria for individual castings should be based on a realistic appraisal of service requirements and the quality that can normally be obtained in production of the particular type of casting.

10.2 Acceptance quality levels shall be established between the purchaser and the manufacturer on the basis of one or more of the following criteria:

10.2.1 No indication equal to or greater than the DAC over an area specified for the applicable quality level of Table 2.

10.2.2 No reduction of back reflection of 75 % or greater that has been determined to be caused by a discontinuity over an area specified for the applicable quality level of Table 2.

10.2.3 Indications producing a continuous response equal to or greater than the DAC with a dimension exceeding the maximum length shown for the applicable quality level shall be unacceptable.

10.2.4 Other criteria agreed upon between the purchaser and the manufacturer.

TABLE 2 Rejection Level

NOTE 1—The areas in the table refer to the surface area on the casting over which a continuous indication exceeding the amplitude reference line or a continuous loss of back reflection of 75 % or greater is maintained.

NOTE 2— Areas shall be measured from the center of the search unit.

NOTE 3—In certain castings, because of very long test distances or curvature of the test surface, the casting surface area over which a given discontinuity is detected may be considerably larger or smaller than the actual area of the discontinuity in the casting; in such cases a graphic plot that incorporates a consideration of beam spread should be used for realistic evaluation of the discontinuity.

Ultrasonic Testing Quality Level	Area, in.^{2}[cm^2] (see 10.2.1 and 10.2.2)	Length, max, in. [mm]
1	0.8 [5]	1.5 [40]
2	1.5 [10]	2.2 [55]
3	3 [20]	3.0 [75]
4	5 [30]	3.9 [100]
5	8 [50]	4.8 [120]
6	12 [80]	6.0 [150]
7	16 [100]	6.9 [175]

10.3 Other means may be used to establish the validity of a rejection based on ultrasonic inspection.

NOTE 4—The areas for the ultrasonic quality levels in Table 2 of Practice A 609/A 609M refer to the surface area on the casting over which a continuous indication exceeding the DAC is maintained.

NOTE 5—Areas are to be measured from dimensions of the movement of the search unit by outlining locations where the amplitude of the indication is 100 % of the DAC or where the back reflection is reduced by 75 %, using the center of the search unit as a reference point to establish the outline of the indication area.

NOTE 6—In certain castings, because of very long metal path distances or curvature of the examination surfaces, the surface area over which a given discontinuity is detected may be considerably larger or smaller than the actual area of the discontinuity in the casting; in such cases, other criteria that incorporate a consideration of beam angles or beam spread must be used for realistic evaluation of the discontinuity.

PROCEDURE B—BACK-WALL REFLECTION CALIBRATION PROCEDURE

11. Apparatus

11.1 Apparatus shall be kept on a regular six month maintenance cycle during which, as a minimum requirement, the vertical and horizontal linearities, sensitivity, and resolution shall be established in accordance with the requirements of Practice E 317.

11.2 *Search Units*—Ceramic element transducers not exceeding 1.25 in. [32 mm] diameter or 1 in.^{2} [645 mm^2] shall be used.

11.3 *Search Units Facing*—A soft urethane membrane or neoprene sheet, approximately 0.025 in. [0.64 mm] thick, may be used to improve coupling and minimize transducer wear caused by casting surface roughness.

11.4 *Calibration/Testing*—The same system, including the urethane membrane, used for calibration shall be used to inspect the casting.

11.5 *Other Inspections*—Other frequencies and type search units may be used for obtaining additional information and pinpointing of individual indications.

11.6 *Couplant*—A suitable liquid couplant, such as clean SAE 30 motor oil or similar commercial ultrasonic couplant, shall be used to couple the search unit to the test surface. Other couplants may be used when agreed upon between the purchaser and supplier.

11.7 *Reference Standards*—Reference standards in accordance with Fig. 3 shall be used to calibrate the instrument for inspecting machined and cast surfaces. Reference standards shall be flaw free and machined within tolerances indicated.

12. Ultrasonic Instrument

12.1 *Type*—Pulsed ultrasonic reflection instrument capable of generating, receiving, and amplifying frequencies of 1 MHz to 5 MHz shall be used for testing.

12.2 *Voltage*—Line voltage shall be suitably regulated by constant voltage equipment and metal housing must be grounded to prevent electric shock.

12.3 *Linearity*—The instrument must provide a linear presentation (within ±5 %) of at least 1.5 in. [40 mm] sweep to peak (S/P).

12.4 *Calibrated Gain Control of Attenuator*—The instrument shall contain a calibrated gain control or signal attenuator (accurate within ±10 %) which will allow indications beyond the linear range of the instrument to be measured.

12.5 *Time-Corrected Gain*—The instrument shall be equipped to compensate for signal decay with distance. A method should be available to equalize signal response at different depths.

13. Qualification

13.1 The requirements for pre-production qualification are as follows:

13.1.1 *Personnel*—The personnel qualification requirements of SNT-TC-1A are applicable. Other personnel qualification requirement documents may be used when agreed upon between the purchaser and the supplier. Records of all personnel shall be available to customers upon request.

13.1.2 *Equipment*—The equipment shall be capable of meeting the requirements in Section 12.

14. Preparation

14.1 *Time of Inspection*—The final ultrasonic acceptance inspection shall be performed after at least an austenitizing heat treatment and preferably after machining. In order to avoid time loss in production, acceptance inspection of cast surfaces may be done prior to machining. Machined surfaces shall be acceptance inspected as soon as possible after machining. Repair welds may be inspected before the postweld heat treatment.

14.2 *Surface Finish*:

14.2.1 *Machined Surfaces*—Machined surfaces subject to ultrasonic inspection shall have a finish that will produce an ultrasonic response equivalent to that obtained from a 250 µin. [6.3 µm] surface. The surface finish shall also permit adequate movement of search units along the surface.

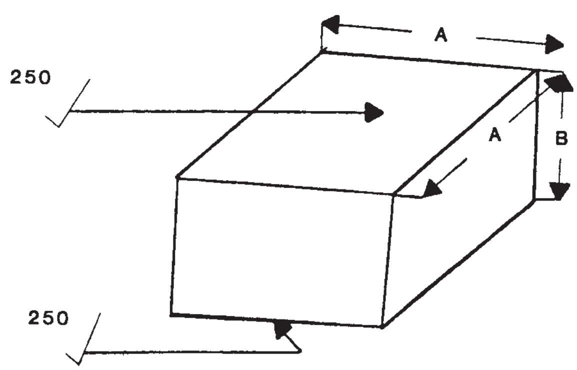
14.2.2 *Casting Surfaces*—Casting surfaces to be ultrasonically inspected shall be suitable for the intended type and quality level (Table 3 and Table 4) of inspection as judged acceptable by a qualified individual as specified in 13.1.1.

14.2.3 *Surface Condition*—All surfaces to be inspected shall be free of scale, machining or grinding particles, excessive paint thickness, dirt, or other foreign matter that may interfere with the inspection.

14.3 *Position of Casting*—The casting shall be positioned such that the inspector has free access to the back wall for the purpose of verifying change in contour.

15. Calibration

15.1 *Calibration Blocks*—Determine the thickness of the material to be ultrasonically inspected. For material thickness of 3 in. [75 mm] or less, use the series of 3 blocks, ½, 2, 5 in. [13, 50, 125 mm] (Fig. 3, B dimension) for calibration. For a



Dimensions, in. [mm]		Material
2 [50]	½ [13]	Specification A 217/A 217M,
2 [50]	2 [50]	Grade WC6 or acoustically similar within ±20 % or 2 dB.
3 [75]	5 [125]	
6 [150]	10 [250]	

Tolerance
All sides to be flat within 0.0002 in. [0.01 mm] and parallel with 0.001 in. [0.03 mm].

FIG. 3 Calibration Blocks

TABLE 3 Acceptance Criteria for Single Isolated Indications

NOTE 1—The area measured by movement of the center of the transducer over the casting surface.
NOTE 2—O = outer wall ⅓, or inner wall ⅓.
C = mid wall ⅓.
E = entire wall.

Quality Level	Maximum Non-Linear Indication, Area, in.^{2}[cm^2]	Position of Indication
1	0	E
2	1 [6]	E
3	1 [6]	O
	2 [13]	C
4	3 [19]	E
5	3 [19]	O
	5 [32]	C
6	5 [32]	E
7	5 [32]	O
	7 [45]	C
8	7 [45]	E
9	7 [45]	O
	9 [58]	C
10	9 [58]	E
11	9 [58]	O
	11 [71]	C

TABLE 4 Acceptance Criteria for Clustered Indications

Quality Level	Cumulative Area of Indications, in.^{2}[cm^2]^{A,B}	Minimum Area in Which Indications Must be Dispersed, in.^{2}[cm^2]^C
1	0	0
2–3	2 [13]	36 [232]
4–5	4 [26]	36 [232]
6–7	6 [39]	36 [232]
8–9	8 [52]	36 [232]
10–11	10 [64]	36 [232]

[A] Regardless of wall location, that is midwall ⅓, innermost ⅓, or outermost ⅓.

[B] Each indication that equals or exceeds the 0.5-in. [18 mm] reference line shall be traced to the position where the indication is equal to 0.25 in. [6 mm]. The area of the location, for the purpose of this evaluation, shall be considered the area that is confined within the outline established by the center of the transducer during tracing of the flaw as required. Whenever no discernible surface tracing is possible, each indication which equals or exceeds the 0.5 in. reference amplitude shall be considered 0.15 in.^{2} [1 cm^2] (three times the area of the ¼ diameter [6 mm] flat bottomed hole to compensate for reflectivity degradation of natural flaw) for the cumulative area estimates.

[C] The indications within a cluster with the cumulative areas traced shall be dispersed in a minimum surface area of the casting equal to 36 in.^{2} [230 cm^2]. If the cumulative areas traced are confined with a smaller area of distribution, the area shall be repair welded to the extent necessary to meet the applicable quality level.

material thickness greater than 3 in., use the series of 3 blocks, 2, 5, 10 in. [50, 125, 250 mm] (Fig. 3, B dimension) for calibration.

15.2 *Calibration of Search Units*—For the thickness of material to be inspected, as determined in 15.1, use the following search units:

15.2.1 For materials 3 in. [75 mm] or less in thickness, use a 2¼ MHz, ½ in. [13 mm] diameter search unit.

15.2.2 For material greater than 3 in. [75 mm] in thickness, use a 2¼ MHz, 1 in. [25 mm] diameter search unit.

15.3 *Calibration Procedure*:

15.3.1 Set the frequency selector as required. Set the reject control in the "OFF" position.

15.3.2 Position the search unit on the entrant surface of the block that completely encompasses the metal thickness to be inspected (Fig. 3) and adjust the sweep control such that the back reflection signal appears approximately, but not more than three-quarters along the sweep line from the initial pulse signal.

15.3.3 Position the search unit on the entrant surface of the smallest block of the series of 3 blocks selected for calibration and adjust the gain until the back reflection signal height (amplitude) is 1.5 in. [40 mm] sweep to peak (S/P). Draw a line on the cathode-ray screen (CRT), parallel to the sweep line, through the peak of the 1.5 in. (S/P) amplitude.

15.3.4 Position the search unit on the entrant surface of the largest block of the series of 3 blocks selected for calibration, and adjust the distance amplitude control to provide a back reflection signal height of 1.5 in. [40 mm] (S/P).

15.3.5 Position the search unit on the entrant surface of the intermediate calibration block of the series of 3 blocks being used for calibration and confirm that the back reflection signal height is approximately 1.5 in. [40 mm] (S/P). If it is not, obtain the best compromise between this block and the largest block of the series of 3 blocks being used for calibration.

15.3.6 Draw a line on the cathode ray tube screen parallel to the sweep line at 0.5 in. [13 mm] (S/P) amplitude. This will be the reference line for reporting discontinuity amplitudes.

15.3.7 For tests on *machined surfaces*, position the search unit on a machined surface of casting where the walls are reasonably parallel and adjust the gain of the instrument until the back reflection signal height is 1.5 in. [40 mm] (S/P). Increase the inspection sensitivity by a factor of three times (10 dB gain) with the calibrated attenuator. Surfaces that do not meet the requirements of 14.2.1 shall be inspected as specified in 15.3.8.

15.3.8 For inspections on *cast surfaces*, position the search unit on the casting to be inspected at a location where the walls are reasonably parallel and smooth (inside and outside diameter) and the surface condition is representative of the surface being inspected. Adjust the gain of the instrument until the back reflection signal height is 1.5 in. [40 mm] (S/P). Increase the inspection sensitivity by a factor of six times (16 dB) by use of the calibrated control or attenuator. A significant change in surface finish requires a compensating adjustment to the gain.

15.3.8.1 Rejectable indications on as-cast surfaces may be reevaluated by surface preparation to 250 µin. [6.3 µm] finish or better, and re-inspected in accordance with 15.3.7 of this practice.

15.3.8.2 It should be noted that some instruments are equipped with decibel calibrated gain controls, in which case the decibel required to increase the sensitivity must be added. Other instruments have decibel calibrated attenuators, in which case the required decibel must be removed. Still other instruments do not have calibrated gains or attenuators. They require external attenuators.

16. Scanning

16.1 *Grid Pattern*—The surface of the casting shall be laid out in a 12 by 12 in. [300 by 300 mm] or any similar grid pattern for guidance in scanning. Grid numbers shall be stenciled on the casting for record purposes and for grid area identity. The stenciled grid number shall appear in the upper right hand corner of the grid. When grids are laid out on the casting surface and they encompass different quality levels, each specific area shall be evaluated in accordance with the requirements of the specific quality level designated for that area.

16.2 *Overlap*—Scan over the surface allowing 10 % minimum overlap of the working diameters of the search unit.

16.3 *Inspection Requirements*—All surfaces specified for ultrasonic (UT) shall be completely inspected from both sides, whenever both sides are accessible. The same search unit used for calibration shall be used to inspect the casting.

17. Additional Transducer Evaluation

17.1 Additional information regarding any ultrasonic indication may be obtained through the use of other frequency, type, and size search unit.

18. Acceptance Criteria

18.1 *Rejectable Conditions*—The locations of all indications having amplitudes greater than the 0.5 in. [13 mm] line given in 15.3.6, when amplitude three times (machined surfaces) or six times (cast surfaces) shall be marked on the casting surface. The boundary limits of the indication shall be determined by marking a sufficient number of marks on the casting surfaces where the ultrasonic signal equals one half the reference amplitude, 0.25 in. [6 mm]. To completely delineate the indication, draw a line around the outer boundary of the center of the number of marks to form the indication area. Draw a rectangle or other regular shape through the indication in order to form a polygon from which the area may be easily computed. It is not necessary that the ultrasonic signal exceed the amplitude reference line over the entire area. At some locations within the limits of the indication, the signal may be less than the reference line, but nevertheless still present such that it may be judged as a continuous, signal indication. Rejectable conditions are as follows and when any of the conditions listed below are found, the indications shall be removed and repair welded to the applicable process specification.

18.2 *Linear Indications*—A linear indication is defined as one having a length equal to or greater than three times its width. An amplitude of ½ in. [13 mm], such as would result from tears or stringer type slag inclusion, shall be removed.

18.3 *Non-Linear Indications*:

18.3.1 *Isolated Indications*—Isolated indications shall not exceed the limits of the quality level designated by the customer's purchase order listed in Table 3. An isolated indication may be defined as one for which the distance between it and an adjacent indication is greater than the longest dimension of the larger of the adjacent indications.

18.3.2 *Clustered Indications*—Clustered indications shall be defined as two or more indications that are confined in a 1 in. [25 mm] cube. Clustered indications shall not exceed the limits of the quality level designated by the customer purchase order in Table 4. Where the distance between indications is less than the lowest dimension of the largest indication in the group, the cluster shall be repair welded.

18.3.3 The distance between two clusters must be greater than the lowest dimension of the largest indication in either cluster. If they are not, the cluster having the largest single indication shall be removed.

18.3.4 All indications, regardless of their surface areas as indicated by transducer movement on the casting surface and regardless of the quality level required, shall not have a through wall distance greater than ⅓ T, where T is the wall thickness in the area containing the indication.

18.3.5 Repair welding of cluster-type indications need only be the extent necessary to meet the applicable quality level for that particular area. All other types of rejectable indications shall be completely removed.

18.3.6 Repair welds of castings shall meet the quality level designated for that particular area of the casting.

18.3.7 Any location that has a 75 % or greater loss in back reflection and exceeds the area of the applicable quality level, and whose indication amplitudes may or may not exceed the 0.5 in. [13 mm] rejection line, shall be rejected unless the reason for the loss in back reflection can be resolved as not being caused by an indication. If gain is added and back echo is achieved without indication percent amplitude exceeding the 0.5 in. [13 mm] rejection line, the area should be accepted.

19. Records

19.1 *Stenciling*—Each casting shall be permanently stenciled to locate inspection zones or grid pattern for ease in locating areas where rejectable indications were observed.

19.2 *Sketch*—A report showing the exact depth and surface location in relation to the stencil numbers shall be made for each rejectable indicator found during each inspection.

19.2.1 The sketch shall also include, but not be limited to, the following:

19.2.1.1 Part identification numbers,

19.2.1.2 Purchase order numbers,

19.2.1.3 Type and size of supplemental transducers used,

19.2.1.4 Name of inspector, and

19.2.1.5 Date of inspection.

20. Product Marking

20.1 Any rejectable areas (those indications exceeding the limits of Section 19) shall be marked on the casting as the inspection progresses. The point of marking shall be the center of the search unit.

21. Keywords

21.1 carbon and low-alloy steel; castings; martensitic stainless steel; ultrasonic

SUPPLEMENTARY REQUIREMENTS

The following supplementary requirement shall be applied only when agreed upon between the purchaser and the supplier to achieve an effective examination of a critical casting area that cannot be effectively examined using a longitudinal beam as a result of casting design or possible discontinuity orientation.

S1. Angle Beam Examination of Steel Castings

S1.1 *Equipment:*

S1.1.1 *Examination Instrument*—Examination shall be conducted with an ultrasonic, pulsed-reflection type of system generating frequencies of at least 0.4 to 5 MHz. Properties of the electronic apparatus shall be the same as those specified in 4.1.

S1.1.2 *Search Units*—Angle-beam search units shall produce an angle beam in steel in the range from 30 to 75° inclusive, measured to the perpendicular of the entry surface of the casting being examined. It is preferred that search units shall have frequency of 0.4 to 5 MHz.

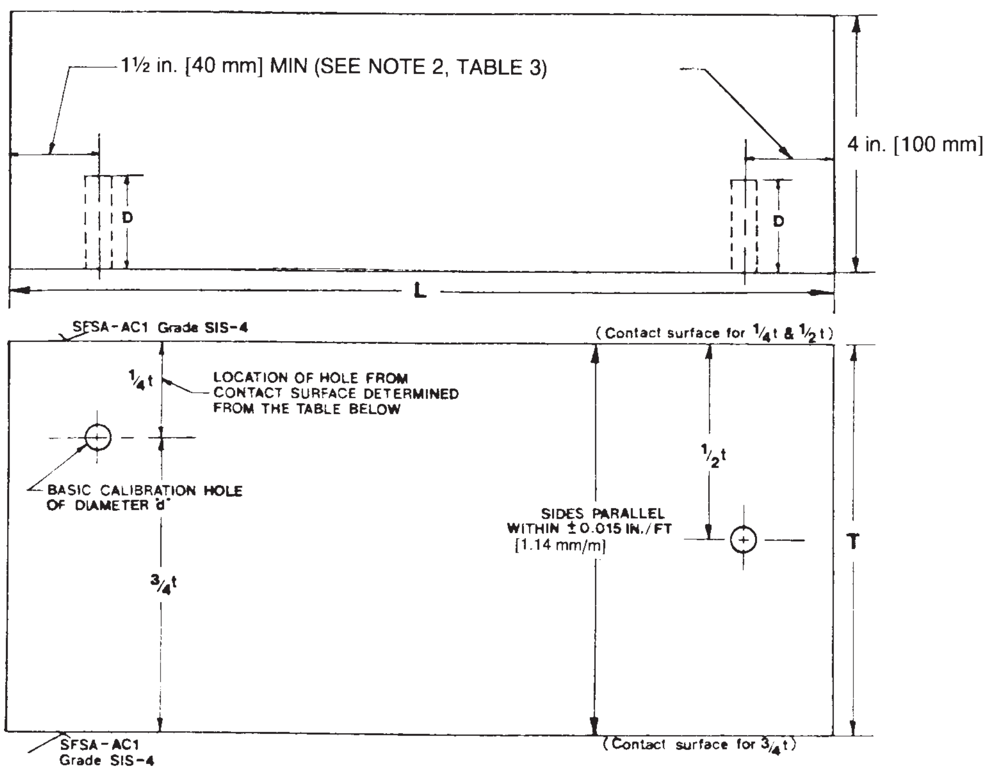
S1.1.3 *Calibration Blocks*—A set of blocks, as shown in Fig. S1.1, with as cast surface equivalent to SCRATA Comparator A3[6] and of a thickness comparable to the sections being examined with side-drilled holes at ¼ *t*, ½ *t*, and ¾ *t* (where *t* = thickness of the block) shall be used to establish an amplitude reference line (ARL).

S1.2 *Calibration of Equipment:*

S1.2.1 Construct the distance amplitude correction curve by utilizing the responses from the side-drilled holes in the basic calibration block for angle beam examination as shown in Fig. S1.1 and Table S1.1.

S1.2.1.1 Resolve and mark the amplitudes of the ¼ *t* and ½ *t* side-drilled holes from the same surface. The side-drilled

[6] Available from Steel Founders Society of America, 205 Park Ave., Barrington, IL 60010-4332.



L = length of block determined by the angle of search unit and the vee-path used,
T = thickness of basic calibration block (see Table S1.1),
D = depth of side-drilled hole (see Table S1.1),
d = diameter of side-drilled hole (see Table S1.1),
t = nominal production material thickness.

FIG. S1.1 Basic Calibration Block for Angle Beam Examination

TABLE S1.1 Dimensions of Calibration Blocks for Angle– Beam Examination

NOTE 1—Dimensions of Calibration Blocks for Angle-Beam Examination For each increase in thickness of 2 in. [50 mm], or a fraction thereof, the hole diameter shall increase 1⁄16 in. [1.6mm].

NOTE 2—For block sizes over 3 in. [75 mm] in thickness, *T*, the distance from the hole to the end of the block shall be ½ *T*, min, to prevent coincident reflections from the hole and the corner. Block fabricated with a 2-in. [50-mm] minimum dimension need not be modified if the corner and hole indications can be easily resolved.

Nominal Production Material Thickness *(t)*, in. [mm]	Basic Calibration Block Thickness *(T)*, in. [mm]	Hole Diameter *(d)*, in 1.002 [mm ± 0.05]	Minimum Depth *(D)*, in. [mm]
Up to 1 [25] incl.	1 [25] or *t*	3⁄32 [2.4]	1½ [40]
Over 1 to 2 [25–50]	2 [50] or *t*	1⁄8 [3.2]	1½ [40]
Over 2 to 4 [50–100]	4 [100] or *t*	3⁄16 [4.8]	1½ [40]
Over 4 to 6 [100–150]	6 [150] or *t*	1⁄4 [6.3]	1½ [40]
Over 6 to 8 [150–200]	8 [200] or *t*	5⁄16 [7.9]	1½ [40]
Over 8 to 10 [200–250]	10 [250] or *t*	3⁄8 [9.5]	1½ [40]
Over 10 [250]	*t*	See Note 1	1½ [40]

hole used for the ¼ *t* amplitude may be used to establish the ¾ *t* amplitude from the opposite surface or a separate hole may be used.

S1.2.1.2 Connect the ¼ *t*, ½ *t*, and ¾ *t* amplitudes to establish the applicable DAC.

S1.2.2 The basic calibration blocks shall be made of material that is acoustically similar to the casting being examined.

S1.2.3 Do not use basic calibration blocks with as cast surface equivalent to SCRATA Comparator A3 to examine castings with surface rougher than SCRATA Comparator A3. Use a machined calibration block for machined surfaces.

S1.2.4 The search unit and all instrument control settings remain unchanged except the attenuator or calibrated gain control.

S1.2.4.1 The attenuator or calibrated gain control may be used to change the signal amplitude during examination to permit small amplitude signals to be more readily detected. Signal evaluation is made by returning the attenuator or calibrated gain control to its original setting.

S1.3 *Data Reporting*—The supplier's report of final ultrasonic examination shall contain the following data:

S1.3.1 The total number, location, amplitude, and area of all indications equal to or greater than 100 % of the distance amplitude curve.

S1.3.2 The examination frequency, type of instrument, type, and size of search units employed, couplant, transfer method, examination operator, supplier's identifying numbers, purchase order number, date, and authorized signature.

S1.3.3 A sketch showing the physical outline of the casting, including dimensions of all areas not examined due to geometric configuration, with the location of all indications in accordance with S1.3.1.

S1.4 *Acceptance Standards*—Acceptance quality levels shall be established between the purchaser and the manufacturer on the basis of one or more of the following criteria:

S1.4.1 No indication equal to or greater than the DAC over an area specified for the applicable quality level of Table 2.

S1.4.2 Other criteria agreed upon between the purchaser and the manufacturer.

Designation: A 610 – 79 (Reapproved 2000)

Standard Test Methods for Sampling and Testing Ferroalloys for Determination of Size[1]

This standard is issued under the fixed designation A 610; 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 These test methods include procedures for the sampling and testing of the various ferroalloys for sizing, either before or after shipment from the plants of the manufacturers.

1.2 They are designed to give results representative of each lot that will be comparable with the manufacturer's certified analysis for the same lot.

1.3 The purchaser may use any sampling procedure he desires, but the results obtained on such samples shall not be a basis for complaint or rejection, unless the procedure followed is of an accuracy equivalent to that prescribed in these test methods.

1.4 The values stated in inch-pound units are to be regarded as the standard. The SI equivalents of inch-pound units may be approximate.

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:*

E 11 Specification for Wire-Cloth Sieves for Testing Purposes[2]

E 32 Practices for Sampling Ferroalloys and Steel Additives for Determination of Chemical Composition[3]

3. Unit Quantities for Sampling and Testing

3.1 Each shipment, except as otherwise agreed upon by the purchaser and the manufacturer, shall constitute a unit for sampling and testing. It is recommended that shipments of any alloy exceeding 100 tons (91 000 kg) be divided into smaller lots for sampling according to some plan best adapted to the material and conditions, such as each cast, each carload, each ladleful or each binful. The division of samples should be in accordance with Practices E 32.

4. Sampling for Size Analysis

4.1 *Lumps*—Conformance of lump material to sizing standards normally shall be judged by visual examination. The inspection judgment shall be made on an increment selected at random. Unless otherwise required, the increment shall be the contents of a unit container of 2000 lb (910 kg) minimum quantity. When more precise data are required for checking on the visual examination, a sizing test shall be made on material from a unit container (usually 2000 to 3000 lb (910 to 1360 kg) of alloy) selected at random.

4.2 *Crushed or Plates*—Sampling for conformance of crushed or plates material to size requirements shall be in accordance with Practices E 32 or by alternative methods which are demonstrated to yield equivalent results. A representative portion of the lot sample (before any reduction in particle size) shall be obtained for screen testing. If necessary, the percentage of sample taken shall be increased to provide sufficient sample in the half reserved for screen testing.

4.2.1 Table 1 lists the amount of material that is to be used for size analysis.

4.2.2 If the top size of the material is 2 in. (50.8 mm) or smaller, the portion for screen test shall be taken from the lot sample by riffling; in larger sizes, by mixing and quartering. Prior to riffling, the starting amount each time must be mixed by coning at least twice.

5. Testing for Size Analysis

5.1 Samples used for screen testing must be dry. If there is a question as to whether the material is suitably dry, a criterion of 0.25 % loss in weight at 230°F (110°C) applies.

5.2 With respect to size characteristics, ferroalloys are usually classified as either "lump" or "crushed" sizes. Although the line of demarcation may vary somewhat, the crushed category refers usually to those sizes which have an upper limit of 4 in. (102 mm) or less. The lump sizes involve all of the other categories that are coarser than 4 in. in top size.

5.3 *Lumps*—Using either weight or lineal measurements as criterion, hand select all pieces from the container that exceed the upper limit of this size category. Determine the total weight percent of the oversize material for conformance against the

[1] These test methods are under the jurisdiction of ASTM Committee A-1 on Steel, Stainless Steel, and Related Alloys and are the direct responsibility of Subcommittee A01.18 on Castings.

Current edition approved March 30, 1979. Published June 1979. Originally published as A 610 – 70. Last previous edition A 610 – 70 (1974).

[2] *Annual Book of ASTM Standards*, Vol 14.02.

[3] *Annual Book of ASTM Standards*, Vol 03.05.

TABLE 1 Amount of Material Required for Testing

Upper Limit of Size Category, in. (mm)	Amount for Testing
Larger than 2 in. (50.8 mm)	200 lb (91 kg) (min)
½ to 2 in. (12.7 to 50.8 mm)	50 to 100 lb (23 to 45 kg)[A]
¼ to ½ in. (6.35 to 12.7 mm)	25 to 50 lb (12 to 23 kg)[A]
4 mesh	700 to 1000 g[A]
20 mesh	300 to 500 g[A]
48 mesh	100 to 300 g[A]
100 mesh	50 to 150 g[A]
200 mesh	50 to 100 g[A]

[A] The larger amounts are to be used for testing alloys of high specific gravity (50 % ferrosilicon and higher density); the smaller amounts are to be used for light alloys and metals (for example calcium silicon and silicon metal).

maximum permitted by these test methods. Determine the amount of undersize by accumulating all pieces from the original container that pass through a grid with an opening the same as the dimension given as the lower limit for the size under test. Then compare the weight percent of this undersize with the test method requirements.

5.4 *Crushed or Plates*:

5.4.1 *Equipment*—Screens used in size analysis shall be in conformance with Specification E 11.

5.4.2 *Procedure*:

5.4.2.1 It is customary practice to use a nest of screens that divides the sample into several size fractions. For coarse sizes, the next is usually rocked by hand about 25 times, removing the top screen, and weighing the amount retained each time. Mechanically driven screen vibrators may be used provided the time is kept to an absolute minimum in the case of the more friable alloys to prevent excessive formation of fines from abrasion. For sizes less than ¼in. (6.35 mm), the test is usually made on a machine that causes particle movement relative to the screens by circular motion and intermittent tapping. A sieving time of 10 min or more is required. In determining sieving time or end point, the criterion is that an additional period of testing does not change the results on any sieve used in the analysis by more than 2 % of the previous value. Each sieve is to be checked for complete sieving.

5.4.2.2 Intermediate fractions, that is, those between the oversize and undersize amounts, are not covered by specifications, but the use of intermediate screens helps prevent overloading the bottom screen. It may be necessary to add the sample in several increments or empty the various screens one or more times during the operation, or both. Excessive times for completion of screening are usually the result of overloading one or more screens.

6. Keywords

6.1 crushed; ferroalloys; lump; plates; sampling; sieving; size; sizing

Designation: A 636 – 76 (Reapproved 2000)

Standard Specification for Nickel Oxide Sinter[1]

This standard is issued under the fixed designation A 636; 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 one grade of nickel oxide sinter, designated as 75 used for alloying in iron and steel melting.

1.2 The values stated in inch-pound units are to be regarded as the standard. The SI equivalents of inch-pound units may be approximate.

2. Referenced Documents

2.1 *ASTM Standards:*

E 29 Practice for Using Significant Digits in Test Data to Determine Conformance with Specifications[2]

E 39 Test Methods for Chemical Analysis of Nickel[3]

3. Ordering Information

3.1 Orders for materials under this specification shall include the following information:

3.1.1 Name of material—nickel oxide sinter,

3.1.2 ASTM designation and year of issue, and

3.1.3 Grade.

3.2 Although nickel oxide sinter may be ordered either by total net weight or contained weight, the customary basis for payment is per pound of contained nickel.

4. Chemical Composition

4.1 Nickel oxide sinter shall conform to the requirements as to chemical composition specified in Table 1.

4.2 The manufacturer shall furnish an analysis of each shipment showing the nickel content.

4.3 The values shown for cobalt, copper, iron and sulfur are expected maximums. Upon request of purchaser, the manufacturer shall furnish an analysis for any of these elements over a period of production mutually agreed upon by manufacturer and the purchaser.

TABLE 1 Chemical Requirements

Element	Composition, %
	Grade 75
Nickel, min	75.00
Cobalt, max	1.30
Copper, max	0.90
Iron, max	0.50
Sulfur, max	0.02

5. Size

5.1 Nickel oxide sinter is available in containers packed to either 50 lb or 22.5 kg of nickel contained, larger uniform weight containers packed to either pound or kilogram weights or in bulk shipment using suitable rail, truck or shipboard means of conveyance.

6. Sampling for Chemical Analysis

6.1 The material shall be sampled in accordance with procedures outlined below:

6.1.1 The sample shall be taken by cutting across the entire stream at regular intervals during the time of movement of the mass being sampled. The quantity to be taken at each interval, and the number of such intervals shall be so proportioned that the total quantity taken shall amount to not less than 0.40 % of the total material being sampled.

6.2 *Treatment of Sample*:

6.2.1 In the case of nickel oxide sinter 75, the sample representing each shipment or lot shall be reduced in amount using a riffle splitter or other suitable mechanical splitter to 1000 g. This 1000-g sample shall be placed in an oven at 250°F (121°C) for ½ h to remove any traces of moisture, and then pulverized to pass an 80-mesh screen using appropriate equipment to avoid sample contamination. Approximately 250 g of this pulverized material shall be split out for copper and sulfur assays, using a riffle splitter or other suitable mechanical splitter. The unused portion of individual shipment (or lot) samples whose copper and sulphur assays are within specification shall be combined by weight into two, three, or four lot

[1] This specification is under the jurisdiction of ASTM Committee A-1 on Steel, Stainless Steel, and Related Alloys and is the direct responsibility of Subcommittee A01.18 on Castings.

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[2] *Annual Book of ASTM Standards*, Vol 14.02.

[3] *Annual Book of ASTM Standards*, Vol 03.05.

composites. Approximately 250 g of the composited material shall be split out, using a riffle splitter or other suitable mechanical splitter and analyzed for nickel. This nickel analysis shall apply to each shipment (or lot) comprising the composite.

7. Chemical Analysis

7.1 Chemical analysis when required shall be made in accordance with the procedures for nickel described in Methods E 39, or alternative method agreed upon by the manufacturer and the purchaser.

7.1.1 When no method is given in Methods E 39 for analysis for a particular element or the method given is not adequate, the analysis shall be made in accordance with a procedure agreed upon between manufacturer and purchaser and such procedure shall apply for referee purposes.

7.2 For purposes of compliance with the specified chemical composition limits, the reported analysis shall be rounded off to the nearest unit in the right-hand place of figures used in expressing the limiting value, in accordance with rounding-off method of Recommended Practice E 29.

8. Rejection

8.1 Any claims or rejections shall be made to the manufacturer within 45 days from receipt of material by the purchaser.

9. Packaging

9.1 The material shall be packaged in sound containers so that the product is not lost or contaminated in shipment.

10. Keywords

10.1 nickel; nickel oxide; sinter

Designation: A 644 – 98 (Reapproved 2003)

Standard Terminology Relating to Iron Castings[1]

This standard is issued under the fixed designation A 644; 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.

ausferrite, *n*—a cast iron matrix microstructure, produced by a controlled thermal process, which consists of predominantly acicular ferrite and high carbon austenite. (See **austempered ductile iron**.)

austempered ductile iron, *n*—a ductile cast iron that has been produced by a controlled thermal process which results in a matrix microstructure consisting of predominately acicular ferrite and high carbon austenite.

austenitize, *vt*—to convert the matrix of a ferrous alloy to austenite by heating above the transformation temperature.

batch, *n*—the component raw materials properly weighed, proportioned, and mixed for delivery to a processing unit. Also, the product output from a processing unit in which there is essentially no product output until all component materials are charged and processed.

brittle fracture, *n*—fracture that occurs without appreciable plastic deformation of the material.

brittle fracture area, *n*—The fraction or percent of the fracture surface that formed by brittle fracture. (When observed with no or low magnification, brittle fracture appears whiter and shinier than ductile fracture.)

capability index (C_p), *n*—for a stable process, the specification range divided by six times the standard deviation.

$$C_p = \frac{(USL - LSL)}{6 \times s}$$

capability index (C_{pk}), *n*—for a stable process, the smaller of the upper capability index (CPU) or the lower capability index (CPL).

carbide, primary, *n*—carbide precipitated in cast iron during solidification.

cast iron, *n*—a generic term for a series of alloys primarily of iron, carbon, and silicon in which the carbon is in excess of the amount which can be retained in solid solution in austenite at the eutectic temperature.

cementite, *n*—a very hard and brittle compound of iron and carbon corresponding to the empirical formula Fe_3C, commonly known as iron carbide.

cementite, primary, *n*—cementite precipitated in cast iron during solidification. Also known as primary carbide. (See **cementite**.)

chill, *n*—an object, usually metal, imbedded in a portion of the mold to accelerate the local rate of heat removal from the metal being cast.

chill, *v*—to accelerate the freezing rate of cast iron, usually in a localized region, to refine the graphite structure or cause formation of primary carbides.

chill, microstructural, *n*—a localized region of primary carbides in a casting made from a cast iron that would normally solidify free of primary carbides.

chilled iron, *n*—a cast iron that would normally solidify free of primary carbide which is purposely caused to solidify as white cast iron, locally or entirely, by accelerated cooling.

compacted graphite iron, *n*—a cast iron that has been treated in the liquid state so as to cause its graphitic carbon to occur in the compacted graphite shape in the as-cast condition. (See **graphite, compacted** and **graphite, spheroidal**.)

confidence level, *n*—the probability, or expected percent of the times, that the selected percent (P %) of the actual population lies within the tolerance interval calculated from the data sample.

direct reduced iron, *n*—iron ores that have been reduced to essentially metallic iron by heat and reducing agents, but without melting, and processed into suitable shapes (typically pellets) for use as a charge material in a melting operation.

dual metal, *n*—two metals of different composition that are fusion bonded at all interfacial surfaces by casting metal of one composition against metal of a second composition.

ductile fracture, *n*—fracture that occurs with appreciable plastic deformation of the material.

ductile fracture area, *n*—The fraction or percent of the fracture surface that formed by ductile fracture. (When observed with no or low magnification, ductile fracture appears grayer and duller than brittle fracture.)

ductile iron, *n*—a cast iron that has been treated in the liquid state so as to cause substantially all of its graphitic carbon to occur as spheroids or nodules in the as-cast condition.

[1] This terminology is under the jurisdiction of ASTM Committee A04 on Iron Castings and is the direct responsibility of Subcommittee A04.91 on Editorial Matters and Nomenclature.

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ferritize, *vt*—to increase the quantity of ferrite in the matrix of a ferrous casting through an appropriate heat treatment.

ferritizing anneal, *n*—the process of producing a predominantly ferritic matrix in cast iron through an appropriate heat treatment.

graphite, compacted, *n*—a graphite shape that is intermediate between flake graphite and nodular graphite that typically appears in a polished section as thick flakes with blunt (compacted) ends.

graphite flake, *n*—an irregularly shaped particle of graphite, usually appearing in a polished section as curved plates, such as found in gray cast irons.

graphite, nodular, *n*—spheroidal shaped graphite typically found in ductile irons and compact clusters of graphite typically found in malleable irons. (See **graphite, spheroidal**, and **temper carbon**.)

graphite, primary, *n*—graphite precipitated in cast iron during solidification.

graphite rosette, *n*—arrangement of graphite flakes in which the flakes extend radially from centers of crystallization in gray cast iron.

graphite, spheroidal, *n*—spheroidal shaped graphite having a polycrystalline radial structure, usually found in ductile iron and to a controlled, limited extent in compacted graphite iron.

graphitize, *vt*—to precipitate graphite in an iron-carbon alloy.

gray iron, *n*—cast iron that has a relatively large proportion of the graphitic carbon present in the form of flake graphite. The metal has a gray fracture.

heat, *n*—the total molten metal output from a single heating in a batch melting process or the total molten metal output from essentially a single heating in a continuous melting operation using basically constant charge and processing conditions and targeted at a fixed metal chemistry at the furnace spout. A heat can also be defined as a fixed time period for a continuous melting operation provided that it is shorter than the time period covered by the above definition.

inoculated iron, *n*—cast iron, either liquid or solid, to which one or more inoculating alloys have been added while the iron was in the molten state.

inoculated iron, fully, *n*—cast iron, either liquid or solid, to which all molten metal additions, including all inoculating alloys, have been added.

inoculating alloy, *n*—an alloy added to molten iron for the principle purpose of nucleating a primary phase such as graphite. Inoculating alloys are frequently used to avoid the formation of primary carbide by enhancing the nucleation of graphite.

lot, *n*—a finite quantity of a given product manufactured under production conditions that are considered uniform.

lower capability index (CPL), *n*—the difference between the sample mean ($\bar{x}$) and the lower specification limit divided by three times the standard deviation.

$$CPL = \frac{(\bar{x} - LSL)}{3 \times s}$$

lower specification limit (LSL), *n*—the lowest specified value.

M, *n*—the number of standard deviations, mutually concurred by the supplier and purchaser, to be used for calculations of statistical conformance to such items as minimums, maximums, specification ranges, and process capability indices.

DISCUSSION—*M* values of three or less were used in establishing initial ASTM specification limits; higher values of *M* result in reduced allowable variability for actual values when the property of interest is bounded on both sides; in the case of a minimum or maximum, a high value of *M* can result in the need for excessively high or low mean property values ($\bar{x}$).

malleable, ferritic, *n*—a ferrous alloy that is cast as white iron but which is converted by an appropriate heat treatment to a microstructure of temper carbon embedded in a ferritic matrix essentially free of pearlite and carbide.

malleable iron, *n*—a cast iron of such composition that it solidifies as white iron, which upon proper heat treatment is converted to a metallic matrix with nodules of temper carbon.

malleable, pearlitic, *n*—a ferrous alloy that is cast as white iron but which is converted by an appropriate heat treatment to a microstructure of temper carbon embedded in a matrix containing a controlled quantity, form, and distribution of pearlite or tempered martensite.

malleableize, *vt*—to convert white iron into malleable iron through an appropriate graphitizing heat treatment.

maximum (non-statistical), *n*—the highest acceptable actual test result; any valid individual test result above the maximum is cause for rejection of the component or material lot being tested.

$$\text{All } x_i \leq \text{Maximum} = USL$$

maximum (statistical), *n*—the highest acceptable statistical test result; for compliance, the sample mean ($\bar{x}$) plus *M* standard deviations(s), where *M* is a matter of agreement between the supplier and purchaser, must be less than, or equal to, the upper specification limit.

$$\bar{x} + M \times s \leq \text{Maximum} = USL$$

DISCUSSION—1—A normal data distribution is assumed for the population from which the data sample was drawn.

DISCUSSION—2— *M* values of three or less were used in establishing initial ASTM specifications limits. Higher values of *M* result in reduced allowable variability for actual values when the property of interest is bounded on both sides. In the case of a minimum or maximum, a high value of *M* can result in the need for excessively high or low mean property values ($\bar{x}$).

mean ($\bar{x}$), *n*—the sum of the individual data points (*x*'s) divided by the number of data points (*n*).

$$\bar{x} = \frac{\Sigma x_i}{n}$$

melt, *n*—the total molten metal produced in a single heat.

merchant pig iron, *n*—pig iron produced for commercial sale to foundries.

minimum (non-statistical), *n*—the lowest acceptable actual test result; any valid individual test result below the minimum is cause for rejection of the component or material lot being tested.

$$\text{All } x_i \geq \text{Minimum} = LSL$$

minimum (statistical), *n*—the lowest acceptable statistical test result; for compliance, the sample mean ($\bar{x}$) minus *M* standard deviation(s), where *M* is a matter of agreement between the supplier and purchaser, must be greater than, or equal to, the lower specification limit (LSL).

$$\bar{x} - M \times s \geq \text{Minimum} = LSL$$

DISCUSSION—1—A normal data distribution is assumed for the population from which the data sample was drawn.

DISCUSSION—2—M values of three or less were used in establishing initial ASTM specification limits; higher values of *M* result in reduced allowable variability for actual values when the property of interest is bounded on both sides; in the case of a minimum or maximum, a high value of *M* can result in the need for excessively high or low mean property values ($\bar{x}$).

mottled iron, *n*—a cast iron containing a mixed structure of gray iron and white iron of variable proportions. The fracture has a mottled appearance.

nodular graphite, *n*—graphite in the form of nodules or spheroids in iron castings.

nodularity, *n*—the volumetric proportion of spheroidal or nodular graphite to total graphite in a ductile iron or a compacted graphite iron matrix (see Test Method A 247, for Evaluating the Microstructure of Graphite in Iron Castings,[2]Types I and II).

nodularity, degree of, *n*—the volumetric proportion of spheroidal or nodular graphite to total graphite in a ductile iron matrix (see Test Method A 247, Types I and II).

nodulizing alloy, *n*—an alloy added to molten iron for the primary purpose of causing the formation of spheroidal graphite during solidification.

pig iron, *n*—the high carbon iron product obtained by the reduction of iron ores, typically in a blast furnace or an electric furnace, and cast into uniform shapes (pigs) having physical and chemical characteristics suitable for end use as foundry melting stock.

range, data, *n*—the absolute value of the difference between the highest and lowest values in a set of data.

range, specification (non-statistical), *n*—the absolute value of the difference between the highest (USL) and lowest (LSL) specified values; for compliance with a non-statistical range, each valid individual test result must lie at, or within, the specification limits.

$$LSL \leq \text{All } x_i \leq USL$$

range, specification (statistical), *n*—the absolute value of the difference between the highest (USL) and lowest (LSL) specified values; for compliance with a statistical range, all calculated values from the mean ($\bar{x}$) minus *M* times the standard deviation(s) to the mean plus *M* times the standard deviation, where *M* is a matter of agreement between the supplier and purchaser, must not lie outside of the specification limits.

$$LSL \leq \bar{x} - M \times s \qquad \text{and} \qquad \bar{x} + M \times s \leq USL$$

DISCUSSION—1—A normal data distribution is assumed for the population from which the data sample was drawn.

DISCUSSION—2—*M* values of three or less were used in establishing initial ASTM specification limits; higher values of *M* result in reduced allowable variability for actual values when the property of interest is bounded on both sides; in the case of a minimum or maximum, a high value of *M* can result in the need for excessively high or low mean property values ($\bar{x}$).

sample, *n*—one or more portions of a liquid or solid material taken in an unbiased manner from a batch, heat, lot, or process stream to be representative of the whole, for subsequent testing to determine the chemical, physical, mechanical, or other quality characteristics of the material, or combination thereof.

standard deviation (*s*), *n*—a measure of the dispersion of a series of results around their average, expressed as the square root of the quantity obtained by summing the squares of the deviations from the average of the results and dividing by the number of observations minus one; it is also the square root of the variance and is calculated as follows:

$$s = \sqrt{\frac{\Sigma(x_i - \bar{x})^2}{(n-1)}}$$

where:
s = estimated standard deviation of the series of results,
x_i = each individual value,
$\bar{x}$ = mean (average) of all values, and
n = number of values.

DISCUSSION—1—A normal data distribution is assumed for the population from which the data sample was drawn.

DISCUSSION—2—It is desirable to use at least 30 data points to calculate the sample mean. The use of smaller sample sizes results in reduced confidence in the estimated value of the standard deviation.

steel scrap, *n*—discarded steel or steel products, generally segregated by composition and size or ''grade,'' suitable for melting.

temper carbon, *n*—compact aggregates or nodules of graphite found in malleable iron as a result of heat treatment.

test bar, *n*—a bar-shaped coupon that is tested with or without subsequent preparation for the determination of physical or mechanical properties.

test coupon, *n*—specially designed casting, or portion thereof, that is used to provide a representative sample of the iron from which it was cast.

test lug, *n*—a sample produced as an appendage on a casting, that may be removed and tested to qualify the casting or the iron from which it was produced.

test specimen, *n*—a test object, suitably prepared from a sample, for evaluation of the chemical, physical, mechanical, or metallurgical quality of the sample.

[2] 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.

tolerance interval, *n*—a range constructed from an experimental data sample so as to statistically enclose P % or more of the population from which the sample was drawn with a confidence level of 100 (1−α) %.

DISCUSSION—As an example, for data from a population with a normal distribution, $\bar{x} \pm K \times s$ will statistically bracket P % or more of the population with confidence 100 (1−α) % where K is a function of the sample size (*n*), P, and α in statistical tables of tolerance factors (K) for population proportion (P) of normal distributions. Upper (U) or lower (L) one-sided tolerance limits can be calculated from $U = \bar{x} + K \times s$ or $L = \bar{x} - K \times s$ such that statistically, P % or more of the population lies below U or above L with confidence 100 (1−α) %. If the data is not from a population with a normal distribution, different tables or approaches, or both, need to be used.

transition temperature, *n*—the test temperature for which the fracture surface of the test specimen shows 50 % ductile and 50 % brittle fracture.

treated iron, *n*—molten cast iron to which all basic alloys and nodulizing alloys have been added but not necessarily all inoculating alloy additions.

upper capability index (CPU), *n*—the difference between the upper specification limit and the sample mean divided by three times the sample standard deviation.

$$CPU = \frac{(USL - \bar{x})}{3 \times s}$$

upper specification limit (USL), *n*—the highest specified value.

white iron, *n*—cast iron in which substantially all of the carbon is in solution and in the combined form. The metal has a white fracture.

Standard Specification for Centrifugally Cast Dual Metal (Gray and White Cast Iron) Cylinders[1]

This standard is issued under the fixed designation A 667/A 667M; 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[2] covers centrifugally cast cylinders with an outer layer of white cast iron and the remainder of the material of gray cast iron. These castings are suitable for pressure containing parts the design strength of which is based on the gray iron portion of the cylinder. These castings are suitable for service at temperatures up to 450°F [230°C].

1.2 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 must be used independent of the other. Combining values from the two systems may result in nonconformance with the specification.

1.3 The following safety hazards caveat pertains only to the test method portion, Section 8, 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 278 Specification for Gray Iron Castings for Pressure-Containing Parts for Temperatures Up to 650°F (350°C)[3]

A 278M Specification for Gray Iron Castings for Pressure-Containing Parts for Temperatures Up to 345°C [Metric][4]

3. Materials and Manufacture

3.1 The melting procedures shall be optional with the foundry.

3.2 The white iron portion of the cylinder shall be made to a minimum hardness of 55 Scleroscope "C". The gray iron portion of the cylinder shall conform to Specification A 278, Class 20 [A 278M, Class 150].

3.3 The casting process shall be controlled to produce a metallurgical bond between the two metal layers.

4. Finish

4.1 All surfaces shall be machined prior to the cylinders being placed into service.

5. Physical Requirements

5.1 *Tensile Requirements*—Tension test specimens removed from the casting shall have a tensile strength not less than 80 % of that specified in 3.2.

5.2 *Thickness of White Cast Iron*:

5.2.1 The thickness of the white cast iron shall be not less than 5 % nor more than 30 % of the total finished wall thickness.

5.2.2 The thickness of the white cast iron shall be determined by ultrasonic testing.

6. Number of Tests

6.1 The number of tension tests shall be in conformance with Specifications A 278 and A 278M.

7. Specimen Preparation

7.1 Separately cast test bars may be used to represent the gray iron portion of the castings. The test bars shall be cast in core sand and have a nominal diameter of 2 in. [50 m]. Tension test specimens shall be machined from test bars to the dimensions given for Specimen C in Specifications A 278 and A 278M.

7.2 At the option of the manufacturer he may substitute test bars taken from the gray iron portion of the casting. The test bars shall be taken midway between the inside diameter of the

[1] This specification is under the jurisdiction of Committee A04 on Iron Castings and is the direct responsibility of Subcommittee A04.01 on Grey and White Iron Castings.

Current edition approved May 10, 2003. Published May 2003. Originally approved in 1972. Last previous edition approved in 1998 as A 667/A 667M – 87 (1998).

[2] For ASME Boiler and Pressure Vessel Code applications see related Specification SA-667 in Section II of that Code.

[3] *Annual Book of ASTM Standards*, Vol. 01.02.

[4] Discontinued. Replaced by A 278/A 278M. See 2000*Annual Book of ASTM Standards*, Vol 01.02.

casting and the interface between the two layers. Tension test specimens machined from these test bars shall conform to the dimensions shown for Specimen C in Specifications A 278 and A 278M.

8. Test Method

8.1 Tension test specimens shall fit the holders of the testing machine in such a way that the load shall be axial. The use of self-aligning shackles is suggested. After reaching a stress equivalent to 15 000 psi [100 MPa] the speed of the moving head of the testing machine shall not exceed ⅛ in. [3.2 mm]/min.

9. Inspection

9.1 The inspector representing the purchaser shall have free 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 manufacturer shall afford the inspector without charge all reasonable facilities 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 the shipment unless otherwise specified and shall be so conducted as not to interfere unnecessarily with the operation of the works.

10. Acceptance and Certification

10.1 Final acceptance of the casting shall follow complete machining of the casting. Upon request of the purchaser and when so specified in the purchase order, a certification shall be made on the basis of acceptance of the material. This shall consist of a copy of the manufacturer's test report or a statement by the supplier accompanied by a copy of the test results that the material has been sampled, tested, and inspected in accordance with the provisions of this specification. Each certification so furnished shall be signed by an authorized agent of the supplier or manufacturer.

11. Product Marking

11.1 Pressure containing castings made in accordance with this specification shall have the name of the manufacturer or his recognized trademark and the class of iron to which it conforms cast or indelibly stamped on the surface indicated by the purchaser or in such a position as not to injure the usefulness of the casting.

Standard Practice for Polyethylene Encasement for Ductile Iron Pipe for Water or Other Liquids[1]

This standard is issued under the fixed designation A 674; 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 practice covers materials and installation procedures for polyethylene encasement to be applied to underground installations of ductile iron pipe. It may also be used for polyethylene encasement of fittings, valves, and other appurtenances to ductile iron pipe systems.

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:*

D 149 Standard Test Method for Dielectric Breakdown Voltage and Dielectric Strength of Solid Electrical Insulating Materials at Commercial Power Frequencies[2]

D 882 Standard Test Method for Tensile Properties of Thin Plastic Sheeting

D 1709 Standard Test Methods for Impact Resistance of Plastic Film by the Free-Falling Dart Method

D 1922 Standard Test Method for Propagation Tear Resistance of Plastic Film and Thin Sheeting by Pendulum Method

D 4976 Standard Specification for Polyethylene Plastics Molding and Extrusion Materials

2.2 *ANSI/AWWA Standards:*

C 600, Installation of Ductile Iron Water Mains and Their Appurtenances[3]

C 105/A21.5, Polyethylene Encasement for Ductile-Iron Pipe Systems[3]

3. Terminology

3.1 *Definitions:*

3.1.1 *polyethylene encasement*—polyethylene material, in tube or sheet form, that is used to encase ductile iron pipe.

3.1.2 *securing overlap*—any one of various methods of holding polyethylene encasement in place at the point of overlap until backfilling operations are completed. This may be accomplished with adhesive tape or plastic tie straps.

3.1.3 *linear low-density polyethylene film*—Film extruded from virgin linear low-density polyethylene raw material.

3.1.4 *high-density, cross-laminated polyethylene film*—Film extruded from virgin high-density polyethylene raw material, which is then molecularly oriented by stretching. Two single-ply layers of the film are then laminated together with their orientations at 90° to one another to form the final product.

4. Requirements

4.1 *Materials*:

4.1.1 *Linear low-density polyethylene film*—Linear low-density polyethylene film shall be manufactured of virgin polyethylene material conforming to the requirements of Specification D 4976 shown in Table 1.

4.1.1.1 *Thickness*—Linear low-density polyethylene film shall have a minimum thickness of 0.008 in. (0.20 mm).

4.1.2 *High-density cross-laminated polyethylene film*—High-density cross-laminated polyethylene film shall be manufactured of virgin polyethylene material conforming to the requirements of Specification D 4976 shown in Table 2.

4.1.2.1 *Thickness*—High-density cross-laminated polyethylene film shall have a minimum thickness of 0.004 in. (0.10 mm).

4.2 *Tube Size*—The tube size for each pipe diameter shall be as listed in Table 3.

4.3 *Color*—Polyethylene film may be supplied with its natural color, colors including white and black, or black (weather-resistant) containing not less than 2 percent carbon black with an average particle diameter of 50 mm or less. A minimum of 2 percent of a hindered-amine ultraviolet inhibitor is required in any natural or colored film except black film containing 2 percent or more carbon black.

4.4 *Marking requirements*—The polyethylene film supplied shall be clearly marked, at a minimum of every 2-ft along its length, containing the following information:

(a) Manufacturer's name or registered trademark

(b) Year of manufacture

(c) ASTM A 674

(d) Minimum film thickness and material type (LLDPE or HDCLPE)

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[1] This practice is under the jurisdiction of ASTM Committee A04 on Iron Castings and is the direct responsibility of Subcommittee A04.12 on Pipes and Tubes.

Current edition approved Oct. 10, 2000. Published November 2000. Originally published as A 674 – 72. Last previous edition A 674 – 95.

[2] *Annual Book of ASTM Standards*, Vol 08.01.

[3] Available from American Water Works Association, 6666 W. Quincy Ave., Denver, CO 80235.

TABLE 1 Linear Low-Density Polyethylene Characteristics

Raw Material Used to Manufacture Polyethylene Encasement Material	
Group, density, and dielectric strength	in accordance with the latest revision of Specification D 4976
Group	2 (Linear)
Density	0.910 to 0.935 g/cm^3
Dielectric strength, volume resistivity	10^{15} ohm-cm, min
Polyethylene Encasement Material	
Tensile strength	3600 psi (24.83 MPa), min (ASTM D 882)
Elongation	800 %, min (ASTM D 882)
Dielectric strength	800 V/mil (31.5 V/μm) thickness, min (ASTM D 149)
Impact resistance	600 g, min (ASTM D 1709 Method B)
Propagation tear resistance	2550 gf, min (ASTM D 1922)

TABLE 2 High-Density Cross-Laminated Polyethylene Characteristics

Raw Material Used to Manufacture Polyethylene Encasement Material	
Group, density, and dielectric strength	in accordance with the latest revision of Specification D 4976
Group	2 (Linear)
Density	0.940 to 0.960 g/cm^3
Dielectric strength, volume resistivity	10^{15} ohm-cm, min
High-Density Cross-Laminated Polyethylene Encasement Material	
Tensile strength	6300 psi (43.47 MPa), min
Elongation	100 %, min
Dielectric strength	800 V/mil (31.5 V/μm) thickness, min
Impact resistance	800 g, min. (ASTM D 1709 Method B)
Propagation tear resistance	250 gf, min. (ASTM D 1922)

TABLE 3 Polyethylene Tube Sizes for Push-On Joint Pipe[A]

Nominal Pipe Diameter, in.	Recommended Polyethylene Flat Tube Width, in. (cm)[B]
3	14 (36)
4	14 (36)
6	16 (41)
8	20 (51)
10	24 (61)
12	27 (69)
14	30 (76)
16	34 (86)
18	37 (94)
20	41 (104)
24	54 (137)
30	67 (170)
36	81 (206)
42	81 (206)
48	95 (241)
54	108 (274)
60	108 (274)
64	121 (307)

[A] These wrap sizes should work with most push-on joint pipe and fitting bell sizes. Where bell circumferences are larger than the sheet sizes shown, the bell areas should be carefully wrapped with cut film sections, effectively lapping and securing cut edges as necessary; or, alternatively, sufficiently large tube or sheet film to effectively cover these joints should be ordered.

[B] For flat sheet polyethylene, see 5.2.3.

(e) Applicable range of nominal pipe diameter size(s)

(f) Warning—Corrosion Protection—Repair Any Damage

4.4.1 *Marking height*—Letters and numerals used for marking items a through e in Section 4.4 shall not be less than 1 in. (25.4 mm) in height. Item f in Section 4.4 shall be not less than 1½in. (38.10 mm) in height.

5. Installation

5.1 *General*:

5.1.1 The polyethylene encasement shall prevent contact between the pipe and the surrounding backfill and bedding material but is not intended to be a completely airtight or watertight enclosure. All lumps of clay, mud, cinders, etc. which may be on the pipe surface shall be removed prior to installation of the polyethylene encasement. During installation, care shall be exercised to prevent soil or embedment material from becoming entrapped between the pipe and the polyethylene.

5.1.2 The polyethylene film shall be fitted to the contour of the pipe to effect a snug, but not tight, encasement with minimum space between the polyethylene and the pipe. Sufficient slack shall be provided in contouring to prevent stretching the polyethylene bridging irregular surfaces, such as bell-spigot interfaces, bolted joints, or fittings, and to prevent damage to the polyethylene due to backfilling operations. Overlaps and ends shall be secured by the use of adhesive tape or plastic tie straps.

5.1.3 For installations below the water table or in areas subject to tidal actions, or both, it is recommended that tube-form polyethylene be used with both ends sealed as thoroughly as possible with adhesive tape or plastic tie straps at the joint overlap. It is also recommended that circumferential wraps of tape or plastic tie straps be placed at 2 ft (0.6 m) intervals along the barrel of the pipe to help minimize the space between the polyethylene and the pipe.

5.2 *Pipe*—This practice includes three different methods for the installation of polyethylene encasement. Method A and B are for use with polyethylene tubes and Method C is for use with polyethylene sheets.

5.2.1 *Method A (see* Fig. 1*)*:

5.2.1.1 Cut the polyethylene tube to a length approximately

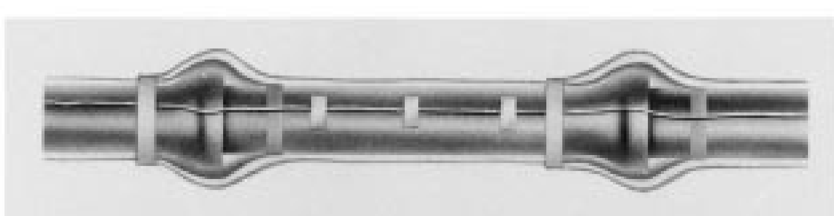

FIG. 1 Method A

2 ft (0.6 m) longer than the length of the pipe section. Slip the tube around the pipe, centering it to provide a 1-ft (0.3-m) overlap on each adjacent pipe section, and bunching it accordion fashion lengthwise until it clears the pipe ends.

5.2.1.2 Lower the pipe into the trench and make up the pipe joint with the preceding section of pipe. A shallow bell hole must be made at joints to facilitate installation of the polyethylene tube.

5.2.1.3 After assembling the pipe joint, make the overlap of the polyethylene tube. Pull the bunched polyethylene from the preceding length of pipe, slip it over the end of the new length of pipe, and secure in place. Then slip the end of the polyethylene from the new pipe section over the end of the first wrap until it overlaps the joint at the end of the preceding length of pipe. Secure the overlap in place. Take up the slack width at the top of the pipe as shown in Fig. 2, to make a snug, but not tight, fit along the barrel of the pipe, securing the fold at quarter points.

5.2.1.4 Repair any rips, punctures, or other damage to the polyethylene with adhesive tape or with a short length of polyethylene tube cut open, wrapped around the pipe, and secured in place. Proceed with installation of the next section of pipe in the same manner.

5.2.2 *Method B (see* Fig. 3*)*:

5.2.2.1 Cut the polyethylene tube to a length approximately 1 ft (0.3 m) shorter than the length of the pipe section. Slip the tube around the pipe, centering it to provide 6 in. (150 mm) of bare pipe at each end. Make the polyethylene snug, but not tight, as shown in Fig. 2; secure ends as described in 5.2.1.

5.2.2.2 Before making up a joint, slip a 3-ft (0.9-m) length of polyethylene tube over the end of the preceding pipe section, bunching it accordion fashion lengthwise. Alternatively, place a 3-ft (0.9 m) length of polyethylene sheet in the trench under the joint to be made. After completing the joint, pull the 3-ft length of polyethylene over or around the joint, overlapping the previously installed on each adjacent section of pipe by at least 1 ft (0.3 m); make snug and secure each end as described in 5.2.1. A shallow bell hole must be made at joints to facilitate installation of the polyethylene tube or sheet.

5.2.2.3 Repair any rips, punctures, or other damage to the polyethylene as described in 5.2.1. Proceed with installation of the next section of pipe in the same manner.

5.2.3 *Method C (see* Fig. 4*)*:

5.2.3.1 Flat sheet polyethylene shall have a minimum width twice the flat tube width shown in Table 3.

5.2.3.2 Cut the polyethylene sheet to a length approximately 2 ft (0.6 m) longer than the length of pipe section. Center the cut length to provide a 1-ft (0.3-m) overlap on each adjacent pipe section, bunching it until it clears the pipe ends. Wrap the polyethylene around the pipe so that it overlaps circumferentially over the top quadrant of the pipe. Secure the cut edge of polyethylene sheet at approximately 3-ft (0.9-m) intervals along the pipe length.

5.2.3.3 Lower the wrapped pipe into the trench and make up the pipe joint with the preceding section of pipe. A shallow bell hole must be made at joints to facilitate installation of the polyethylene. After completing the joint, make the overlap as described in 5.2.1.

5.2.3.4 Repair any rips, punctures, or other damage to the polyethylene as described in 5.2.1. Proceed with installation of the next section of pipe in the same manner.

5.3 *Pipe-Shaped Appurtenances*—Bends, reducers, offsets, and other pipe-shaped appurtenances shall be covered with polyethylene in the same manner as the pipe.

5.4 *Odd-Shaped Appurtenances*—Wrap valves, tees, crosses, and other odd-shaped pieces which cannot practically be wrapped in a tube, with a flat sheet or split length of polyethylene tube. Pass the sheet under the appurtenance and bring up around the body. Make seams by bringing the edges together, folding over twice, and taping down. Handle slack width and overlaps at joints as described in 5.2.1. Tape polyethylene securely in place at valve stem and other penetrations.

5.5 *Repairs*—Repair any cuts, tears, punctures, or damage to polyethylene with adhesive tape or with a short length of polyethylene tube cut open, wrapped around the pipe covering the damaged area, and secured in place.

5.6 *Openings in Encasement*—Make openings for branches, service taps, blow-offs, air valves, and similar appurtenances, by making an X-shaped cut in the polyethylene and temporarily folding the film back. After the appurtenance is installed, tape the slack securely to the appurtenance and repair the cut, as well as any other damaged areas in the polyethylene, with tape. Direct service taps may also be made through the polyethylene, with any resulting damage areas being repaired as described previously. The preferred method of making direct service taps consists of applying two or three wraps of adhesive tape completely around the polyethylene encased pipe to cover the area where the tapping machine and chain will be mounted. This method minimizes possible damage to the polyethylene

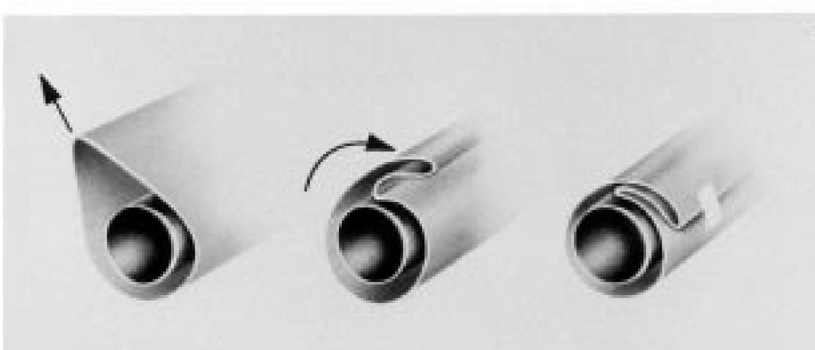

FIG. 2 Slack Reduction Procedure—Methods A and B

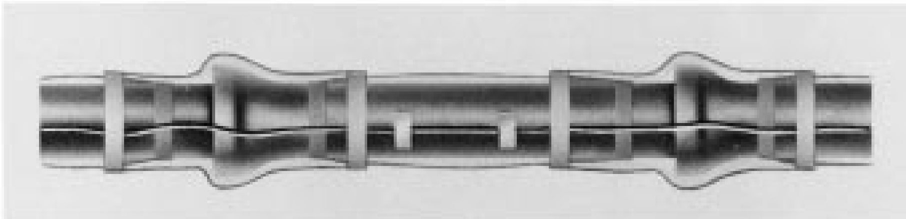

FIG. 3 Method B

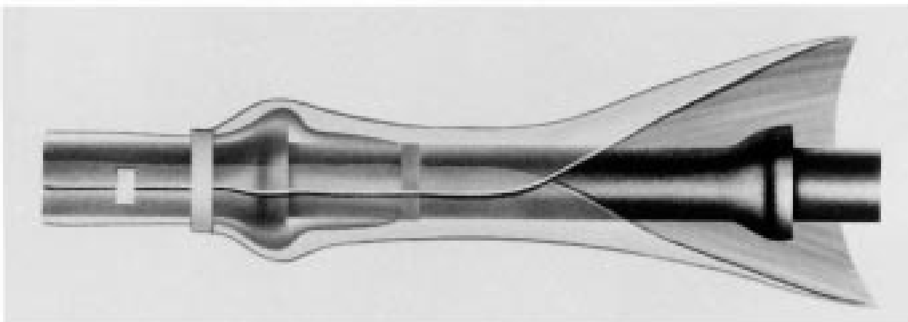

FIG. 4 Method C

during the direct tapping procedure. After the tapping machine is mounted, the corporation stop is installed directly through the tape and polyethylene as shown in Fig. 5. Experience has shown that this method is very effective in eliminating damage to the polyethylene encasement by the tapping machine and chain during the tapping operation. After the direct tap is completed, the entire circumferential area should be closely inspected for damage and repaired if needed.

5.7 *Junctions Between Wrapped and Unwrapped Pipe*—Where polyethylene wrapped pipe joins a pipe that is not wrapped, extend the polyethylene tube to cover the unwrapped pipe a distance of at least 3 ft (0.9 m). Secure the end with circumferential turns of adhesive tape. Service lines of dissimilar metals shall be wrapped with polyethylene or a suitable dielectric tape for a minimum clear distance of 3 ft (0.9 m) away from the ductile-iron pipe.

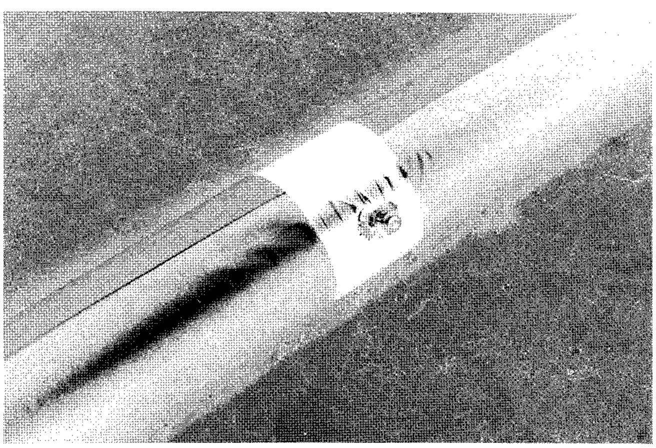

FIG. 5 Preferred Method for Making Direct Service Taps on PE Encased Iron Pipe

5.8 *Backfill for Polyethylene Wrapped Pipe*—Backfill material shall be the same as specified for pipe without polyethylene wrapping. Take special care to prevent damage to the polyethylene wrapping when placing backfill. Backfill material shall be free of cinders, refuse, boulders, rocks, stones, or other material that could damage polyethylene. In general, backfilling practice should be in accordance with the latest revision of ANSI/AWWA C 600.

6. Inspection and Certification by Manufacturer

6.1 *Quality control and inspection*—The manufacturer shall establish the necessary quality control and inspection practice to ensure compliance with this standard.

6.2 *Manufacturer's statement*—The manufacturer shall, if required by the purchaser's specifications, provide a sworn statement that the inspection and all applicable material requirements of Section 4.1 have been met and that all results comply with the requirements of this standard.

6.3 *Freedom from defects*—All polyethylene film shall be clean, sound, and without defects that could impair service.

7. Keywords

7.1 corrosion protection; ductile iron pipe; polyethylene encasement; soil-test evaluation; stray direct current

APPENDIX

(Nonmandatory Information)

X1. PROCEDURES FOR SOIL SURVEY TESTS AND OBSERVATIONS AND THEIR INTERPRETATION TO DETERMINE WHETHER DUCTILE IRON PIPE FOR WATER OR OTHER LIQUIDS REQUIRES POLYETHYLENE ENCASEMENT

X1.1 Scope

X1.1.1 In the appraisal of soil and other conditions that affect the corrosion rate of ductile iron pipe (see Note X1.1), a minimum number of factors must be considered. They are outlined in the following sections. A method of evaluating and interpreting each factor and a method of weighting each factor to determine whether polyethylene encasement should be used are subsequently described.

NOTE X1.1—The information contained in Appendix X1 is also applicable to grey iron pipe. Although grey iron pressure pipe is no longer produced in the United States, many miles of this product remain in service.

These methods should be employed only by qualified personnel who are experienced in soil analysis and evaluation of conditions potentially corrosive to ductile-iron pipe. Factors such as moisture content, soil temperature, location of soil sample with respect to pipe, time between removal of soil sample and testing, and other factors can significantly affect the soil-test evaluation. For example, certain soil environments are generally accepted to be potentially corrosive to ductile-iron pipe based on experience, and thus do not require evaluation to determine the need for corrosion protection. Such environments include, but are not limited to, coal, cinders, muck, peat, mine wastes, and landfill areas high in foreign materials. Experience with existing installations and potential for stray direct current corrosion should also be taken into consideration as a part of the evaluation.

X1.2 Applicable Document

X1.2.1 *ANSI/AWWA Standard*:

C105/A21.5, Polyethylene Encasement for Ductile-Iron Pipe Systems[3]

X1.3 Earth Resistivity

X1.3.1 There are three methods for determining earth resistivity: four-pin, single-probe, and soil-box. In the field, a four-pin determination should be made with pins spaced at approximate pipe depth. This method yields an average of resistivity from the surface to a depth equal to pin spacing. However, results are sometimes difficult to interpret where dry top soil is underlain with wetter soils and where soil types vary with depth. The Wenner configuration is used in conjunction with a resistance meter.[4] For all-around use, a unit with a capacity of up to 10 Ω is suggested because of its versatility in permitting both field and laboratory testing in most soils.

X1.3.2 Because of the aforementioned difficulty in interpretation, the same unit may be used with a single probe that yields resistivity at the point of the probe. A boring is made into the subsoil so that the probe may be pushed into the soil at the desired depth.

X1.3.3 Inasmuch as the soil may not be typically wet, a sample should be removed for resistivity determination, which may be accomplished with any one of several laboratory units that permits the introduction of water to saturation, thus simulating saturated field conditions. Each of these units is used in conjunction with a soil resistance meter.

X1.3.4 Interpretation of resistivity results is extremely important. To base an opinion on a four-pin reading with dry top soil averaged with wetter subsoil would probably result in an inaccurate premise. Only by determining the resistivity in soil at pipe depth can an accurate interpretation be made. Also, every effort should be made to determine the local situation concerning ground-water table, presence of shallow ground water, and approximate percentage of time the soil is likely to be water saturated.

X1.3.5 With ductile iron pipe, resistance to corrosion through products of corrosion is enhanced if there are dry periods during each year. Such periods seem to permit hardening or toughening of the corrosion scale or products, which then become impervious and serve as better insulators.

X1.3.6 In making field determinations of resistivity, temperature is important. The result obtained increases as temperature decreases. As the water in the soil approaches freezing, resistivity increases greatly, and, therefore, is not reliable. Field determinations under frozen soil conditions should be avoided. Reliable results under such conditions can be obtained only by collection of suitable subsoil samples for analysis under laboratory conditions at suitable temperature.

X1.3.7 *Interpretation of Resistivity*—Because of the wide variance in results obtained under the methods described, it is difficult specifically to interpret any single reading without knowing which method was used. It is proposed that interpretation be based on the lowest reading obtained with consideration being given to other conditions, such as normal moisture content of the soil in question. Because of the lack of exact correlation between experiences and resistivity, it is necessary to assign ranges of resistivity rather than specific numbers. In Table X1.1, points are assigned to various ranges of resistivity. These points, when considered along with points assigned to other soil characteristics, are meaningful.

X1.4 pH

X1.4.1 In the pH range from 0.0 to 4.0, the soil serves well as an electrolyte. In the pH range from 6.5 to 7.5, soil conditions are optimum for sulfate reduction. In the pH range from 8.5 to 14.0, soils are generally quite high in dissolved salts, yielding a low soil resistivity.

X1.4.2 In testing pH, a combination pH electrode is pushed into the soil sample and a direct reading is made, following

[4] The Vibroground manufactured by Associated Research, Inc. has been found satisfactory for earth resistivity testing.

TABLE X1.1 Soil-Test Evaluation[A]

Soil Characteristics	Points
Resistivity, ohm-cm (based on water-saturated soil-box):	
<1500	10
≥1500 to 1800	8
>1800 to 2100	5
>2100 to 2500	2
>2500 to 3000	1
>3000	0
pH:	
0–2	5
2–4	3
4–6.5	0
6.5–7.5	0[B]
7.5–8.5	0
>8.5	3
Redox potential:	
> +100 mV	0
+50 to +100 mV	3.5
0 to +50 mV	4
Negative	5
Sulfides:	
Positive	3.5
Trace	2
Negative	0
Moisture:	
Poor drainage, continuously wet	2
Fair drainage, generally moist	1
Good drainage, generally dry	0

[A]Ten points = corrosive to or ductile iron pipe; protection is indicated.
[B]If sulfides are present and low or negative redox potential results are obtained, three points shall be given for this range.

suitable temperature setting on the instrument. Normal procedures are followed for standardization.

X1.5 Oxidation-Reduction (Redox) Potential

X1.5.1 The oxidation-reduction (redox) potential of a soil is significant because the most common sulfate-reducing bacteria can live only under anaerobic conditions. A redox potential greater than +100 mV shows the soil to be sufficiently aerated so that it will not support sulfate reducers. Potentials of 0 to +100 mV may or may not indicate anaerobic conditions; however, a negative redox potential definitely indicates the anaerobic conditions in which sulfate reducers thrive. The redox test is performed using a pH/mV meter with a combination ORP electrode inserted into the soil sample. It should be noted that soil samples removed from a boring or excavation can undergo a change in redox potential on exposure to air. Such samples should be tested immediately on removal from the excavation. Experience has shown that heavy clays, muck, and organic soils are often anaerobic, and these soils should be regarded as potentially corrosive.

X1.6 Sulfides

X1.6.1 The sulfide determination is recommended because of its field expediency. A positive sulfide reaction reveals a potential problem due to sulfate-reducing bacteria. The sodium azide-iodine qualitative test is used. In this determination, a solution of 3 % sodium azide in a 0.1 *N* iodine solution is introduced into a test tube containing a sample of the soil in question. Sulfides catalyze the reaction between sodium azide and iodine, with the resulting evolution of nitrogen. If strong bubbling or foaming results, sulfides are present, and the presence of sulfate-reducing bacteria is indicated. If very slight bubbling is noted, sulfides are probably present in small concentration and the result is noted as a trace.

X1.7 Moisture Content

X1.7.1 Since prevailing moisture content is extremely important to all soil corrosion, every effort must be made to determine this condition. It is not proposed, however, to determine specific moisture content of a soil sample, because of the probability that content varies throughout the year, but to question local authorities who are able to observe the conditions many times during the year. (Although mentioned in X 1.3, this variability factor is being reiterated to emphasize the importance of notation.)

X1.8 Soil Description

X1.8.1 In each investigation, soil types should be completely described. The description should include color and physical characteristics, such as particle size, plasticity, friability, and uniformity. Observation and testing will reveal whether the soil is high in organic content; this should be noted. Experience has shown that in a given area, corrosivity may often be reflected in certain types and colors of soil. This information is valuable for future investigations or for determining the most likely soils to suspect. Soil uniformity is important because of the possible development of local corrosion cells due to the difference in potential between unlike soil types, both of which are in contact with the pipe. The same is true for uniformity of aeration. If one segment of soil contains more oxygen than a neighboring segment, a corrosion cell can develop from the difference in potential. This cell is known as a differential aeration cell.

X1.8.2 There are several basic types of soil that should be noted: sand, loam, silt, clay, muck. Unusual soils, such as peat or soils high in foreign material, should also be noted and described.

X1.9 Potential Stray Direct Current

X1.9.1 Any soil survey should include consideration of possible stray direct current with which the gray or ductile cast iron pipe installation might interfere. The widespread use of rectifiers and ground beds for cathodic protection of underground structures has increased the potential of stray direct current. Proximity of such cathodic protection systems should be noted. Among other potential sources of stray direct current are electric railways, industrial equipment, including welding, and mine transportation equipment. Normally, the amount of stray current influence from cathodic protection systems on an electrically discontinuous ductile iron pipeline will be negligible. It is not detrimental to the expected life of the system, unless the pipeline comes close to an impressed current cathodic protection anode bed where the current density is high. When ductile iron pipelines are exposed to high density stray current environments, the pipeline should be rerouted or the anode bed relocated. If neither of these options is feasible, the ductile iron pipe in this area should be electrically bonded together, electrically isolated from adjacent pipe, polyethylene encased, and appropriate test leads and "current drain" installed.

X1.10 Experience with Existing Installations

X1.10.1 The best information on corrosivity of soil with respect to ductile iron pipe is the result of experience with this material in the area in question. Every effort should be made to acquire such data by questioning local officials and, if possible, by actual observation of existing installations.

X1.11 Soil-Test Evaluation

X1.11.1 Using the soil-test procedures described herein, the following tests are considered in evaluating corrosivity of the soil: resistivity, pH, redox potential, sulfides, and moisture. For each of these tests, results are categorized according to their contribution to corrosivity. Points are assigned based on experience with ductile iron pipe. When results of these five test observations are available, the assigned points are totaled. If the sum is equal to ten or more, the soil is corrosive to ductile iron pipe and protection against exterior corrosion should be provided. This system is limited to soil corrosion and does not include consideration of stray direct current. Table X1.1 lists points assigned to the various test results.

X1.12 General

X1.12.1 These notes deal only with ductile iron pipe, the soil environment in which they will serve, and methods of determining the need for polyethylene encasement.

X1.13 Uniquely Severe Environments

X1.13.1 Research and experience has shown that polyethylene encasement alone is a viable corrosion protection system for ductile and gray iron pipe in most environments. However, other options should be considered for environments where all the following characteristics co-exist: (1) soil resistivity ≤500 ohm-cm; (2) anaerobic conditions in which sulfate reducing bacteria thrive {neutral pH (6.5 to 7.5), low or negative redox-potential (negative to +100 mV), and the presence of sulfides (positive or trace)}; and (3) water table intermittently or continually above the invert of the pipe.

Designation: A 701 – 96 (Reapproved 2000)

Standard Specification for Ferromanganese-Silicon[1]

This standard is issued under the fixed designation A 701; 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 a manganese-silicon alloy designated as ferromanganese-silicon.

2. Referenced Documents

2.1 *ASTM Standards:*

E 29 Practice for Using Significant Digits in Test Data to Determine Conformance with Specifications[2]

E 31 Methods for Chemical Analysis of Ferroalloys[3]

E 32 Practices for Sampling Ferroalloys and Steel Additives for Determination of Chemical Composition[3]

3. Ordering Information

3.1 Orders for material under this specification shall include the following information:

3.1.1 Quantity,

3.1.2 Name of material,

3.1.3 ASTM designation and year of issue,

3.1.4 Size desired,

3.1.5 Requirement for packaging, and

3.1.6 Reports requested with shipment.

3.2 The basis of payment shall be per pound of alloy.

4. Chemical Requirements

4.1 The alloy shall conform to the chemical requirements as shown in Table 1.

4.2 The manufacturer shall furnish an analysis of each shipment as requested by the customer.

4.3 The values shown in Table 2 are expected maximums for the elements listed.

5. Size

5.1 The alloy is available in the sizes shown in Table 3.

5.2 The sizes listed in Table 3 are typical of the product as shipped from the seller's plant. Some deterioration of size can be expected in transit. This system is based on the relative friability as indicated in the Appendix.

TABLE 1 Recommended Specification for Ferromanganese-Silicon

Element	Composition, %
Manganese	63 to 66
Carbon, max	0.08
Silicon	28 to 32
Phosphorus, max	0.05

6. Sampling

6.1 The material shall be sampled in accordance with Practices E 32.

6.2 Other methods of sampling may be used if mutually agreed upon between the purchaser and the seller. In case of discrepancies, Practices E 32 shall be used as the referee.

7. Chemical Analysis

7.1 Chemical procedures for analysis of ferroalloy components are not standardized. The chemical content procedures

TABLE 2 Recommended Supplementary Chemical Requirements for Ferromanganese-Silicon

Element	Composition, max, %
Arsenic	0.15
Tin	0.010
Lead	0.050
Chromium	0.50

TABLE 3 Ferromanganese-Silicon Sizes

Sizes	Tolerance
75 lb by 2 in. (34.0 kg by 50.8 mm)	
50 lb by 1 in. (22.7 kg by 25.4 mm)	
6 by 1/2 in. (152.4 mm by 12.70 mm)	
3 in. by down (76.2 mm by down)	10 % passing 1/4 in. (6.3 mm) screen, max
2 in. by down (50.8 mm by down)	10 % passing 1/4 in. (6.3 mm) screen, max

[1] This specification is under the jurisdiction of ASTM Committee A-1 on Steel, Stainless Steel, and Related Alloys and is the direct responsibility of Subcommittee A01.18 on Castings.

Current edition approved May 10, 1996. Published June 1996. Originally published as A 701 – 74. Last previous edition A 701 – 74 (1990)ϵ[1].

[2] *Annual Book of ASTM Standards*, Vol 14.02.

[3] *Annual Book of ASTM Standards*, Vol 03.05.

must be mutually agreed upon between the purchaser and the manufacturer if there are differences in results.

7.2 *Special Analysis Requirements*—Analysis for additional elements other than those listed in Table 1 and Table 2 shall be agreed upon between the purchaser and the manufacturer. Such elements in trace quantities shall be reported as less than "<" the limit of analytical equipment. This shall be mutually agreed uon between the purchaser and the manufacturer.

7.3 For purposes of determining conformance with this specification, the reported analysis shall be rounded to the nearest unit in the last right-hand place of figures used in expressing the limiting value, in accordance with the rounding method of Practice E 29.

8. Inspection

8.1 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.

9. Rejection

9.1 Any claim or rejection shall be made to the seller within 45 days from receipt of material by the purchaser.

10. Packaging and Package Marking

10.1 The material shall be packed in containers suitably designed to withstand shipping handling or shipped in bulk so that no material is lost or contaminated in transit.

11. Keywords

11.1 ferromanganese-silicon

APPENDIX

(Nonmandatory Information)

X1. FRIABILITY RATINGS

Code No.	Definition
1	Very tough materials which are susceptible to little, if any, breakage during shipment or handling. (Example: low-carbon ferrochrome)
2	Some breakage of large pieces probable in shipping and handling. No appreciable fines produced from either lump or crushed sizes. (Example: chrome metal)
3	Appreciable reduction in size of large pieces possible in shipping and handling. No appreciable production of fines in handling of crushed sizes. (Example: ferrovanadium)
4	Appreciable reduction in size of large pieces upon repeated handling. Some fines produced upon repeated handling of crushed sizes. (Example: Standard ferromanganese)
5	Appreciable reduction in size in repeated handling of large pieces. Appreciable fines may be produced in the handling of crushed sizes. (Example: 50 percent ferrosilicon)
6	This category represents the most friable alloys. (Example: calcium-silicon)

Standard Specification for Steel Castings, General Requirements, for Pressure-Containing Parts[1]

This standard is issued under the fixed designation A 703/A 703M; 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[2] covers a group of common requirements that, unless otherwise specified in an individual specification, shall apply to steel castings for pressure-containing parts under each of the following ASTM specifications:

Title of Specification	ASTM Designation
Steel Castings, Carbon, Suitable for Fusion Welding for High-Temperature Service	A 216/A 216M
Steel Castings, Martensitic Stainless and Alloy, for Pressure-Containing Parts Suitable for High-Temperature Service	A 217/A 217M
Steel Castings, Austenitic, for High-Temperature Service	A 351/A 351M
Steel Castings, Ferritic and Martensitic, for Pressure-Containing Parts Suitable for Low-Temperature Service	A 352/A 352M
Steel Castings, Alloy, Specially Heat-Treated, for Pressure-Containing Parts, Suitable for High-Temperature Service	A 389/A 389M
Steel Castings Suitable for Pressure Service	A 487/A 487M

1.2 This specification also covers a group of supplementary requirements which may be applied to the above specifications as indicated therein. These are provided for use when additional testing or inspection is desired and apply only when specified individually by the purchaser in the order.

1.3 In case of conflict between the requirements of the individual specification and this general specification, the former shall prevail.

1.4 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 must be used independently of the other. Combining values from the two systems may result in nonconformance with the specification. Inch-pound units are applicable for material ordered to Specification A 703 and SI units for material ordered to Specification A 703M.

2. Referenced Documents

2.1 *ASTM Standards:* [3]

A 216/A 216M Specification for Steel Castings, Carbon, Suitable for Fusion Welding, for High-Temperature Service

A 217/A 217M Specification for Steel Castings, Martensitic Stainless and Alloy, for Pressure-Containing Parts Suitable for High-Temperature Service

A 351/A 351M Specification for Castings, Austenitic, Austenitic-Ferritic (Duplex), for Pressure-Containing Parts

A 352/A 352M Specification for Steel Castings, Ferritic and Martensitic, for Pressure-Containing Parts, Suitable for Low-Temperature Service

A 370 Test Methods and Definitions for Mechanical Testing of Steel Products

A 380 Practice for Cleaning, Descaling, and Passivation of Stainless Steel Parts, Equipment, and Systems

A 389/A 389M Specification for Steel Castings, Alloy, Specially Heat-Treated, for Pressure-Containing Parts, Suitable for High-Temperature Service

A 487/A 487M Specification for Steel Castings Suitable for Pressure Service

A 488/A 488M Practice for Steel Castings, Welding, Qualifications of Procedures and Personnel

A 609/A 609M Practice for Castings, Carbon, Low-Alloy, and Martensitic Stainless Steel, Ultrasonic Examination Thereof

A 751 Test Methods, Practices, and Terminology for Chemical Analysis of Steel Products

A 800/A 800M Practice for Steel Casting, Austenitic Alloy, Estimating Ferrite Content Thereof

A 802/A 802M Practice for Steel Castings, Surface Acceptance Standards, Visual Examination

A 903/A 903M Specification for Steel Castings, Surface Acceptance Standards, Magnetic Particle and Liquid Penetrant Inspection

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[1] This specification is under the jurisdiction of ASTM Committee A01 on Steel, Stainless Steel and Related Alloys and is the direct responsibility of Subcommittee A01.18 on Castings.

Current edition approved April 1, 2004. Published May 2004. Originally approved in 1974. Last previous edition approved in 2003 as A 703/A 703M – 03.

[2] For ASME Boiler and Pressure Vessel Code applications see related Specification SA-703/SA-703M in Section II of that Code.

[3] 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.**

A 941 Terminology Relating to Steel, Stainless Steel, Related Alloys, and Ferroalloys
A 967 Specification for Chemical Passivation Treatments for Stainless Steel Parts
A 991/A 991M Test Method for Conducting Temperature Uniformity Surveys of Furnaces Used to Heat Treat Steel Products
E 29 Practice for Using Significant Digits in Test Data to Determine Conformance With Specifications
E 94 Guide for Radiographic Examination
E 125 Reference Photographs for Magnetic Particle Indications on Ferrous Castings
E 165 Test Method for Liquid Penetrant Examination
E 186 Reference Radiographs for Heavy-Walled (2 to 4½-in. (51 to 114-mm)) Steel Castings
E 208 Test Method for Conducting Drop-Weight Test to Determine Nil-Ductility Transition Temperature of Ferritic Steels
E 280 Reference Radiographs for Heavy-Walled (4½ to 12-in. (114 to 305-mm)) Steel Castings
E 340 Test Method for Macroetching Metals and Alloys
E 446 Reference Radiographs for Steel Castings up to 2 in. (51 mm) in Thickness
E 709 Guide for Magnetic Particle Examination

2.2 *ANSI Standard:*
B16.5 Steel Pipe Flanges and Flanged Fittings[4]

2.3 *Standards of the Manufacturer's Standardization Society of the Valve and Fitting Industry:*
MSS SP 53 Quality Standard for Steel Castings for Valves, Flanges and Fittings, and Other Piping Components (Dry Powder Magnetic Particle Inspection Method)[5]
MSS SP 54 Quality Standard for Steel Castings for Valves, Flanges and Fittings, and Other Piping Components (Radiographic Inspection Method)[5]

3. Terminology

3.1 *Definitions:*

3.1.1 The definitions in Test Methods and Definitions A 370 and Terminology A 941 are applicable to this specification and those listed in 1.1.

3.1.2 *chaplet*, *n*—a chaplet is a metallic support placed in a mold cavity to maintain the spacing between a core and the mold.

3.1.3 *electronic data interchange (EDI)*, *n*—the computer-to-computer exchange of business information in a standard format such as ANSI ASC X12.

3.1.4 *heat*, *n*—all the molten metal poured from a single furnace or all the molten metal from two or more furnaces poured into a single ladle or casting prior to the replenishing of the furnace(s).

3.1.5 *internal chill*, *n*—an internal chill is a metallic device placed in a mold cavity to increase the rate of heat removal at that location.

4. Materials and Manufacture

4.1 *Melting Process*—The steel shall be made by open-hearth or electric-furnace process, with or without separate refining such as argon-oxygen-decarburization (AOD), unless otherwise designated by the individual specification.

4.2 *Heat Treatment*:

4.2.1 Ferritic and martensitic steel shall be cooled after pouring to provide substantially complete transformation of austenite prior to heat treatment to enhance mechanical properties.

4.2.2 Castings shall be heat treated in the working zone of a furnace that has been surveyed in accordance with Test Method A 991/A 991M.

4.2.2.1 When castings are heat treated at temperatures above 2000°F [1100°C], then the working zone shall have been established by a survey performed at not more than 25°F [15°C] below nor more than 200°F [110°C] above the minimum heat treatment temperature specified for the grade. If a minimum heat treatment temperature is not specified for the grade, then the survey temperature shall be not more than 50°F [30°C] below nor more than 175°F [100°C] above the furnace set point used.

4.2.2.2 The maximum variation in measured temperature as determined by the difference between the highest temperature and the lowest temperature shall be as agreed between the purchaser and producer except that during production heat treatment no portion of the furnace shall be below the minimum specified temperature nor above the maximum specified temperature for the grade being processed.

5. Chemical Composition

5.1 *Chemical Analysis*—Chemical analysis of materials covered by this specification shall be in accordance with Test Methods A 751.

5.2 *Heat Analysis*—An analysis of each heat shall be made by the manufacturer to determine the percentages of the elements specified. The analysis shall be made from a test sample preferably taken during the pouring of the heat. When drillings are used, they shall be taken not less than ¼ in. [6.4 mm] beneath the surface. The chemical composition thus determined shall be reported to the purchaser, or his representative, and shall conform to the requirements in the individual specification for the grade being poured.

5.3 *Product Analysis*—A product analysis may be made by the purchaser from material representing each heat, lot, or casting. The analysis shall be made on representative material. Due to the possibility of decarburization, carbon and alloy steel samples for carbon analysis shall be taken no closer than ¼ in. [6.4 mm] to a cast surface except that castings too thin for this shall be analyzed on representative material. The chemical composition thus determined shall meet the requirements specified in the applicable specification for the grade involved, or shall be subject to rejection by the purchaser, except that the chemical composition determined for carbon and low-alloy steel castings may vary from the specified limits by the amounts shown in Table 1. The product analysis tolerances of Table 1 are not applicable as acceptance criteria for heat analysis by the casting manufacturer.

[4] Available from American National Standards Institute, 25 W. 43rd St., 4th Floor, New York, NY 10036.

[5] Available from the Manufacturers' Standardization Society of the Valve and Fittings Industry, 127 Park St., NE, Vienna, VA 22180.

TABLE 1 Product Analysis Tolerances for Carbon and Low-Alloy Steels

Element	Range[A]	Tolerances[B,C] over max or under min, Limit, %
Carbon (C)	up to 0.65 %	$0.03 \times \% C_L + 0.02$
	above 0.65 %	0.04 %
Manganese (Mn)	up to 1 %	$0.08 \times \% Mn_L + 0.01$
	above 1 %	0.09
Silicon (Si)	up to 0.60 %	$0.22 \times \% Si_L - 0.01$
	above 0.60 %	0.15 %
Phosphorus (P)	all	$0.13 \times \% P_L + 0.005$
Sulfur (S)	all	$0.36 \times \% S_L + 0.001$
Nickel (Ni)	up to 2 %	$0.10 \times \% Ni_L + 0.03$
	above 2 %	0.25 %
Chromium (Cr)	up to 2 %	$0.07 \times \% Cr_L + 0.04$
	above 2 %	0.18 %
Molybdenum (Mo)	up to 0.6 %	$0.04 \times \% Mo_L + 0.03$
	above 0.6 %	0.06 %
Vanadium (V)	up to 0.25 %	$0.23 \times \% V_L + 0.004$
	above 0.25 %	0.06 %
Tungsten (W)	up to 0.10 %	$0.08 \times \% W_L + 0.02$
	above 0.10 %	0.02 %
Copper (Cu)	up to 0.15 %	$0.18 \times \% Cu_L + 0.02$
	above 0.15 %	0.05 %
Aluminum (Al)	up to 0.03 %	0.01 %
	0.03 to 0.10 %, incl.	$0.08 \times \% Al + 0.02$
	above 0.10 %	0.03 %

[A] The range denotes the composition limits up to which the tolerances are computed by the equation, and above which the tolerances are given by a constant.

[B] The subscript $_L$ for the elements in each equation indicates that the limits of the element specified by the applicable specification are to be inserted into the equation to calculate the tolerance for the upper limit and the lower limit, if applicable, respectively. Examples of computing tolerances are presented in the footnote *C.*

[C] To compute the tolerances, consider the manganese limits 0.50 − 80 % of Grade WC4 of Specification A 217/A 217M. According to Table 1, the maximum permissible deviation of a product analysis below the lower limit 0.50 is 0.05 % = ($0.08 \times 0.50 + 0.01$). The lowest acceptable product analysis of Grade WC4, therefore, is 0.45 %. Similarly, the maximum permissible deviation above the upper limit of 0.80 % is 0.074 % = ($0.08 \times 0.80 + 0.01$). The highest acceptable product analysis of Grade WC4, therefore, is 0.874. For Grade WCC of Specification A 216/A 216M, the maximum manganese content is 1.20 % if the carbon content is 0.20 %. In this case, the highest acceptable product analysis is 1.29 = (1.20 + 0.09).

5.4 *Unspecified Elements*—When chemical analysis for elements not specified for the grade ordered is desired, Supplementary Requirement S1 may be specified.

5.4.1 Grade substitution for stainless and nickel base alloy castings is not permitted. Grade substitution occurs when the material supplied: *(1)* contains an element, other the nitrogen, that is not specified in the ordered grade, and *(2)* the amount of that element equals or exceeds the minimum requirement for the element in another grade for which it is specified. For this requirement, a grade is defined as an alloy described individually in a table of chemical requirements within any specification listed within the scope of this section.

5.5 The substitution of a grade or composition different from that specified by the purchaser is prohibited.

5.6 Where more than one ladle is poured into a single casting, the molten metal in each ladle must conform to the specified chemical requirements.

6. Mechanical Test Methods

6.1 All mechanical tests shall be conducted in accordance with Test Methods and Definitions A 370.

7. Tensile Requirements

7.1 One tension test shall be made from each heat, and shall conform to the tensile requirements specified. Test bars shall be poured in special blocks from the same heat as the castings represented, except that for investment castings the test specimens shall be cast in the same type of mold as the castings.[6]

7.2 The bar from which the test specimen is taken shall be heat treated in production furnaces to the same procedure as the castings it represents.

7.3 Test specimens may be cut from heat treated castings, at the producer's option, instead of from test bars.

7.4 *Investment Castings*—For investment castings, the specimens may be cast to shape or machined from blocks to dimensions in accordance with Test Methods and Definitions 370 or the ICI bar shown in Fig. 1.

7.5 *Other Castings*—Unless otherwise specified by the purchaser, test coupons may be cast integrally with the castings or as separate blocks in accordance with Fig. 2 and Table 2, with Fig. 3, or with Fig. 4, except when Supplementary Requirement S26 is specified. The test coupon in Fig. 4 shall be employed only for austenitic alloy castings with cross sections less than 2½ in. [63.5 mm]. Tension test coupons shall be machined or ground to the form and dimension shown in Fig. 6 of Test Methods and Definitions A 370.

7.6 If any specimen shows defective machining or develops flaws, it may be discarded and another substituted from the same heat.

7.7 To determine conformance with the tension test requirements, an observed value or calculated value shall be rounded off in accordance with Practice E 29 to the nearest 500 psi [5 MPa] for yield and tensile strength and to the nearest 1 % for elongation and reduction of area.

8. Repair by Welding

8.1 Repair by welding shall be in accordance with the requirements of individual specification using procedures and welders qualified in accordance with Practice A 488/A 488M.

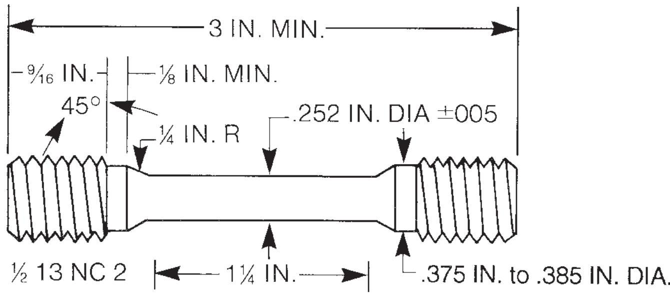
9. Flanges

9.1 When a flange from a flanged casting is removed to make a weld end casting, discontinuities may be observed that would not have been detrimental in a flanged casting. The disposition of the casting shall be subject to agreement between the purchaser and manufacturer.

10. Quality

10.1 The surface of the casting shall be free of adhering sand, scale, cracks, and hot tears as determined by visual examination. Other surface discontinuities shall meet the visual acceptance standards specified in the order. Practice A 802/ A 802M or other visual standards may be used to define acceptable surface discontinuities and finish. Unacceptable

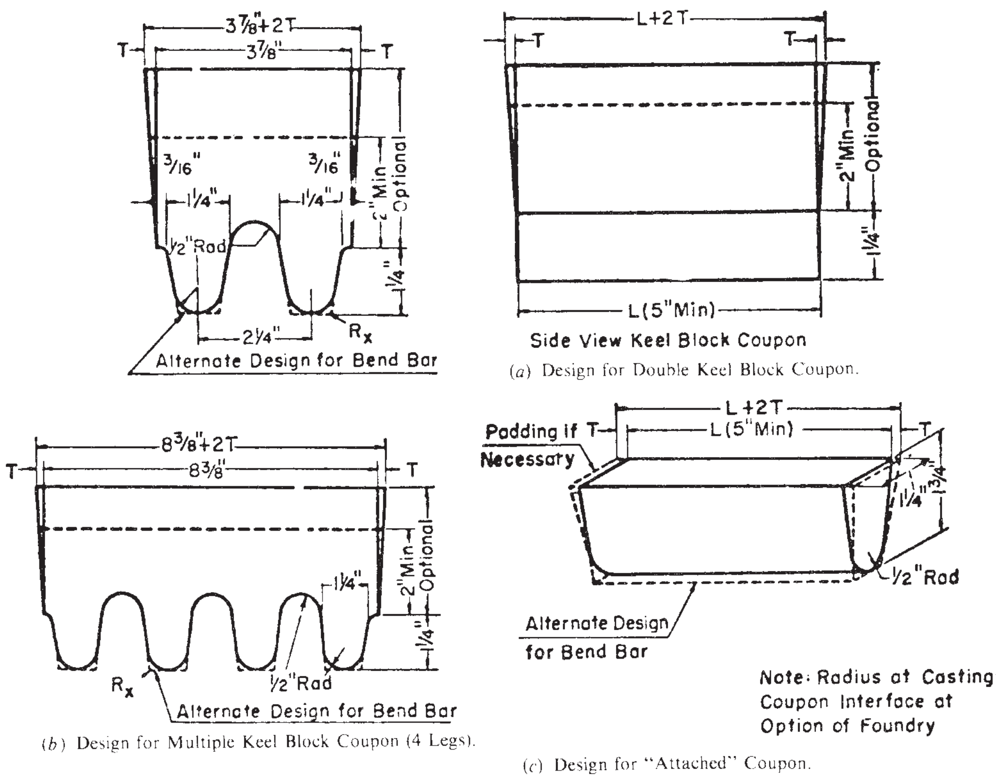
[6] Information on the relationship of mechanical properties determined on test coupons obtained as specified in 7.1 and 7.4 with those obtained from the casting may be found in "The Steel Castings Handbook," Fifth Edition, Steel Founders' Society of America, 1980, pp. 15–35 through 15–43.



Metric Equivalents

in.	0.005	1⁄8	0.252	0.375	0.385	9⁄16	1 1⁄4	3
[mm]	[0.15]	[3]	[6.40]	[9.50]	[9.75]	[15]	[30]	[75]

FIG. 1 Design and Dimensions of the ICI Test Bar



Metric Equivalents

in.	3⁄16	1⁄2	1 1⁄4	1 3⁄4	2	2 1⁄4	3 7⁄8	5	8 1⁄8
mm	4.8	13	32	45	51	57	98	127	213

FIG. 2 Test Coupons for Castings (see Table 2 for Details of Design)

visual surface discontinuities shall be removed and their removal verified by visual examination of the resultant cavities.

10.2 The castings shall not be peened, plugged, or impregnated to stop leaks.

10.3 Internal chills and chaplets may be used in the manufacture of castings. However, the chills, chaplets, and affected cast material must be completely removed.

11. Hydrostatic Tests

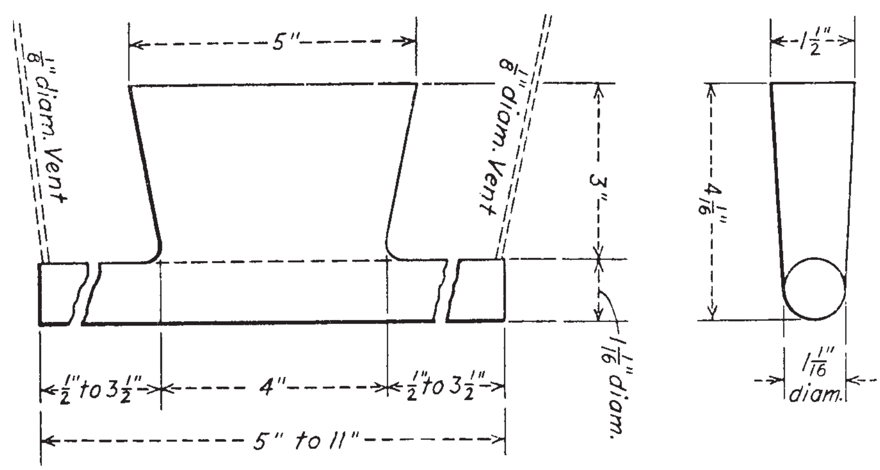
11.1 Each casting shall be tested after machining to the hydrostatic shell test pressures prescribed in ANSI B16.5 for the applicable steel rating for which the casting is designed. Casting shall show no leaks. Castings ordered for working pressures other than those in the standard ANSI ratings, or those listed for which test pressures are not specified by ANSI

TABLE 2 Details of Test Coupon Design for Casting (See Fig. 2)

NOTE 1—*Test Coupons for Large and Heavy Steel Castings:* The test coupons in Fig. 2 are to be used for large and heavy steel castings. However, at the option of the foundry the cross-sectional area and length of the standard coupon may be increased as desired.

NOTE 2—*Bend Bar:* If a bend bar is required, an alternate design (as shown by dotted lines in Fig. 2) is indicated.

Leg Design [125 mm]		Riser Design	
1. *L* (length)	A 5 in. [125 mm] minimum length will be used. This length may be increased at the option of the foundry to accommodate additional test bars (see Note 1).	1. *L* (length)	The length of the riser at the base will be the same as the top length of the leg. The length of the riser at the top therefore depends on the amount of taper added to the riser.
2. End taper	Use of and size of end taper is at the option of the foundry.	2. Width	The width of the riser at the base of a multiple-leg coupon shall be *n*, 2 ¼ [57 mm] − ⅝ [16 mm] where *n* equals the number of legs attached to the coupon. The width of the riser at the top is therefore dependent on the amount of taper added to the riser.
3. Height	1 ¼ in. [32 mm]		
4. Width (at top)	1 ¼ in. [32 mm] (see Note 1).		
5. Radius (at bottom)	½ in. [13 mm], max		
6. Spacing between legs	A ½-in. [13-mm] radius will be used between the legs.		
7. Location of test bars	The tensile, bend, and impact bars will be taken from the lower portion of the leg (see Note 2).	3. *T* (riser taper)	Use of and size is at the option of the foundry.
		Height	The minimum height of the riser shall be 2 in. [51 mm]. The maximum height is at the option of the foundry for the following reasons: (*a*) Many risers are cast open, (*b*) different compositions may require variation in risering for soundness, (*c*) different pouring temperatures may require variation in risering for soundness.
8. Number of legs	The number of legs attached to the coupon is at the option of the foundry providing they are equispaced according to Item 6.		
9. R_s	Radius from 0 to approximately 1⁄16 in. [2 mm].		



Metric Equivalents

in.	mm	in.	mm
⅛	3.2	3½	88.9
½	12.7	4	101.6
1 1⁄16	27.0	4 1⁄16	103.2
1½	38.1	5	127.0
3	76.2	11	279.4

NOTE—Pour through head; cover molten head with powdered charcoal, coke dust, etc., immediately after pouring, in order to keep head fluid as long as possible.

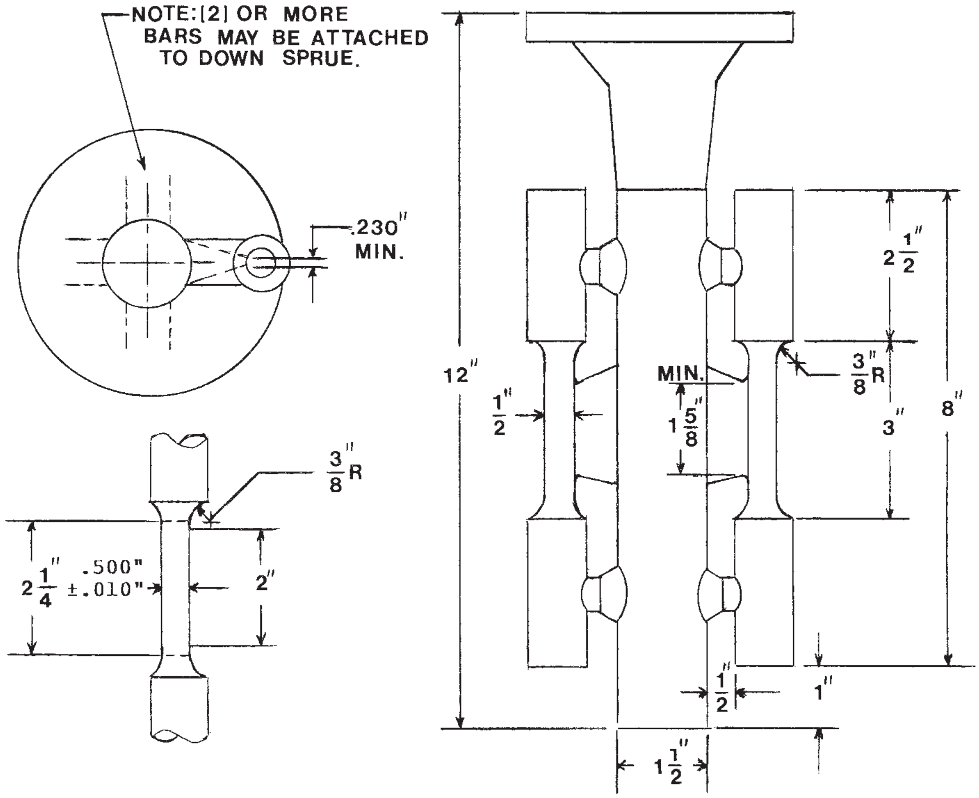
FIG. 3 Test Block for Tension Test Specimen

B16.5, shall be tested at a pressure agreed upon between manufacturer and the purchaser.

11.2 It is realized that the foundry may be unable to perform the hydrostatic test prior to shipment, or that the purchaser may wish to defer testing until additional work or machining has been performed on the casting. Castings ordered in the rough state for final machining by the purchaser may be tested hydrostatically prior to shipment by the manufacturer at pressures to be agreed upon with the purchaser. However, the foundry is responsible for the satisfactory performance of the castings under the final test required in 10.1.

12. Workmanship, Finish, and Appearance

12.1 All castings shall be made in a workmanlike manner and shall conform to the dimensions on drawings furnished by the purchaser. When the pattern is supplied by the purchaser,



Metric Equivalents

in.	mm	in.	mm
0.010	0.254	1⅝	41.275
0.230	5.842	2¼	57.15
⅜	9.525	2½	63.5
½	12.7	3	76.2
1	25.4	8	203.2
1½	38.1	12	304.8

NOTE—Coupons produced in this manner are suitable for austenitic alloys only. The mold may be preheated for pouring to produce a sound coupon.

FIG. 4 Cast-To-Shape Test Coupon for Tension Test Specimen

the dimensions of the casting shall be as predicated by the pattern unless otherwise agreed upon.

12.2 Machined welding ends shall be suitably protected against damage during shipping.

13. Retests

13.1 If the results of the mechanical tests for any heat, lot, or casting do not conform to the requirements specified, retests are permitted as outlined in Test Methods and Definitions A 370. At the manufacturer's option, castings may be reheat-treated and retested. When castings are reheat-treated, they may not be reaustenitized more than three times without the approval of the purchaser. Testing after reheat treatment shall consist of the full number of specimens taken from locations complying with the specification or order.

14. Inspection

14.1 The manufacturer shall afford the purchaser's inspector all reasonable facilities necessary to satisfy that the material is being produced and furnished in accordance with the applicable specification. Foundry inspection by the purchaser shall not interfere unnecessarily with the manufacturer's operations. All tests and inspections, with the exception of product analysis (5.2), shall be made at the place of manufacture unless otherwise agreed.

15. Rejection and Rehearing

15.1 Any rejection based on test reports shall be reported to the manufacturer within 30 days from the receipt of the test reports by the purchaser.

15.2 Material that shows unacceptable discontinuities as determined by the acceptance standards specified in the order subsequent to its acceptance at the manufacturer's works will be rejected, and the manufacturer shall be notified within 30 days after discovery of the rejectable condition.

15.3 Samples that represent rejected material shall be preserved for two weeks from the date of transmission of the test report. In case of dissatisfaction with the results of the tests, the manufacturer may make claim for a rehearing within that time.

16. Certification

16.1 The manufacturer's certification shall be furnished to the purchaser stating that the material was manufactured, sampled, tested, and inspected in accordance with the material specification (including year of issue) and was found to meet the requirements.

16.2 As applicable, the certification shall also include:

16.2.1 Material specification and grade,

16.2.2 Pattern number,

16.2.3 Heat number or serial number traceable to a heat number,

16.2.4 Chemical analysis of the heat,

16.2.5 Mechanical property results required by the specification and supplementary requirements specified in the purchase order,

16.2.6 Statement of satisfactory inspection, visual, and nondestructive testing specified in the purchase order,

16.2.7 Manufacturer's name, and

16.2.8 Additional purchase order requirements.

16.3 A signature is not required on the certification. However, the document shall clearly identify the organization submitting the certification. Notwithstanding the absence of a signature, the organization submitting the certification is responsible for its content.

16.4 A manufacturer's certification 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 provided it conforms to any existing EDI agreement between the purchaser and the supplier.

17. Product Marking

17.1 Castings shall be marked for material identification with the grade symbols (WCB, WC9, CF8M, and so forth). In addition, heat numbers, or serial numbers that are traceable to heat numbers, shall be marked on all pressure-containing castings individually weighing 50 lb [22.7 kg] or more. Pressure-containing castings weighing less than 50 lb [22.7 kg] shall be marked with either the heat number or a lot number that will identify the casting as to the month in which it was poured. Marking shall be in such position as not to injure the usefulness of the casting.

17.2 On castings for which impact property requirements are specified, stamped markings using low-stress stamps shall be on a raised pad when such pad can be made a part of the castings.

17.3 Castings shall be marked with the manufacturer's identification or symbol except when other provisions have been made between the manufacturer and purchaser.

18. Keywords

18.1 castings; general requirements; pressure containing; steel

SUPPLEMENTARY REQUIREMENTS

The following standardized supplementary requirements are for use when desired by the purchaser and when allowed by and listed in the individual specifications. They shall not apply unless specified in the order, in which event the specified tests shall be made by the manufacturer before shipment of the castings.

S1. Unspecified Elements

S1.1 Limits may be established for elements not specified for the grade ordered by agreement between the manufacturer and purchaser. The results of the analysis for the agreed-upon elements shall be reported.

S2. Destruction Tests

S2.1 Purchaser may select representative castings from each heat and cut up and etch, or otherwise prepare, the sections for examination for internal defects. Should injurious defects be found that evidence unsound steel or faulty foundry technique, all the castings made from that particular pattern, heat, and heat treatment charge may be rejected. All the rejected castings, including those cut up, shall be replaced by the manufacturer without charge.

S3. Bend Test

S3.1 One bend test shall be made from a test coupon from each heat in accordance with Test Methods and Definitions A 370, and shall be machined to 1 by ½-in. [25 by 13-mm] section with corners rounded to a radius not over 1⁄16 in. [1.6 mm].

S3.2 The specimen shall withstand being bent longitudinally at room temperature through an angle of 90° about a pin the diameter of which shall be the specimen thickness for carbon steels, and 1 in. [25 mm] for other steels. The specimen shall show no cracks on the outside of the bent portion of the specimen.

S3.3 Bend test specimens may be cut from heat-treated castings instead of from test bars when agreed upon between manufacturer and purchaser.

S3.4 If any test specimen shows defective machining or develops flaws, it may be discarded and another specimen substituted from the same heat.

S4. Magnetic Particle Inspection

S4.1 Castings shall be examined for surface and near surface discontinuities by magnetic particle inspection. The examination shall be in accordance with Guide E 709; and types and degrees of discontinuities considered shall be judged by the Reference Photographs E 125. Extent of examination, time of examination, and basis for acceptance shall be agreed upon between the manufacturer and purchaser. A specification which may be used as a basis for such agreement is MSS SP 53.

S4.2 Personnel performing the examination shall be qualified in accordance with an acceptable written practice.

S5. Radiographic Inspection

S5.1 Castings shall be examined for internal defects by means of X rays or gamma rays. The procedure shall be in accordance with Guide E 94 and types and degrees of discontinuities considered shall be judged by Reference Radiographs E 446, E 186, or E 280. Extent of examination and basis for acceptance shall be agreed upon between the manufacturer and purchaser. A specification that may be used as a basis for such agreement is MSS SP 54.

S5.2 Radiographic examination of castings may be performed before or after any heat treatment.

S5.3 Personnel performing the examination shall be qualified in accordance with an acceptable written practice.

S6. Liquid Penetrant Inspection

S6.1 Castings shall be examined for surface discontinuities by means of liquid penetrant inspection. The examination shall be in accordance with Test Method E 165. Areas to be inspected, time of inspection, methods and types of liquid penetrants to be used, developing procedure, and basis for acceptance shall be agreed upon between the manufacturer and purchaser. A specification that may be used as a basis for such agreement is Specification A 903/A 903M.

S6.2 Personnel performing the examination shall be qualified in accordance with an acceptable written practice.

S7. Ultrasonic Inspection

S7.1 Castings shall be examined for internal defects by means of ultrasonic inspection. The inspection procedure shall be in accordance with Practice A 609/A 609M. Extent of examination, methods of testing, and basis for acceptance shall be agreed upon between the manufacturer and purchaser. A standard that may be used as a basis for such agreement is Practice A 609/A 609M.

S7.2 Ultrasonic examination of castings shall be performed after at least one heat treatment above the critical temperature range but need not be repeated after subsequent heat treatment.

S7.3 Personnel performing the examination shall be qualified in accordance with an acceptable written practice.

S8. Charpy Impact Test

S8.1 Charpy impact test properties shall be determined on each heat from a set of three charpy V-notch specimens made from a test coupon in accordance with Test Methods and Definitions A 370, and tested at a test temperature agreed upon by the manufacturer and purchaser. The acceptance requirements shall be either energy absorbed, lateral expansion, or percent shear area, or all three, and shall be that agreed upon by the manufacturer and purchaser. Test specimens shall be prepared as Type A and tested in accordance with Test Methods and Definitions A 370.

S8.2 *Absorbed Energy*—Average energy value of three specimens shall be not less than specified, with not more than one value permitted to fall below the minimum specified and no value permitted below the minimum specified for a single specimen.

S8.3 *Lateral Expansion*—Lateral expansion value shall be agreed upon by the manufacturer and purchaser.

S8.4 *Percent Shear Area*—Percent shear area shall be agreed upon by the manufacturer and purchaser.

S9. Drop Weight Tests

S9.1 Drop weight test properties shall be determined from each heat by preparing and testing either Type P1, P2, or P3 specimens in accordance with Test Method E 208. The crack starter weld shall be deposited on the surface of the specimen that was nearest to the casting surface. Each test shall consist of at least two specimens tested at a temperature agreed upon by the manufacturer and purchaser. Each specimen shall exhibit "no break" performance.

S10. Examination of Weld Preparation

S10.1 Magnetic particle or liquid penetrant examination of cavities prepared for welding shall be performed to verify removal of those discontinuities found unacceptable by the inspection method specified for the casting. The method of performing magnetic particle or liquid penetrant examination shall be in accordance with Guide E 709 or Test Method E 165. Unless other degrees of shrinkage or types of discontinuities found in the cavities are specified, Type II, Internal Shrinkage, of Reference Photographs E 125, of Degree 2 in sections up to 2 in. [50 mm] thick and of Degree 3 in sections over 2 in. [50 mm] thick shall be acceptable.

S12. Prior Approval of Major Weld Repairs

S12.1 Major weld repairs shall be subject to the prior approval of the purchaser.

S13. Hardness Test

S13.1 A hardness test shall be made in accordance with Test Methods and Definitions A 370. The test location and the hardness requirements shall be agreed upon between the manufacturer and the purchaser.

S14. Tension Test from Each Heat and Heat Treatment Charge

S14.1 One tension test shall be made for each heat and heat treatment charge.

S15. Quench and Temper Heat Treatment

S15.1 The castings shall be quenched and tempered. Castings so treated shall be marked QT.

S17. Tension Test from Castings

S17.1 In addition to the tensile test required in Section 6, test material shall be cut from heat treated castings. The mechanical properties and location for the test material shall be agreed upon by the manufacturer and purchaser.

S18. Tension Test for Castings Each Weighing 10 000 lb [4500 kg] or More

S18.1 Two tensile tests shall be made for each casting. The test specimens shall be prepared in accordance with Section 6. The location of the test bars shall be agreed upon by the manufacturer and purchaser.

S20. Weld Repair Charts

S20.1 Unless other criteria are agreed upon between the manufacturer and the purchaser, weld repairs made to correct leakage on hydrostatic testing; or weld repairs for which the depth of the cavity required for welding exceeds 20 % of the actual wall thickness or 1 in. [25 mm], whichever is smaller; or weld repairs for which the area of the cavity required for welding exceeds approximately 10 in.^{2} [65 mm^2], shall be documented.

S20.2 Weld repairs requiring documentation shall be documented on sketches or photographs, or both. The sketches or photographs shall show the location and major dimensions of cavities prepared for weld repair. The weld repair documentation shall be submitted to the purchaser at the completion of the order.

S21. Heat Treatment Furnace Record

S21.1 A heat treatment chart showing time and temperature shall be prepared and be available for inspection by the purchaser.

S22. Heat Treatment

S22.1 Test specimens shall be heat-treated together with the castings they represent. Heat-treated specimens shall be tested and shall meet the tensile and impact properties specified.

S22.2 The remaining test specimens from Supplementary Requirement S22.1 representing the casting shall be treated thermally after the final (foundry) heat-treatment to simulate heat-treatments below the critical temperature which the casting may receive during fabrication, and then tested for mechanical properties. Time, temperature and cooling rate shall be as stated in the order. In the case of postweld heat-treatment, the total time at temperature or temperatures for the test material shall be at least 80 % of the total time at temperature or temperatures during actual postweld heat-treatment of the fabrication of which the casting or castings are a part. The total time at temperature or temperatures for the test material may be performed in a single cycle. When this Supplementary Requirement is specified, the welding qualification test metal must be processed in the same manner.

S23. Macroetch Test

S23.1 Apply Supplementary Requirement S1 for the spectrographic determination and reporting of the total residual aluminum content of all heats of ferritic and martensitic steels subjected to this macroetch test.

S23.2 When the heat analysis indicates a total residual aluminum content in excess of 0.08 %, the manufacturer shall etch a cross section of the casting with the heaviest section for which this supplementary requirement is invoked, or a coupon attached to that heaviest section or an area directly under a riser (Note S23.1). Cross sections, from a separately cast test block from the same heat and of a thickness representative of the heaviest section of castings purchased under this supplementary requirement, may also be used for macroetch testing. The etching shall be performed on the selected section after its heat-treatment, that is, after annealing, normalizing, or quenching and tempering following the initial cooling of the steel below the transformation range.

NOTE S23.1—High strength martensitic castings, in particular, may be damaged beyond use if the etch is applied directly to the casting.

S23.3 The preparation of the surface and the macroetching procedure with solution No. 1 (1:1 HCl) of Table 5 in Test Method E 340 shall be followed. The resulting etched surface shall be compared and rated with the reference photographs in Fig. S23.1 depicting 10 levels of severity of intergranular network structures indicative of the presence of aluminum nitride, or other constituents prone toward precipitating at grain boundaries during solidification and subsequent cooling. Table S23.1 relates the severity levels shown in these photographs with specific delineation widths and percent of boundary outlining in the etched structures.

S23.4 Castings represented by etched structures exhibiting a network rating in excess of Severity Level 4 shall be considered unacceptable until further evaluations are completed. The acceptability of individual castings may be determined by etching sections of each casting to ascertain the network severity level. Disposition of unacceptable castings shall be a matter of agreement between the manufacturer and purchaser. Those castings exhibiting etched severity levels greater than four may be further evaluated by any of the following agreed upon methods:

S23.4.1 Fracture testing to determine the amount of "rock candy" structure.

S23.4.2 Mechanical testing (bend, tensile, and so forth) to determine the ductility characteristics.

S23.4.3 Weld testing to determine crack susceptibility in the heat-affected zone of a circular groove welded with cellulose coated electrodes.

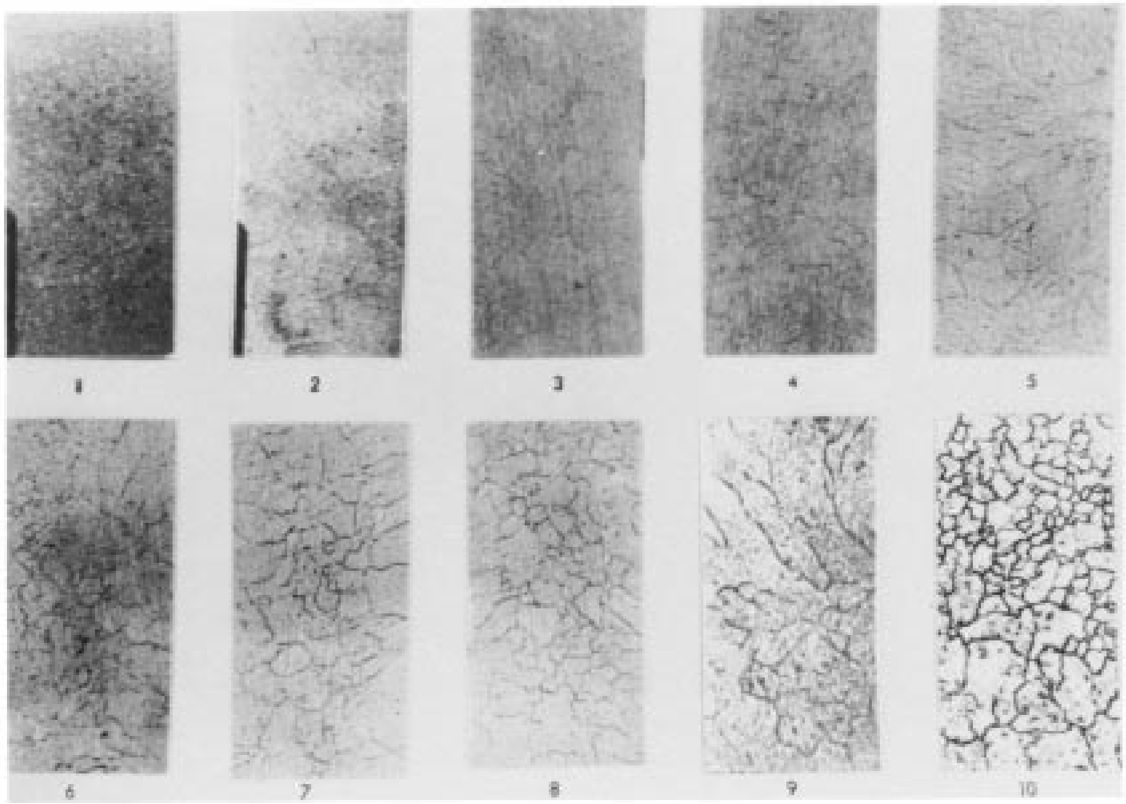
S23.5 Alternatively, by agreement, it is permissible to subject castings from an unacceptable heat to a high temperature solution treatment prior to the normal production heat-treatment and subsequently macroetch test each casting.

S23.6 Heavy section castings (3) whose configurations are amenable to the attachment of test coupons representative of the section thickness involved and from which standard 0.505 in. [12.827 mm] diameter tension specimens may be machined are exempt from this macroetch test if the results of the tension test on the coupon after heat-treatment of the casting meet the minimum requirements specified for the grade of steel involved.

NOTE S23.2—For purposes of this supplementary requirement, a heavy section casting is defined as one having a wall thickness of 1½ in. [37 mm] or greater in combination with a casting weight of at least 1000 lb [455 kg].

S24. Specified Ferrite Content Range

S24.1 The chemical composition of the heat shall be controlled such that the ferrite content, as determined by the



NOTE 1—The 10 levels of severity of intergranular network structures shown are indicative of the presence of aluminum nitride precipitation in the primary austenitic grain boundaries.

FIG. S23.1 Reference Photographs of Macroetched Cast Steel

TABLE S23.1 Descriptive Data Applicable to Network Structures Shown in Fig. S23.1

NOTE—These ratings are based on the physical width and continuity of the precipitate pattern developed by the acid etchant on the primary austenitic grain boundaries of the cast steel. Supplementary testing is normally conducted to determine the final disposition of castings with ratings of 5 or greater.

Rating	Delineation Width, in.	Boundary Outline, %
1	Fine–0.001	20
2	Fine–0.001	40
3	Fine–0.001	60
4	Fine–0.002	80
5	Fine–0.002	100
6	Medium–0.005	100
7	Heavy–0.010	100
8	0.020	100
9	$\frac{1}{32}$	100
10	$\frac{1}{16}$	100

chemical composition procedure of Practice A 800/A 800M, shall be in conformance with the specified ferrite content range.

S24.2 The specified ferrite content range shall be as agreed upon between the manufacturer and the purchaser. The minimum specified ferrite content range shall be 10 % with the minimum ferrite content being no lower than the percent necessary to achieve the minimum mechanical properties required for the alloy.

S24.3 Should the purchaser wish to have the ferrite content determined by either magnetic response or metallographic methods, the purchaser should impose supplementary requirement S1 or S2 of Practice A 800/A 800M.

S25. Heat Treatment Certification

S25.1 Heat treatment temperature and cycle times shall be shown on the certification report.

S26. Alternate Tension Test Coupons and Specimen Locations for Castings (in-lieu of Test Bars Poured from Special Blocks)

S26.1 Test blocks may be cast integrally with the castings or as separate blocks. Test blocks shall be heat-treated together with the castings they represent.

S26.2 The casting thickness, *T*, is the maximum thickness of the pressure containing wall of the casting exclusive of padding added for directional solidification, flanges, appendages, and sections designated by the designer as noncritical. The order, inquiry, and drawing shall designate what the test dimension, *T*, is for the casting.

S26.3 One of the following shall apply:

S26.3.1 The longitudinal centerline of the test specimen shall be taken at least ¼ *T* from the *T* dimension surface and all of the gage length must be at least 1*T* from any other heat-treated surface, exclusive of the surface opposite the *T* dimension surface. (See Fig. S26.1 (a).) For cylindrical castings, the longitudinal centerline of the specimens shall be taken at least ¼ *T* from the outside or inside and all of the gage length must be at least *T* from the as-heat-treated end. (See Fig. S26.1 (b).)

S26.3.2 For ferritic and martensitic castings, partial severing of test blocks prior to final heat treatment is permitted.

S26.3.3 Where separately cast test coupons are used, the dimension shall not be less than 3 *T* by 3 *T* by *T* and each specimen shall meet the requirements of S26.3.1, except that when *T* exceeds 5 in. [125 mm], the dimension may be 15 by 15 by 5 in. [375 by 375 by 125 mm], by agreement between the manufacturer and the purchaser. The test coupon shall be of the same heat of steel and shall receive substantially the same casting practices as the production casting it represents. Centrifugal castings may be represented by statically cast coupons. (See Fig. S26.2.)

S26.3.4 When agreed upon between the manufacturer and the purchaser, castings that are cast or machined to essentially the finished configuration prior to heat-treatment shall have test specimens removed from a prolongation or other stock on the casting at a location below the nearest heat-treated surface indicated on the order. The specimen location shall be at a distance below the nearest heat-treated surface equivalent to at least the greatest distance that the indicated high-tensile-stress surface will be from the nearest heat-treated surface and a minimum of twice this distance from a second heat-treated surface, except that the test specimens shall be no nearer than ¾ in. [19 mm] to a heat-treated surface and 1½ in. [38 mm] from a second heat-treated surface. (See Fig. S26.3.)

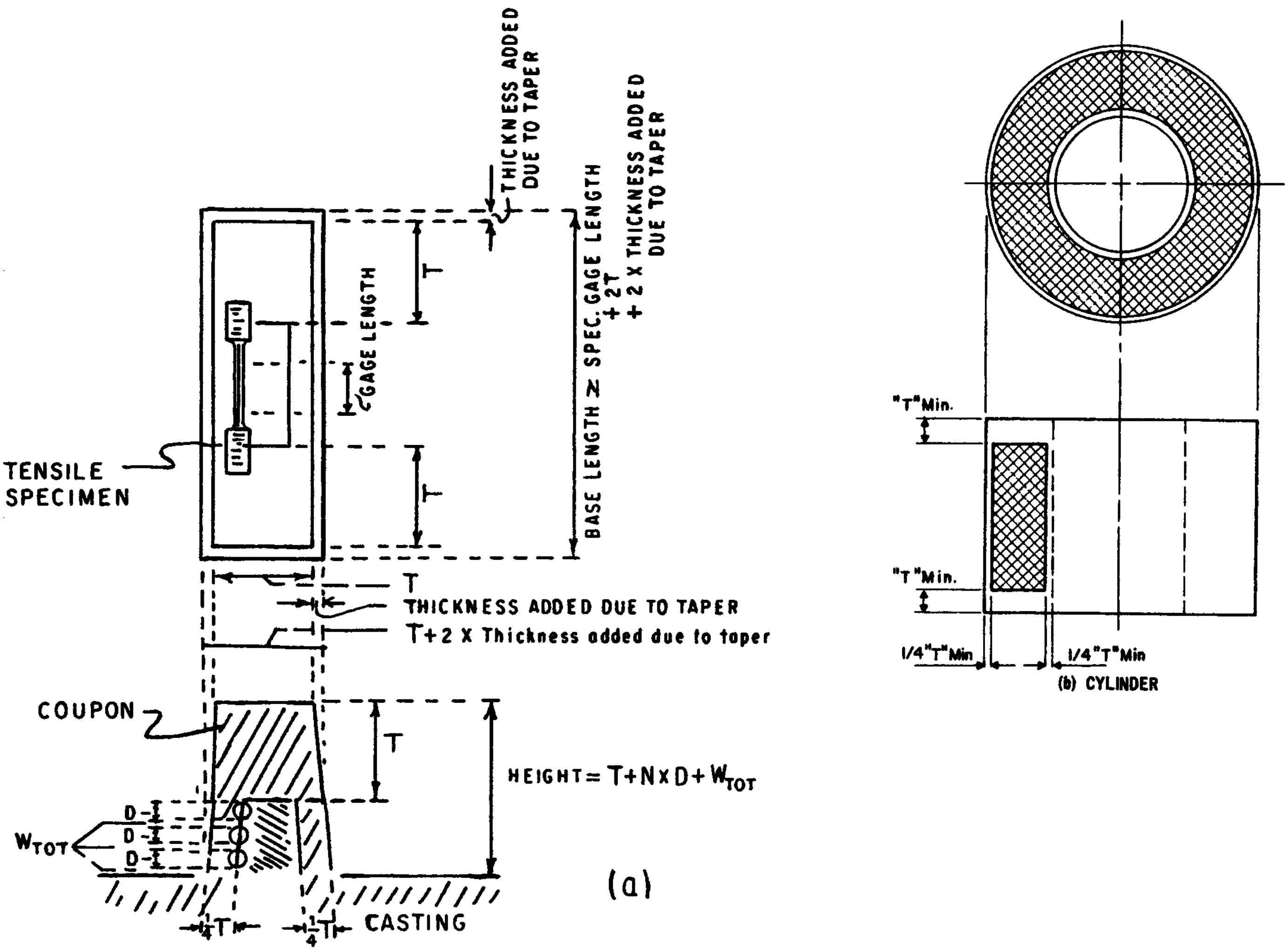
S26.3.5 Where specimens are to be removed from the body of quenched and tempered castings, either the requirements of S26.3.1 shall be met or a steel thermal buffer pad or thermal insulation or other thermal barriers shall be used during heat-treatment. Steel thermal buffer pads shall be a minimum of *T* by *T* by 3 *T* in length and shall be joined to the casting surface by a partial penetration weld completely sealing the buffered surface. Test specimens shall be removed from the casting in a location adjacent to the center third of the buffer pad. They shall be located at a minimum distance of ½ in. [13 mm] from the buffered surface and ¼ *T* from other heat-treated surfaces (see Fig. S26.4). When thermal insulation is used, it shall be applied adjacent to the casting surface where the test specimens are to be removed. The producer shall demonstrate that the cooling rate of the test specimen location is no faster than that of specimens taken by the method described in S26.3.1

S27. Hot Isostatic Pressing (HIPing)

S27.1 Castings shall be processed by Hot Isostatic Pressing (HIPing). The processing parameters for the HIPing process may be subject to an agreement between the manufacturer and purchaser.

S28. Cleaning of Stainless Steels

S28.1 Final cleaning of the casting surfaces shall be performed in accordance with one of the cleaning methods in Practice A 380 or Specification A 967 as agreed upon between the purchaser and supplier. Acceptance testing shall be subject to agreement between the purchaser and supplier.



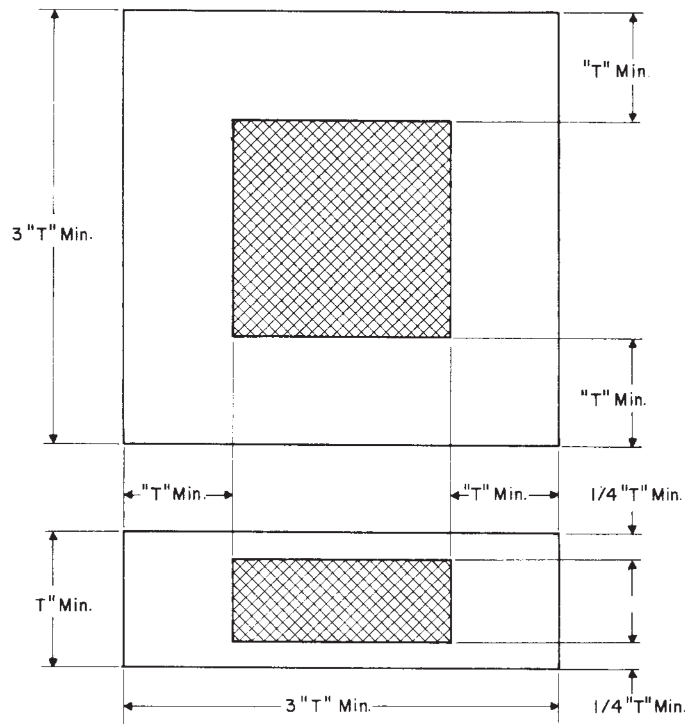
Minimum length of the base — Specimen gage length + 2x*T* + 2*x* the thickness due to the taper.
Minimum width of the base — *T* + 2*x* the thickness added due to the taper.
Minimum height — $T + NxD + W_{tot}$.

The taper is to be selected by the producer for ease of drawing the pattern from the mold.
where:

N = number of specimens to be cut from one side of the coupon,
D = diameter of the specimens, and
W_{tot} = total width of metal required to remove the coupon from the casting, and to machine specimens from the coupon.

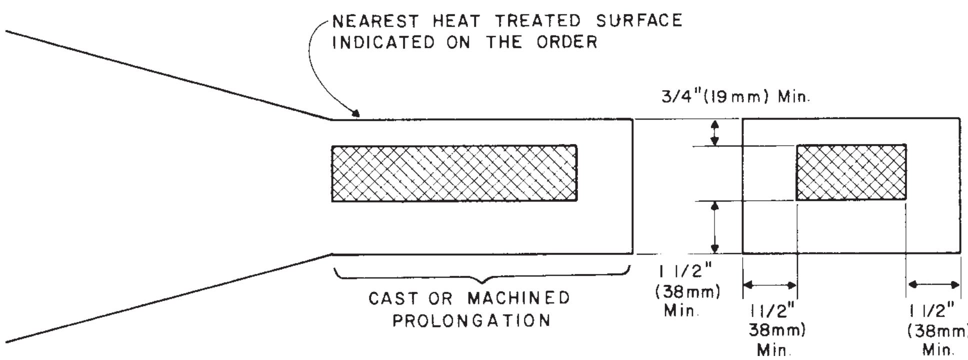
NOTE—Longitudinal axis and gage length of test specimen must be within shaded zone.

FIG. S26.1 Specimen from Casting



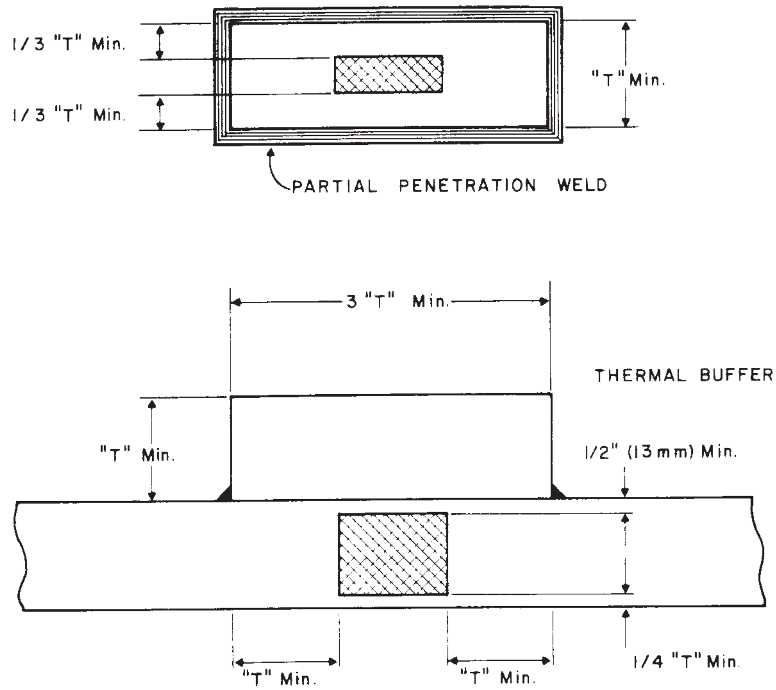
NOTE—Longitudinal axis and gage length of test specimen must be within cross-hatched zone.

FIG. S26.2 Separately Cast Block



NOTE—Longitudinal axis and gage length of test specimen must be within cross-hatched zone.

FIG. S26.3 Prolongation Test Specimen



NOTE—Longitudinal axis and gage length of test specimen must be within cross-hatched zone.

FIG. S26.4 Thermal Buffer Pads

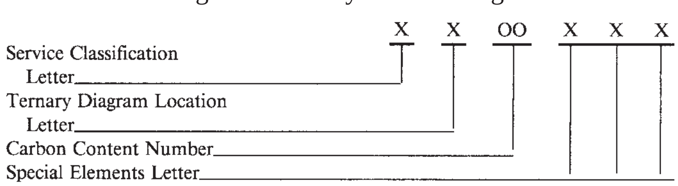
APPENDIXES

(Nonmandatory Information)

X1. ALLOY DESIGNATIONS FOR CAST STAINLESS STEELS

X1.1 Cast stainless steels are usually specified on the basis of composition using the alloy designation system established by the Alloy Casting Institute (ACI). The ACI designations, for example, CF8M, have been adopted by ASTM and are preferred for cast alloys over the designations used by the American Iron and Steel Institute for similar wrought steels.

X1.2 This nomenclature system has served successfully to accommodate changes in old alloys and to designate new ones.



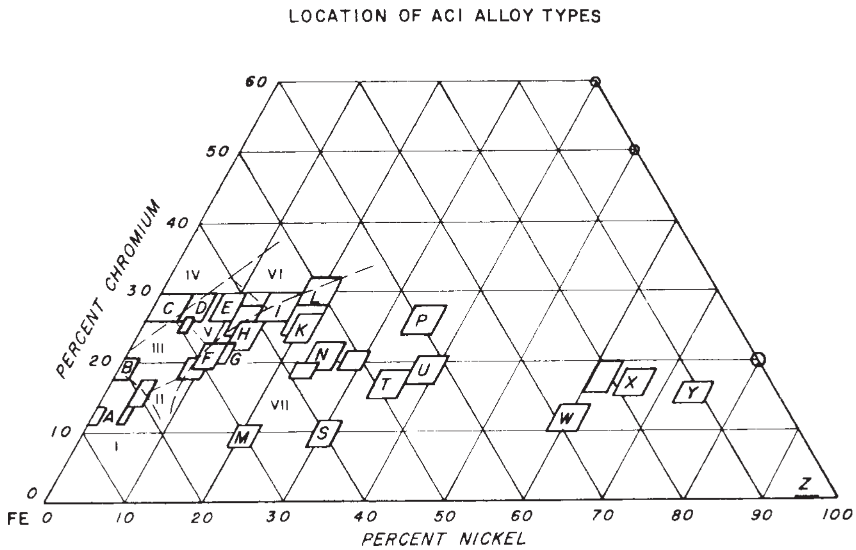
X1.2.1 *Service Classification Letter*—The first letter of the cast stainless steel designation system identifies the intended service application of the alloy. The letter C indicates corrosion-resistant service, and the letter H indicates the heat-resistant service at and above 1200°F [649°C].

X1.2.2 *Ternary Diagram Location Letter*—The second letter indicates the approximate location of the nickel and chromium contents of the alloy grade on the FeCrNi ternary diagram shown in Fig. X1.1.

X1.2.3 *Carbon Content Number*—For C service classifications, this single or dual digit numeral represents the maximum carbon content in units of 0.01 %. For H service classifications, this number represents the midpoint of the range of carbon content in terms of 0.01 % with a ±0.05 % limit.

X1.2.4 *Special Elements Letter*—Additional letters following the numeral represent special chemical elements in the alloy grade, such as M for molybdenum, C for columbium, Cu for copper, W for tungsten. There are two exceptions; the letter A indicates "Controlled Ferrite,'' and the letter F indicates "Free Machining."

X1.3 In Fig. X1.1, unlettered NiCr ranges are associated with the nearest lettered location. They may be the result of differences between corrosion and heat-resistant types or because of the influence of additional elements: for example, the precipitation hardening grade CB-7Cu.



NOTE—The approximate areas of microstructures to be expected at room temperature are indicated as follows:
I—Martensite
II—Martensite and untransformed austenite
III—Ferrite plus martensite and untransformed austenite
IV—Ferrite
V—Ferrite plus austenite
VI—Ferrite plus austenite plus sigma
VII—Austenite
Carbides also may be present depending on carbon content and thermal history.

FIG. X1.1 Letters Assigned to Chromium and Nickel Ranges in ACI Designation System

X2. ADDITION OF NEW GRADES TO PRODUCT SPECIFICATIONS COVERED BY A 703/A 703M

X2.1 Data should be provided from a minimum of ten production heats. This data should include:

X2.1.1 Chemical composition.

X2.1.2 Mechanical properties, as applicable to the product specification being cited. These may include, but are not limited, to the following:

X2.1.2.1 Ultimate tensile strength,

X2.1.2.2 Yield strength or yield point,

X2.1.2.3 Elongation,

X2.1.2.4 Reduction of area,

X2.1.2.5 Hardness, and

X2.1.2.6 Impact properties (Charpy V-Notch).

X2.1.3 The test coupon size from which the test specimens were removed, stated for each test.

X2.1.4 Heat treatment requirements.

X2.1.5 Welding procedure. (It is desired that the welding be performed with commercially available consumables.)

X2.1.6 Whether the material is covered by any patents, and if so, the expiration dates of those patents.

X2.2 The inclusion of the proposed material should be supported by written request from at least one purchaser or user indicating the need for the new grade.

SUMMARY OF CHANGES

Committee A01 has identified the location of selected changes to this standard since the last issue (A 703/A 703M – 03) that may impact the use of this standard. (Approved April 1, 2004.)

(1) Deleted Supplementary Requirement S29, Heat Treatment in the Working Zone of a Surveyed Furnace.

Committee A01 has identified the location of selected changes to this standard since the last issue (A 703/A 703M – 02) that may impact the use of this standard. (Approved July 10, 2003.)

(1) Revised 4.2 to include requirements for performing temperature uniformity surveys of heat treatment furnaces.

Designation: A 716 – 03

Standard Specification for Ductile Iron Culvert Pipe[1]

This standard is issued under the fixed designation A 716; 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 14 to 64-in. ductile-iron culvert pipe centrifugally cast.

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 following safety hazards caveat pertains only to the test methods portions, Sections 6 and 7, 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:* [2]

E 8 Test Methods for Tension Testing of Metallic Materials

E 23 Test Methods for Notched Bar Impact Testing of Metallic Materials

2.2 *ANSI/AWWA Standards:*

C 150/A21.50 Thickness Design of Ductile-Iron Pipe[3]

C 151/A21.51 Ductile-Iron Pipe Centrifugally Cast, for Water[3]

2.3 *AASHTO Standard:*

AASHTO T-99 Moisture Density Relations of Soils Using a 5.5-lb (2.5-kg) Rammer 12-in. (305-mm) Drop[4]

3. General Requirements

3.1 The pipe shall be manufactured of ductile iron that meets the requirements of Sections 6 and 7. See Table 1 for pipe thicknesses and weights; see also Fig. 1.

TABLE 1 Standard Wall Thickness^A and Weight of Push-On Joint Ductile-Iron Culvert Pipe

Nominal Diam., in.	Pressure Class	Nominal Thickness, in. (mm)	Maximum Depth of Cover, Ft. (m)	18-ft (5.5mm) Laying Length, Weight per, Length, lb (kg)	20-ft (6.1 mm) Laying Length, Weight per, Length, lb (kg)
14	250	0.28 (7.1)	41 (12.5)	770 (349)	855 (388)
16	250	0.30 (7.6)	41 (12.5)	940 (426)	1040 (472)
18	250	0.31 (7.9)	40 (12.2)	1090 (494)	1205 (547)
20	250	0.33 (8.4)	40 (12.2)	1290 (585)	1425 (646)
24	200	0.33 (8.4)	37 (11.3)	1550 (703)	1710 (776)
30	150	0.34 (8.6)	33 (10.1)	2000 (907)	2210 (1002)
36	150	0.38 (9.7)	33 (10.1)	2675 (1213)	2955 (1340)
42	150	0.41 (10.4)	32 (9.8)	3415 (1549)	3765 (1708)
48	150	0.46 (12.4)	33 (10.1)		4805 (2180)
54	150	0.51 (13.0)	33 (10.1)		6035 (2737)
60	150	0.54 (13.7)	33 (10.1)		6930 (3143)
64	150	0.56 (14.2)	33 (10.1)		7680 (3484)

^{A} Nominal thickness is based on the minimum Pressure Class ductile iron pipe available installed in Type 5 trench condition in accordance with ANSI/AWWA C150/A21.50, as shown in Fig. 1, with a maximum ring deflection of 5 % and maximum ring stress of 48,000 psi (331 MPa). Wall thickness of pipe to serve at other depths of cover may be calculated in accordance with ANSI/AWWA C150/A21.50, allowing 5 % maximum ring deflection.

3.2 The pipe shall be provided with suitable joints, such as push-on or other types of joints that prevent lateral displacement. Plain-end pipe for use with suitable couplings may be furnished.

3.3 Unless otherwise specified, pipe shall have a nominal length of 18 or 20 ft (5.5 or 6.1 m). A maximum of 20 % of the total number of pipe of each size specified in an order may be furnished as much as 24 in. (610 mm) shorter than the nominal laying length, and an additional 10 % may be furnished as much as in 6 in. (152 mm) shorter than the nominal laying length.

4. Tolerances or Permitted Variations

4.1 *Dimensions*—The spigot end, bell, and socket of the pipe and the accessories shall be gaged with suitable gages at sufficiently frequent intervals to assure that the dimensions comply with the requirements of this specification. The smallest inside diameter (ID) of the sockets and the outside diameter (OD) of the spigot ends shall be tested with circular gages. Other socket dimensions shall be gauged as may be appropriate.

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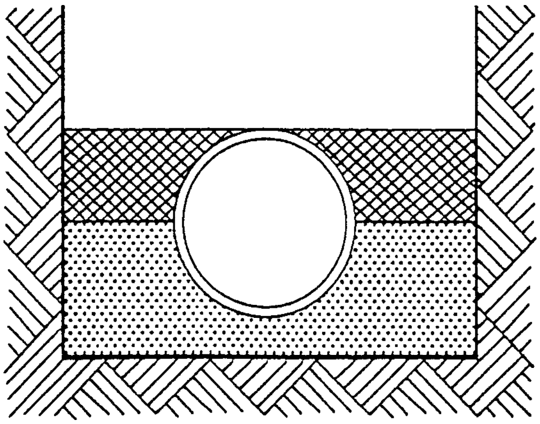
[1] This specification is under the jurisdiction of ASTM Committee A04 on Iron Castings and is the direct responsibility of Subcommittee A04.12 on Pipes and Tubes.

Current edition approved Dec. 1, 2003. Published January 2004. Originally approved in 1975. Last previous edition approved in 1999 as A 716 – 99.

[2] 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.

[3] Available from American National Standards Institute, 25 West 43rd Street, 4th Floor, New York, NY 10036.

[4] Available from the American Association of State Highway and Transportation Officials, 444 N. Capitol, Washington, DC 20001.



NOTE 1—Pipe is bedded to its centerline in compacted granular material with a minimum of 4 in. (102 mm) under the pipe. Compacted granular or select[A] material is used to the top of the pipe. (Material is compacted to approximately 90 % Standard Proctor in accordance with AASHTO Standard T-99.)

[A] Loose soil or select material is defined as native soil excavated from the trench, free of rocks, foreign material, and frozen earth.

FIG. 1 Type 5 Trench

4.2 *Thickness*—Minus thickness tolerances of pipe shall not exceed those shown below:

Nominal Size, in.	Minus Tolerance, in. (mm)
14 to 42	0.07 (1.8)
48	0.08 (2.0)
54 to 64	0.09 (2.3)

NOTE 1—An additional minus tolerance of 0.02 in (0.05 mm) shall be permitted along the barrel of the pipe for a distance not to exceed 12 in. (305 mm).

4.3 *Weight*—The weight of any single pipe shall not be less than the tabulated weight by more than 5 %.

5. Coating

5.1 All pipe shall be coated inside and outside with an asphaltic material approximately 1 mil (0.025 mm) thick. The finished coating shall be continuous and smooth, neither brittle when cold, nor sticky when exposed to the sun, and shall be strongly adherent to the pipe.

6. Acceptance Tests

6.1 The standard acceptance tests for the physical characteristics of the pipe shall be as follows:

6.2 *Tension Test*—Unless otherwise specified by the purchaser, a tension test specimen shall be cut longitudinally or circumferentially from the midsection of the pipe wall. In case of dispute, the specimen shall be cut longitudinally. This specimen shall be machined and tested in accordance with Fig. 2 and Test Methods E 8. The yield strength shall be determined by the 0.2 % offset, halt-of-pointer, or extension-under-load methods. If check tests are to be made, the 0.2 % offset method shall be used. All specimens shall be tested at room temperature 70 ± 10°F (21 ± 6°C).

6.2.1 *Acceptable Values*—The acceptance values for test specimens shall be as follows:

Grade of iron	60-42-10
Minimum tensile strength, psi (MPa)	60 000 (413.7)
Minimum yield strength, psi (MPa)	42 000 (289.6)
Minimum elongation, %	10

6.3 *Charpy Impact Test*—Tests shall be made in accordance with Test Methods E 23, except that dimensions of the specimens shall be 0.500 in. (12.70 mm) by full thickness of pipe wall. Unless otherwise specified by the purchaser, the Charpy notched impact test specimen shall be in accordance with Fig. 3, except that it may be cut circumferentially. In case of dispute, the specimen shall be cut in accordance with Fig. 3. If the pipe wall thickness exceeds 0.40 in. (10.2 mm), the Charpy impact specimen may be machined to a nominal thickness of 0.40 in. (10.2 mm). In all tests, impact values are to be corrected to a standard wall thickness, t_s = 0.40 in. (10.2 mm), by calculation as follows:

$$\text{Impact value (corrected)} = \frac{t_s}{t} \times \text{impact value (actual)}$$

where:
t = the thickness of the specimen, in. (mm).

The Charpy impact test machine anvil shall not be moved to compensate for the variation of cross-section dimensions of the test specimen.

6.3.1 *Acceptance Value*—The corrected acceptance value for notched impact test specimens shall be a minimum of 7 ft·lbf (9.49 J) for tests conducted at 70 ± 10°F (21 ± 6°C).

6.4 *Sampling*—At least one tension specimen shall be taken during each casting period of approximately 3 h. At least one 70 ± 10°F (21 ± 6°C) Charpy impact specimen shall be taken during each operating hour. Specimens shall be selected to properly represent extremes of pipe diameters and wall thicknesses.

7. Additional Control Tests by Manufacturer

7.1 An additional low-temperature impact test shall be made from at least 10 % of the sample coupons taken for the required 70 ± 10°F (21 ± 6°C) Charpy impact test specified in 6.4 to check compliance with a minimum corrected value of 3 ft·lbf (4.07 J) for tests conducted at −40°F ± 2°F (−40°C ± 1°C). Test specimens shall be prepared and tested in accordance with 6.3.

7.2 In addition, the manufacturer shall conduct such other tests as may be necessary to ensure compliance with this specification.

8. Additional Tests Required by Purchaser

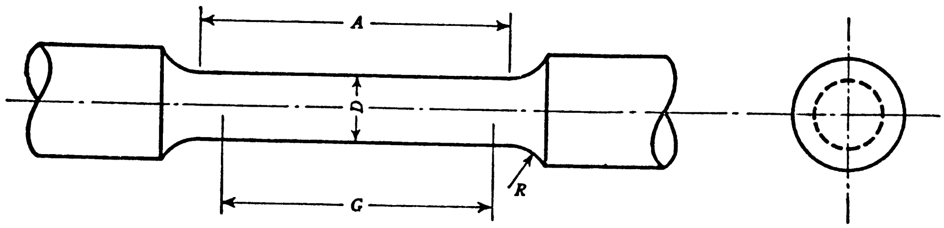
8.1 When tests other than those required in this specification are required by the purchaser, such tests shall be specified in the purchaser's specifications.

9. Inspection and Certification by Manufacturer

9.1 The manufacturer shall establish the necessary quality-control and inspection practice to ensure compliance with this specification.

9.2 The manufacturer shall, if required by the purchaser's specifications, furnish a sworn statement that the inspection and all of the specified tests have been made and that all results thereof comply with the requirements of this specification.

9.3 All pipes shall be without defects that could impair service. Repairing of defects by welding or other methods shall



NOTE 1—The reduced section (*A*) may have a gradual taper from the ends toward the center with the ends not more than 0.005 in. (0.13 mm) larger in diameter than the center on the standard specimen and not more than 0.003 in. (0.08 mm) larger in diameter than the center on the small size specimens.

NOTE 2—If desired, on the small size specimens the length of the reduced section may be increased to accommodate an extensometer. However, reference marks for the measurement of elongation should nevertheless be spaced at the indicated gage length (*G*).

NOTE 3—The gage length and fillets shall be as shown, but the ends may be of any form to fit the holders of the testing machine in such a way that the load shall be axial. If the ends are to be held in grips it is desirable, if possible to make the length of the grip section great enough to allow the specimen to extend into the grips a distance equal to two thirds or more of the length of the grips.

Dimension	Standard Specimen	Small-Size Specimens Proportional to Standard			
	0.50-in (12.7-mm) Round	0.350-in. (8.89-mm) Round	0.250-in. (6.35-mm) Round	0.175-in. (4.45-mm) Round	0.125-in. (3.18-mm) Round
G	2.000 ± 0.005 (50.80 ± 0.13)	1.400 ± 0.005 (35.56 ± 0.13)	1.000 ± 0.005 (25.40 ± 0.13)	0.700 ± 0.005 (17.78± 0.13)	0.500 ± 0.005 (12.70 ± 0.13)
D	0.500 ± 0.010 (12.70 ± 0.25)	0.350 ± 0.007 (8.89 ± 0.18)	0.250 ± 0.005 (6.35 ± 0.13)	0.175 ± 0.005 (4.44 ± 0.13)	0.125 ± 0.005 (3.18 ± 0.13)
R, min	3⁄8 (9.5)	1⁄4 (6.4)	3⁄16 (4.8)	3⁄32 (2.4)	3⁄32 (2.4)
A, min	2 1⁄4 (57.2)	1 3⁄4 (44.4)	1 1⁄4 (31.8)	3⁄4 (19)	5⁄8 (15.9)
T [A]	0.71 and greater (18.0)	0.50 to 0.70 (12.7 to 17.8)	0.35 ± 0.49 (8.9 to 12.4)	0.25 to 0.34 (6.4 ± 8.6)	0.18 to 0.24 (4.6 to 6.1)

[A] Thickness of the section from the wall of the pipe from which the tension specimen is to be machined.

FIG. 2 Tension-Test Specimen

not be allowed if such repairs could adversely affect the serviceability of the pipe or its capability to meet strength requirements of this specification.

10. Inspection by Purchaser

10.1 If the purchaser desires to inspect pipe at the manufacturer's plant, the purchaser shall so state in the purchaser's specifications and describe the conditions (such as time and the extent of inspection) under which the inspection shall be made.

10.2 The purchaser's representative shall have free access to those areas of the manufacturer's plant that are necessary to determine compliance with this standard specification. The manufacturer shall make available for the use of the purchaser's representative such gages as are necessary for inspection. The manufacturer shall provide the purchaser's representative with assistance as necessary for handling of pipe.

11. Delivery and Acceptance

11.1 All pipe and accessories shall comply with this standard specification. Pipe and accessories not complying with this standard specification shall be replaced by the manufacturer at the agreed point of delivery. The manufacturer shall not be liable for shortages or damaged pipe after acceptance at the agreed point of delivery, except as recorded on the delivery receipt or similar document by the carrier's agent.

12. Foundry Records

12.1 The results of the acceptance tests (Section 6) and low-temperature impact tests (Section 7) shall be recorded and retained for 1 year, and shall be available to the purchaser at the foundry. Written transcripts shall be furnished, if required by the purchaser's specification.

13. Defective Specimens and Retests

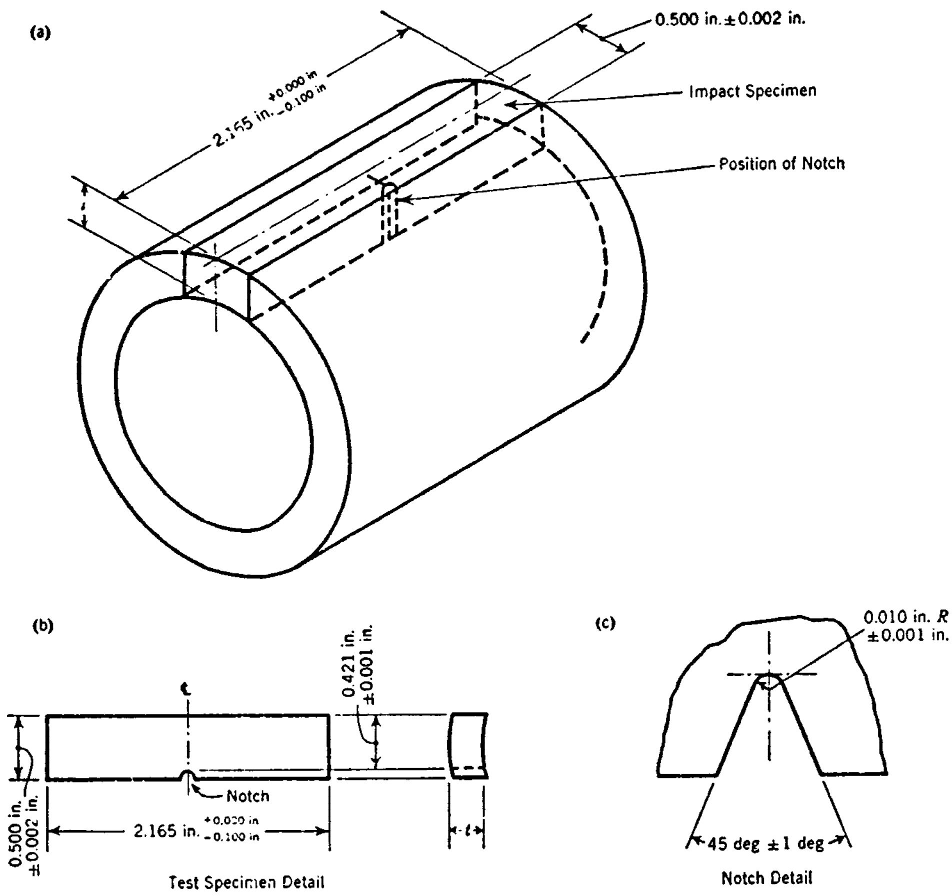
13.1 When any mechanical-test specimen shows defective machining or lack of continuity of metal, it shall be discarded and replaced by another specimen. When any sound test specimen fails to meet the specified mechanical property requirements, the lot of pipe from which the specimen was obtained shall be separated from acceptable pipe. The lot may be either retested, re-heat treated as necessary and retested, or rejected. A retest shall be made on two additional sound test specimens taken from the same lot as the specimen that failed. Pipe that are re-heat treated or retested, or both, shall meet the requirements of 4.1, 6, and 7.

14. Rejection of Pipe

14.1 If the results of any physical acceptance test fail to meet the requirements of Sections 6, 7, or 13, all pipe cast in the same period shall be rejected, except as provided in Section 15.

15. Determining Rejection

15.1 The manufacturer may determine the amount of pipe to be rejected by making similar additional tests of pipe, of the same size as the rejected pipe, until the rejected lot is bracketed, in order of manufacture, by an acceptable test at each end of the interval in question. When pipe of one size is rejected from a casting period, the acceptability of pipe of



NOTE 1—t = pipe-wall thickness.

in.	mm	in.	mm
−0.100	−2.54	0.100	2.54
+0.000	+0.00	0.421	10.69
0.001	0.03	0.500	12.70
0.002	0.05	2.165	54.99
0.010	0.25		

FIG. 3 Impact Test Specimen

different sizes from that same period may be established by developing the acceptance tests for these sizes as specified in Section 6.

16. Marking Pipe

16.1 The weight, class, or nominal thickness, and casting period shall be shown on each pipe. The manufacturer's mark, the country where cast, the year in which the pipe was produced, and the letter "DI" or "DUCTILE" shall be cast or metal stamped on the pipe and letters and number shall be not less than ½ in. (13 mm) in height. When required in the purchaser's specifications, initials not exceeding four in number shall be cast or stamped on the pipe. All required markings shall be clear and legible, and all cast or metal stamped marks shall be on or near the bell.

17. Weighing the Pipe

17.1 Each pipe shall be weighed and the weight shown on the outside or inside of the bell or spigot end.

18. Keywords

18.1 ductile iron culvert pipe; elongation; mechanical properties; tensile strength; yield strength

Designation: A 732/A732M – 02

Standard Specification for Castings, Investment, Carbon and Low Alloy Steel for General Application, and Cobalt Alloy for High Strength at Elevated Temperatures[1]

This standard is issued under the fixed designation A 732/A732M; 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 carbon and low-alloy steel castings made by the investment casting process.

1.2 Fifteen grades of steel and two cobalt alloy grades are covered (see Appendix).

NOTE 1—An investment casting is one that is produced in a mold, obtained by investing (surrounding) an expendable pattern with a refractory slurry which is allowed to solidify. The expendable pattern may consist of wax, plastic, or other material and is removed by heating prior to filling the mold with liquid metal.

1.3 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 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 370 Test Methods and Definitions for Mechanical Testing of Steel Products[2]

A 488/A488M Practice for Steel Castings, Welding, Qualifications of Procedures and Personnel[3]

A 941 Terminology Relating to Steel, Stainless Steel, Related Alloys, and Ferroalloys[4]

E 21 Test Methods for Elevated Temperature Tension Tests of Metallic Materials[5]

E 30 Test Methods for Chemical Analysis of Steel, Cast Iron, Open-Hearth Iron, and Wrought Iron[6]

E 94 Guide for Radiographic Examination[7]

E 125 Reference Photographs for Magnetic Particle Indications on Ferrous Castings[7]

E 139 Practice for Conducting Creep, Creep-Rupture, and Stress-Rupture Tests of Metallic Materials[5]

E 165 Test Method for Liquid Penetrant Examination[7]

E 192 Reference Radiographs for Investment Steel Castings for Aerospace Applications[7]

E 350 Test Methods for Chemical Analysis of Carbon Steel, Low-Slloy Steel, Silicon Electrical Steel, Ingot Iron, and Wrought Iron[6]

E 446 Reference Radiographs for Steel Castings up to 2 in. (51 mm) in Thickness[7]

E 709 Guide for Magnetic Particle Examination[7]

3. Ordering Information

3.1 Orders for material under this specification should include the following information:

3.1.1 Description of the casting by part or pattern number or drawing,

3.1.2 ASTM designation and year of issue,

3.1.3 Grade of steel,

3.1.4 Quantity,

3.1.5 Options in the specification (4.1, 5.3, 6.1, 9.1, and 10.3), and

3.1.6 Supplementary requirements.

4. Heat Treatment

4.1 Castings shall be supplied in the heat-treated condition with the exception of Grades 21 and 31. Heat treatment shall be either annealing, normalizing and tempering, or quenching and tempering to obtain either the specified properties or other properties that might be agreed upon within each grade. In this latter instance, Supplementary Requirement S19 should be used. Grades 21 and 31 shall be supplied in the as-cast condition unless otherwise agreed upon.

4.2 Heat treatment shall be performed after the castings have been allowed to cool below the transformation range.

[1] This specification is under the jurisdiction of ASTM committee A01 on Steel, Stainless Steel and Related Alloys and is the direct responsibility of Subcommittee A01.18 on Castings.

Current edition approved Sept. 10, 2002. Published October 2002. Originally published as A 732 – 76. Last previous edition A 732/A 732M – $98^{\epsilon 1}$.

[2] *Annual Book of ASTM Standards*, Vol 01.03.

[3] *Annual Book of ASTM Standards*, Vol 01.02.

[4] *Annual Book of ASTM Standards*, Vol 01.01.

[5] *Annual Book of ASTM Standards*, Vol 03.01.

[6] *Annual Book of ASTM Standards*, Vol 03.05.

[7] *Annual Book of ASTM Standards*, Vol 03.03.

4.3 Definitions of terms relating to heat treatment shall be in accordance with Terminology A 941.

5. Chemical Composition

5.1 The castings shall conform to the requirements for chemical composition specified in Table 1 and Table 2.

5.2 *Cast or Heat Analysis*—An analysis of each cast or heat shall be made by the manufacturer to determine the percentages of the elements specified in Table 1 and Table 2. The analysis shall be made from a test sample taken preferably during the pouring of the heat, or from a master heat (Note 2) which is remelted with only minor additions for deoxidization. The chemical composition determined from the heat or master heat shall be reported to the purchaser, or his representative, and shall conform to the requirements in Table 1.

NOTE 2—A master heat is refined and alloyed metal of a single furnace charge, not exceeding 10 000 lb [4500 kg].

5.3 *Product-Check-Verification Analysis*—A product analysis may be made by the purchaser from material representing each heat, lot, or casting. The analysis shall be made on representative material. Due to the possibility of decarburization, carbon and alloy steel samples for carbon analysis shall be taken no closer than ¼ in. [6.4 mm] to a cast surface except

TABLE 2 Chemical Requirements-Cobalt Alloys

Type	Grade 21	Grade 31
Carbon	0.20–0.30	0.45–0.55
Manganese, max.	1.00	1.00
Silicon, max	1.00	1.00
Phosphorus, max	0.040	0.040
Sulfur, max	0.040	0.040
Chromium	25.0–29.0	24.5–26.5
Nickel	1.7–3.8	9.5–11.5
Cobalt	remainder	remainder
Molybdenum	5.0–6.0	...
Tungsten	...	7.0–8.0
Vanadium	...	...
Columbium + Tantalum	...	...
Nitrogen	...	...
Iron, max.	3.00	2.00
Boron	0.007 max	0.005–0.015

TABLE 1 Chemical Requirements

Grade	1A	2A,2Q	3A,3Q	4A,4Q	5N	6N	7Q	8Q
Type	Low Carbon IC 1020[A]	Medium Carbon IC 1030	Medium Carbon IC 1040	Medium Carbon IC 1050	Vanadium IC 6120	Manganese Molybdenum IC 4020	Chromium Molybdenum IC 4130	Chromium Molybdenum IC 4140
Carbon	0.15 to 0.25	0.25 to 0.35	0.35 to 0.45	0.45 to 0.55	0.30 max	0.35 max	0.25 to 0.35	0.35 to 0.45
Manganese	0.20 to 0.60	0.70 to 1.00	0.70 to 1.00	0.70 to 1.00	0.70 to 1.00	1.35 to 1.75	0.40 to 0.70	0.70 to 1.00
Phosphorus, max	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04
Sulfur, max	0.045	0.045	0.045	0.045	0.045	0.045	0.045	0.045
Silicon	0.20 to 1.00	0.20 to 1.00	0.20 to 1.00	0.20 to 1.00	0.20 to 0.80	0.20 to 0.80	0.20 to 0.80	0.20 to 0.80
Nickel								
Chromium							0.80 to 1.10	0.80 to 1.10
Molybdenum						0.25 to 0.55	0.15 to 0.25	0.15 to 0.25
Vanadium					0.05 to 0.15			
Residual Elements:								
Copper	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50
Nickel	0.50	0.50	0.50		0.50	0.50		0.50
Chromium	0.35	0.35	0.35		0.35	0.35		
Molybdenum + Tungsten	0.25				0.25			
Tungsten		0.10	0.10	0.10		0.25	0.10	0.10
Total content of residual elements	1.00	1.00	1.00	0.60	1.00	1.00	0.60	1.00

Grade	9Q	10Q	11Q	12Q	13Q	14Q	15A
Type	Chrome Nickel Molybdenum IC 4330	Chrome Nickel Molybdenum IC 4340	Nickel Molyb-denum IC 4620	Chromium Vanadium IC 6150	Chrome Nickel Molybdenum IC 8620	Chrome Nickel Molybdenum IC 8630	Chromium IC 52100
Carbon	0.25 to 0.35	0.35 to 0.45	0.15 to 0.25	0.45 to 0.55	0.15 to 0.25	0.25 to 0.35	0.95 to 1.10
Manganese	0.40 to 0.70	0.70 to 1.00	0.40 to 0.70	0.65 to 0.95	0.65 to 0.95	0.65 to 0.95	0.25 to 0.55
Phosphorus, max	0.04	0.04	0.04	0.04	0.04	0.04	0.04
Sulfur, max	0.045	0.045	0.045	0.045	0.045	0.045	0.045
Silicon	0.20 to 0.80	0.20 to 0.80	0.20 to 0.80	0.20 to 0.80	0.20 to 0.80	0.20 to 0.80	0.20 to 0.80
Nickel	1.65 to 2.00	1.65 to 2.00	1.65 to 2.00		0.40 to 0.70	0.40 to 0.70	
Chromium	0.70 to 0.90	0.70 to 0.90		0.80 to 1.10	0.40 to 0.70	0.40 to 0.70	1.30 to 1.60
Molybdenum	0.20 to 0.30	0.20 to 0.30	0.20 to 0.30		0.15 to 0.25	0.15 to 0.25	
Vanadium				0.15 min			
Residual Elements:							
Copper	0.50	0.50	0.50	0.50	0.50	0.50	0.50
				0.50			0.50
Chromium			0.35				
Molybdenum + Tungsten				0.10			
Tungsten	0.10	0.10	0.10		0.10	0.10	0.10
Total content of residual elements	0.60	1.00	1.00	1.00	1.00	1.00	0.60

[A] Investment Casting (IC) numbers are to be used only for nomenclature comparison.

that castings too thin for this shall be analyzed on representative material. The chemical composition thus determined shall meet the requirements specified in Table 1 and Table 2.

5.4 *Referee Analysis*—Test methods E 30 and E 350 shall be used for reference purposes. When a comparison is made between the heat analysis and product analysis, the reproducibility data, R_2, in the precision statement of test methods E 350 shall be used as a guide.

6. Workmanship, Finish, and Appearance

6.1 The castings shall conform substantially to the shapes and sizes indicated by the patterns and drawings submitted by the purchaser. Casting tolerances or deviations from drawing dimensions shall be agreed upon between the purchaser and the manufacturer and shall be on the drawing.

7. Quality Assurance

7.1 The surface of the casting shall be examined visually and shall be free of adhering refractory, scale, cracks, hot tears, and other injurious imperfections. Castings may have a gate evidence of 0.03 in. [0.8 mm] maximum on surfaces subject to subsequent machining and 0.01 in. [0.3 mm] maximum on the surfaces not subject to machining.

7.2 When additional inspection is desired, Supplementary Requirements S4, S5, or S6 may be ordered.

7.3 The castings shall not be peened or plugged or impregnated to stop leaks.

8. Repair by Welding

8.1 Repairs shall be made using procedures and welders qualified under Practice A 488/A 488M.

8.2 Welding shall be accomplished with a filler metal that produces a weld deposit with a chemical composition similar to the casting. Castings ordered in the annealed condition or for subsequent hardening shall be annealed after weld repairs. Castings ordered heat treated shall be tempered in accordance with the qualified welding procedure after weld repairs with the exception of Grades 1A and 2A where postheat treatment is optional.

8.3 Welds shall be inspected to the same quality standards as are used to inspect the castings.

9. Inspection

9.1 The manufacturer shall afford the purchaser's inspector all reasonable facilities necessary to satisfy him that the material is being produced and furnished in accordance with this specification. Foundry inspection by the purchaser shall not interfere unnecessarily with the manufacturer's operations. All tests and inspections with the exception of product analysis (see 5.3) shall be made either at the place of manufacture or a laboratory with the capability to perform analyses or mechanical tests to the applicable ASTM specifications.

10. Rejection and Rehearing

10.1 Any rejection based on tests made in accordance with 5.3 shall be reported to the manufacturer within 30 days from receipt of samples by the purchaser.

10.2 Material that shows injurious defects subsequent to its acceptance at the manufacturer's works may be rejected, and the manufacturer shall be notified.

10.3 Castings rejected in accordance with this specification shall be made available to the manufacturer for his review and concurrence.

11. Certification

11.1 Upon request of the purchaser in the contract or order, a manufacturer's certification that the material was manufactured and tested in accordance with the specification (including year date), together with a report of the test results, shall be furnished at the time of shipment.

12. Product Marking

12.1 Castings shall be marked for identification as agreed upon by the manufacturer and the purchaser.

13. Keywords

13.1 alloy steel; carbon steel; cobalt alloys; investment castings; steel castings

SUPPLEMENTARY REQUIREMENTS

One or more of the following supplementary requirements shall be applied only when specified by the purchaser in the inquiry or order. Details of these supplementary requirements shall be agreed upon in writing by the manufacturer and the purchaser.

S1. Residual Elements

S1.1 The manufacturer shall determine the percentage of residual elements shown in Table 1 and Table 2 and report these results to the purchaser or his representative.

S3. Tension Test (Castings Heat-Treated by Manufacturer)

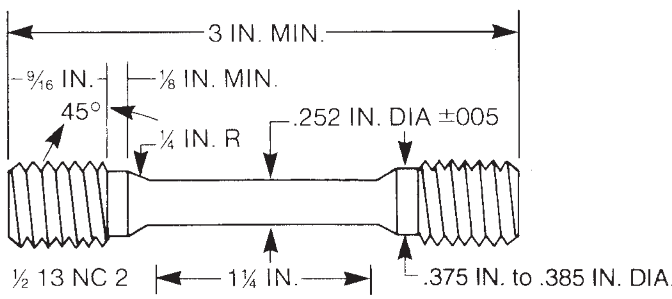
S3.1. Tensile properties shall be determined from material representing each heat. The bar from which the test specimen is taken shall be heat-treated with production castings to the same procedure as the castings it represents. The results shall conform to the requirements specified in Table 3, or to properties agreed upon, and shall be reported to the purchaser or his representative.

S3.2 The test specimens shall be cast in the same type mold as the casting. They may be cast to shape or machined from blocks. The specimens shall be machined to dimensions in accordance with Test Methods and Definitions A 370 or the ICI bar shown in Fig. 1. Tension tests shall be performed in accordance with Test Methods and Definitions A 370.

TABLE 3 Tensile Requirements

Grade	Tensile strength, min		Yield strength, min		Elongation, in 2-in. [50-mm] or 4 diameters	Heat Treatment
	ksi	[MPa]	ksi	[MPa]		
1A	60	[414]	40	[276]	24	A[A]
2A	65	[448]	45	[310]	25	A
2Q	85	[586]	60	[414]	10	Qt[B]
3A	75	[517]	48	[331]	25	A
3Q	100	[689]	90	[621]	10	Qt
4A	90	[621]	50	[345]	20	A
4Q	125	[862]	100	[689]	5	Qt
5N	85	[586]	55	[379]	22	Nt[C]
6N	90	[621]	60	[414]	20	Nt
7Q	150	[1030]	115	[793]	7	Qt
8Q	180	[1241]	145	[1000]	5	Qt
9Q	150	[1030]	115	[793]	7	Qt
10Q	180	[1241]	145	[1000]	5	Qt
11	120	[827]	100	[689]	10	Qt
12Q	190	[1310]	170	[1172]	4	Qt
13Q	105	[724]	85	[586]	10	Qt
14Q	150	[1030]	115	[793]	7	Qt
15A[D]	...	...	...	...	...	A

[A] Annealed.
[B] Quenched and tempered.
[C] Normalized and tempered.
[D] Hardness Rockwell B, 100 max.



Metric Equivalents

Metric Equivalents

in.	0.005	1⁄8	0.252	0.375	0.385	9⁄16	1 1⁄4	3
[mm]	[0.15]	[3]	[6.40]	[9.50]	[9.75]	[15]	[30]	[75]

FIG. 1 Design and Dimensions of the ICI Test Bar

S3.3 If the results of the mechanical test for any heat do not conform to the requirements specified, the castings may be reheat-treated and retested. If any test specimen shows defective machining or develops flaws, it may be discarded, and another specimen substituted from the same heat.

S4. Magnetic Particle Inspection

S4.1 The casting shall be examined by magnetic particle inspection. The method of performing the magnetic particle test shall be in accordance with Practice E 709. The types and degrees of discontinuities considered may be judged by reference Photographs E 125. The extent of the examination and the basis for acceptance shall be subject to agreement between the manufacturer and the purchaser.

S5. Radiographic Inspection

S5.1 The casting shall be examined for internal defects by means of X rays or gamma rays. The inspection procedure shall be in accordance with Guide E 94, and the types and degrees of defects considered shall be judged by Reference Radiographs E 446 or E 192. The extent of examination and the basis of acceptance shall be subject to agreement between the manufacturer and the purchaser.

S6. Liquid Penetrant Inspection

S6.1 The casting shall be examined by liquid penetrant inspection. The method of performing the liquid penetrant test shall be in accordance with Practice E 165. The extent of the examination, the methods and types of penetrants to be used, the developing procedure, and the basis for acceptance shall be subject to agreement between the manufacturer and the purchaser. There are no ASTM reference standards for investment castings for liquid penetrant examination.

S19. Mechanical Properties

S19.1 Mechanical properties other than those specified in Table 3 may be ordered for each of the grades. The properties shall be agreed upon between the manufacturer and the purchaser.

S25. Tension Test (Castings Heat-Treated by Purchaser)

S25.1 The manufacturer shall heat-treat a tension specimen from the same heat to determine whether the castings are capable of being heat-treated to the specified properties. The results shall conform to the requirements specified in Table 3, or to properties agreed upon, and shall be reported to the purchaser or his representative.

S25.2 The test specimens shall be cast in the same type mold as the casting. They may be cast to shape or machined from blocks. The specimen shall be machined to dimensions in accordance with Test Methods and Definitions A 370 or the ICI bar shown in Fig. 1. Tension tests shall be performed in accordance with Test Methods and Definitions A 370.

S25.3 If the results of the mechanical test for any heat do not conform to the requirements specified, an additional test bar may be reheat-treated and retested, but no more than two retests shall be permitted. If any test specimen shows defective machining or develops flaws, it may be discarded and another specimen substituted from the same heat.

S26. High Temperature Tension Test

S26.1 High-temperature tension tests shall be required when specified in the inquiry, contract, or order. When so specified, the properties obtained shall be reported to the purchaser or his representative and shall conform to the requirements prescribed in Table S26.1. The tension test shall be performed in accordance with Test Methods E 21.

S27. Stress Rupture Test

S27.1 Stress rupture tests shall be required when specified in the inquiry, contract, or order. When so specified, the properties obtained shall be reported to the purchaser or his representative and shall conform to the requirements prescribed in Table S27.1. The stress rupture test shall be performed in accordance with Practice E 139.

TABLE S26.1 Elevated-Temperature Tensile Requirements

Grade	21	31
Condition	as cast	as cast
Test temperature:		
°F	1500	1500
°C	820	820
Tensile strength, min:		
ksi	52.0	55.0
MPa	360	380
Elongation in 4*D*, min , %	10	10

TABLE S27.1 Stress Rupture Requirements

Grade	21	31
Condition	as cast	as cast
Test temperature:		
°F	1500	1500
°C	820	820
Stress:		
ksi	23.0	30.0
MPa	160	205
Rupture life, min, h	15	15
Elongation in 4*D*, min, %	5	5

APPENDIX

(Nonmandatory Information)

X1. GUIDE TO CLASSIFICATION OF COBALT ALLOY CASTINGS

X1.1 This guide is appended to the specification as a source of information; it is not mandatory and does not form a part of the specification.

X1.1.1 This specification itself is intended to provide both the manufacturer and the purchaser of alloy castings with a means of production control on the basis of acceptance through mutually acceptable, sound, standard requirements.

X1.1.2 This guide has been prepared as an aid to prospective users of alloy castings covered by the specification in determining the classification best suited for a particular application with due consideration to the particular requirements for that application.

X1.2 *Stress for Design*—The old method of basing design calculations on 50 % of the limiting creep stress is conservative, but it is relatively crude and has the disadvantage that the resulting stress values do not have a consistent relation to life expectancy. Design with the stress that should produce rupture in 100 000 h is frequently satisfactory, though it should be recognized that this is an extrapolated value and provides no assurance that the installation will actually endure for this time. Among the factors that can result in shorter life are reduction of the effective cross-sectional area by hot-gas corrosion, thermal stresses superimposed on the normal working stresses, and overheating. Usually overheating is the most serious of these, since in general a 200°F [110°C] increase in temperature will cut the rupture strength in half.

X1.3 *Grade 21 (Cobalt-base—27 % Cr, 5.5 % Mo, 2.8 % Ni):*

X1.3.1 This grade is resistant to oxidizing and reducing atmospheres at temperatures up to 2100°F [1150°C]. The alloy has good strength at elevated temperatures and is used in many applications where resistance to thermal shock is important. The alloy can be produced as sand, shell, or investment castings.

X1.3.2 *Composition*—This grade is of the austenitic, solid solutioning type and possesses its basic strength characteristics without the need of heat treatment. However, the alloy is so designed that aging occurs in the 1300 to 2100°F [700 to 1150°C] range by the formation of carbides, thus strengthening the alloy in service. The high chromium imparts the excellent oxidation resistance of the alloy and contributes, along with the molybdenum, to the strength of the alloy.

X1.3.3 *Mechanical Properties*—This grade can be used for applications of high stress up to 1500°F [815°C] and moderate strength requirements to 2100°F [1150°C]. The average as-cast tensile strength at 1500°F is 62 000 psi [430 MPa] with 16 % elongation. The alloy exhibits good impact strength even in the age-strengthened condition. The average charpy *V*-notch impact strength after aging is above 20 ft·lb [27 J] in the 1200 to 1800°F [650 to 980°C] range. Table X1.1 contains typical stress-rupture data for this alloy.

X1.3.4 *Applications*—This grade can be used for applications of high stress up to 1500°F and for moderate strength

TABLE X1.1 Typical Stress-Rupture Data for Grade 21

Test Temperature		Average Initial Stress for Rupture							
°F	°C	10 h		100 h		500 h		1000 h	
		Psi	MPa	Psi	MPa	Psi	MP[a	Psi	MPa
1400	760	42 000	290	24 000	165	18 000	124	15 000	103
1500	815	27 500	189	19 000	131	15 000	103	13 500	93
1700	925	17 000	117	13 000	90	10 800	74	10 000	69
1800	980	12 500	86	9 400	65	7 700	53	7 000	48

requirements up to 2100°F. In the past, it has been used successfully for gas turbine blades and vanes, as well as for turbosupercharger blading applications.

X1.4 *Grade 31 (Cobalt-base—25.5 % Cr, 10.5 % Ni, 7.5 % W):*

X1.4.1 This grade has been one of the most useful high-temperature alloys in the past. The alloy is used for high-strength applications to about 1500°F [815°C] and moderate-strength applications to 1800°F [980°C]. It has excellent oxidation resistance, thermal shock resistance, and fatigue life. The alloy can be produced as a sand, shell, or investment casting.

X1.4.2 *Composition*—This grade is the austenitic, solid solutioning type and possesses its basic strength characteristics without the need of heat treatment. However, the alloy is so designed that aging and strengthening occur in service through the precipitation of carbides. Also, it is sometimes necessary to employ a solution heat-treatment for heavy sections of castings to develop optimum strength.

X1.4.3 *Mechanical Properties*—Until the introduction of the vacuum-melted nickel-base, precipitation-hardening alloys, the solid solution cobalt-base alloys were considered the stronger of the available engineering materials for high temperature applications. At 1500°F [815°C] this grade has an average as-cast tensile strength of 63 200 psi [43.5 MPa] and an elongation of 15 %. The combination of strength with high ductility is an advantage over other alloys which exhibit ductilities in the order of 5 % or less. Table X1.2 contains typical stress-rupture data for this alloy.

X1.4.4 *Applications*—This grade can be used for applications of high stress up to 1500°F [816°C] and for moderate strength requirements up to 2100°F [1149°C]. In the past, it has been used extensively for blading and vanes for gas turbine and turbosuperchargers.

TABLE X1.2 Typical Stress-Rupture Data for Grade 31

Test Temperature		Average Initial Stress for Rupture							
°F	°C	10 h		100 h		500 h		1000 h	
		Psi	MPa	Psi	MPa	Psi	MPa	Psi	MPa
1350	730	49 000	338	44 000	303	40 000	276	39 000	269
1500	815	33 000	228	27 000	159	23 000	159	22 000	152
1700	925	20 000	138	17 000	117	15 400	106	14 500	100
1800	980	13 000	90	11 300	78	10 200	70	9 800	68

SUMMARY OF CHANGES

Committee A01 has identified the location of selected changes to this standard since the last issue (D 732/D 732M – 98$^{\epsilon 1}$) that may impact the use of this standard.

(1) Added tungsten to Table 1.
(2) Changed "unspecified elements" to "residual elements" in Table 1.
(3) Changed significant figures in Table 2.

Standard Specification for Castings, Iron-Chromium, Iron-Chromium-Nickel, Corrosion Resistant, for General Application[1]

This standard is issued under the fixed designation A 743/A 743M; 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 iron-chromium and iron-chromium-nickel alloy castings for general corrosion-resistant application. The grades covered by this specification represent types of alloy castings suitable for broad ranges of application which are intended for a wide variety of corrosion environments.

NOTE 1—For alloy castings for severe corrosion-resistant service, reference should be made to Specification A 744/A 744M. For general heat-resistant alloy castings, reference should be made to Specification A 297/A 297M. For nickel alloy castings for corrosion-resistant service, reference should be made to Specification A 494/A 494M.

1.2 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 must be used independently of the other. Combining values from the two systems may result in nonconformance with the specification. Inch-pound units are applicable for material ordered to Specification A 743 and SI units for material ordered to Specification A 743M.

2. Referenced Documents

2.1 *ASTM Standards:*

A 262 Practices for Detecting Susceptibility to Intergranular Attack in Austenitic Stainless Steels[2]

A 297/A297M Specification for Steel Castings, Iron-Chromium and Iron-Chromium-Nickel, Heat-Resistant, for General Application[3]

A 370 Test Methods and Definitions for Mechanical Testing of Steel Products[2]

A 447/A447M Specification for Steel Castings, Chromium-Nickel-Iron Alloy (25-12 Class), for High-Temperature Service[3]

A 494/A494M Specification for Castings, Nickel and Nickel Alloy[3]

A 744/A744M Specification for Castings, Iron-Chromium-Nickel, Corrosion Resistant, for Severe Service[3]

A 781/A781M Specification for Castings, Steel and Alloy, Common Requirements, for General Industrial Use[3]

3. General Conditions for Delivery

3.1 Material furnished to this specification shall conform to the requirements of Specification A 781/A 781M, including any supplementary requirements that are indicated on the purchase order. Failure to comply with the general requirements of Specification A 781/A 781M constitutes nonconformance with this specification. In case of conflict between the requirements of this specification and Specification A 781/A 781M, this specification shall prevail.

4. Ordering Information

4.1 Orders for material to this specification should include the following, as required, to describe the material adequately:

4.1.1 Description of the casting by pattern number or drawing,

4.1.2 Grade,

4.1.3 Heat treatment,

4.1.4 Options in the specification, and

4.1.5 Supplementary requirements desired, including the standards of acceptance.

5. Process

5.1 The steel shall be made by the electric furnace process with or without separate refining such as argon-oxygen decarburization (AOD).

6. Heat Treatment

6.1 Castings shall be heat treated in accordance with the requirements in Table 1.

[1] This specification is under the jurisdiction of ASTM Committee A01 on Steel, Stainless Steel, and Related Alloys and is the direct responsibility of Subcommittee A01.18 on Castings.

Current edition approved May 10, 2003. Published May 2003. Originally approved in 1977. Last previous edition approved in 1998 as A 743/A 743M – 98a.

[2] *Annual Book of ASTM Standards*, Vol 01.03.

[3] *Annual Book of ASTM Standards*, Vol 01.02.

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

TABLE 1 Heat Treatment Requirements

Grade	Heat Treatment
CF8, CG3M, CG8M, CG12, CF20, CF8M, CF8C,CF16F, CF16Fa	Heat to 1900°F [1040°C] minimum, hold for sufficient time to heat casting to temperature, quench in water or rapid cool by other means.
CH10, CH20, CE30, CK20	Heat to 2000°F [1093°C] minimum, hold for sufficient time to heat casting to temperature, quench in water or rapid cool by other means.
CA15, CA15M, CA40, CA40F	(*1*) Heat to 1750°F [955°C] minimum, air cool and temper at 1100°F [595°C] minimum, or (*2*) Anneal at 1450°F [790°C] minimum.
CB30, CC50	(*1*) Heat to 1450°F [790°C] minimum, and air cool, or (*2*) Heat to 1450°F [790°C] minimum, and furnace cool.
CF3, CF3M, CF3MN	(*1*) Heat to 1900°F [1040°C] minimum, hold for sufficient time to heat casting to temperature, and cool rapidly. (*2*) As cast if corrosion resistance is acceptable.
CN3M	Heat to 2150°F [1175°C] minimum, hold for sufficient time to heat casting to temperature, quench in water or rapid cool by other means.
CN3MN	Heat to 2100°F [1150°C] minimum, hold for sufficient time to heat casting to temperature, quench in water or rapid cool by other means.
CN7M, CG6MMN	Heat to 2050°F [1120°C] minimum, hold for sufficient time to heat casting to temperature, quench in water or rapid cool by other means.
CN7MS	Heat to 2100°F [1150°C] minimum, 2150°F [1180°C] maximum, hold for sufficient time (2 h minimum) to heat casting to temperature and quench in water.
CA6NM	Heat to 1850°F [1010°C] minimum, air cool to 200°F [95°C] or lower prior to any optional intermediate temper and prior to the final temper. The final temper shall be between 1050°F [565°C] and 1150°F [620°C].
CA6N	Heat to 1900°F [1040°C], air cool, reheat to 1500°F [815°C], air cool, and age at 800°F [425°C], holding at each temperature sufficient time to heat casting uniformly to temperature.
CF10SMnN	Heat to 1950°F [1065°C] minimum, hold for sufficient time to heat casting to temperature, quench in water or rapid cool by other means.
CA28MWV	(*1*) Heat to 1875–1925°F [1025–1050°C], quench in air or oil, and temper at 1150°F [620°C] minimum, or (*2*) Anneal at 1400°F [760°C] minimum.
CK3MCuN	Heat to 2100°F [1150°C] minimum, hold for sufficient time to heat casting to temperature, quench in water or rapid cool by other means.
CK35MN	Heat to 2100-2190F [1150-1200C], hold for sufficient time to heat casting to temperature, quench in water or rapid cool by other means.
CB6	Heat between 1800°F [980°C] and 1920°F [1050°C], forced air, cool to 120°F [50°C] maximum, and temper between 1100°F and 1160°F [595°C and 625°C].

TABLE 2 Chemical Requirements

NOTE—CD4MCu has been deleted from A 743/A 743M and added to A 890/A 890M. CD4MCu may now be supplied and purchased in compliance with A 890/A 890M. The chemical and mechanical property requirements of CD4MCu were identical in A 743/A 743M and A 890/A 890M at the time of removal from A 743/A 743M.

Grade (UNS)	Type	Composition, %												
		Carbon, max	Manganese, max	Silicon, max	Phosphorus, max	Sulfur, max	Chromium	Nickel	Molybdenum	Columbium	Selenium	Copper	Tungsten, max	Vanadium, max	Nitrogen
CF8 (J92600)	19 Chromium, 9 Nickel	0.08	1.50	2.00	0.04	0.04	18.0–21.0	8.0–11.0	...	...	...	...	...	...	...
CG12 (J93001)	22 Chromium, 12 Nickel	0.12	1.50	2.00	0.04	0.04	20.0–23.0	10.0–13.0	...	...	...	...	...	...	...
CF20 (J92602)	19 Chromium, 9 Nickel	0.20	1.50	2.00	0.04	0.04	18.0–21.0	8.0–11.0	...	...	...	...	...	...	...
CF8M (J92900)	19 Chromium, 10 Nickel, with Molybdenum	0.08	1.50	2.00	0.04	0.04	18.0–21.0	9.0–12.0	2.0–3.0	...	...	...	...	...	...
CF8C (J92710)	19 Chromium, 10 Nickel, with Columbium	0.08	1.50	2.00	0.04	0.04	18.0–21.0	9.0–12.0	...	[A]	...	...	...	...	...
CF16F (J92701)	19 Chromium, 9 Nickel, Free Machining	0.16	1.50	2.00	0.17	0.04	18.0–21.0	9.0–12.0	1.50 max	...	0.20–0.35	...	...	...	...
CF16Fa	19 Chromium, 9 Nickel, Free Machining	0.16	1.50	2.00	0.04	0.20–0.40	18.0–21.0	9.0–12.0	0.40–0.80	...	...	...	...	...	...
CH10 (J93401)	25 Chromium, 12 Nickel	0.10	1.50	2.00	0.04	0.04	22.0–26.0	12.0–15.0	...	. . .	...	...	...	...	...

TABLE 2 *Continued*

Grade (UNS)	Type	Composition, % Carbon, max	Manganese, max	Silicon, max	Phosphorus, max	Sulfur, max	Chromium	Nickel	Molybdenum	Columbium	Selenium	Copper	Tungsten, max	Vanadium, max	Nitrogen
CH20 (J93402)	25 Chromium, 12 Nickel	0.20	1.50	2.00	0.04	0.04	22.0–26.0	12.0–15.0	...	...	...	...	...	...	...
CK20 (J94202)	25 Chromium, 20 Nickel	0.20	2.00	2.00	0.04	0.04	23.0–27.0	19.0–22.0	...	...	...	...	...	...	...
CE30 (J93423)	29 Chromium, 9 Nickel	0.30	1.50	2.00	0.04	0.04	26.0–30.0	8.0–11.0	...	...	...	...	...	...	...
CA15 (J91150)	12 Chromium	0.15	1.00	1.50	0.04	0.04	11.5–14.0	1.00 max	0.50 max	...	...	...	...	...	...
CA15M (J91151)	12 Chromium	0.15	1.00	0.65	0.040	0.040	11.5–14.0	1.0 max	0.15–1.0	...	...	...	...	...	...
CB30 (J91803)	20 Chromium	0.30	1.00	1.50	0.04	0.04	18.0–21.0	2.00 max	...	...	...	[B]	...	...	...
CC50 (J92615)	28 Chromium	0.50	1.00	1.50	0.04	0.04	26.0–30.0	4.00 max	...	...	...	...	...	...	...
CA40 (J91153)	12 Chromium	0.20–0.40	1.00	1.50	0.04	0.04	11.5–14.0	1.0 max	0.5 max	...	...	...	...	...	...
CA40F (J91154)	12 Chromium, Free Machining	0.20–0.40	1.00	1.50	0.04	0.20–0.40	11.5–14.0	1.0 max	0.5 max	...	...	...	...	...	...
CF3 (J92500)	19 Chromium, 9 Nickel	0.03	1.50	2.00	0.04	0.04	17.0–21.0	8.0–12.0	...	...	...	...	...	...	...
CF10SMnN (J92972)	17 Chromium, 8.5 Nickel with Nitrogen	0.10	7.00–9.00	3.50–4.50	0.060	0.030	16.0–18.0	8.0–9.0	...	...	...	...	...	...	0.08–0.18
CF3M (J92800)	19 Chromium, 10 Nickel, with Molybdenum	0.03	1.50	1.50	0.04	0.04	17.0–21.0	9.0–13.0	2.0–3.0	...	...	...	...	...	...
CF3MN (J92804)	19 Chromium, 10 Nickel, with Molybdenum, and Nitrogen	0.03	1.50	1.50	0.040	0.040	17.0–22.0	9.0–13.0	2.0–3.0	...	...	...	...	...	0.10–0.20
CG6MMN (J93790)		0.06	4.00–6.00	1.00	0.04	0.03	20.5–23.5	11.5–13.5	1.50–3.00	0.10–0.30	...	...	...	0.10–0.30	0.20–0.40
CG3M (J92999)	19 Chromium, 11 Nickel, with Molybdenum	0.03	1.50	1.50	0.04	0.04	18.0–21.0	9.0–13.0	3.0–4.0	. . .	. . .	. . .	. . .	. . .	. . .
CG8M (J93000)	19 Chromium, 11 Nickel, with Molybdenum	0.08	1.50	1.50	0.04	0.04	18.0–21.0	9.0–13.0	3.0–4.0	...	...	...	...	...	...
CN3M (J94652)		0.03	2.0	1.0	0.03	0.03	20.0–22.0	23.0–27.0	4.5–5.5	...	...	...	...	...	...
CN3MN (J94651)	21 Chromium, 24 Nickel with Molybdenum and Nitrogen	0.03	2.00	1.00	0.040	0.010	20.0–22.0	23.5–25.5	6.0–7.0	...	...	0.75 max	...	...	0.18–0.26
CN7M (N08007)	20 Chromium, 29 Nickel, with Copper and Molybdenum	0.07	1.50	1.50	0.04	0.04	19.0–22.0	27.5–30.5	2.0–3.0	...	...	3.0–4.0	...	...	...
CN7MS (J94650)	19 Chromium, 24 Nickel, with Copper and Molybdenum	0.07	1.00	2.50–3.50	0.04	0.03	18.0–20.0	22.0–25.0	2.5–3.0	...	...	1.5–2.0	...		
CA6NM (J91540)	12 Chromium, 4 Nickel	0.06	1.00	1.00	0.04	0.03	11.5–14.0	3.5–4.5	0.40–1.0	...	...	...	...	...	...
CA6N	11 Chromium, 7 Nickel	0.06	0.50	1.00	0.02	0.02	10.5–12.5	6.0–8.0	...	...	...	...	...	...	...

TABLE 2 *Continued*

Grade (UNS)	Type	Composition, %													
		Carbon, max	Manganese, max	Silicon, max	Phosphorus, max	Sulfur, max	Chromium	Nickel	Molybdenum	Columbium	Selenium	Copper	Tungsten, max	Vanadium, max	Nitrogen
CA28MWV (J91422)	12 Chromium, with Molybdenum, Tungsten and Vanadium	0.20–0.28	0.50–1.00	1.0	0.030	0.030	11.0–12.5	0.50–1.00	0.90–1.25	...	...	...	0.90–1.25	0.20–0.30	...
CK3MCuN (J93254)	20 Chromium 18 Nickel, with Copper and Molybdenum	0.025	1.20	1.00	0.045	0.010	19.5–20.5	17.5–19.5	6.0–7.0	. . .	. . .	0.50–1.00	. . .	. . .	0.180–0.240
CK35MN	23 Chromium, 21 Nickel, with Molybdenum and Nitrogen	0.035	2.00	1.00	0.035	0.020	22.0-24.0	20.0-22.0	6.0-6.8	. . .	. . .	0.40	. . .	. . .	0.21-0.32
CB6 (J91804)	16 Chromium, 4 Nickel	0.06	1.00	1.00	0.04	0.03	15.5–17.5	3.5–5.5	0.5 max	. . .	. . .	. . .	. . .	. . .	. . .

[A] Grade CF8C shall have a columbium content of not less than eight times the carbon content and not more than 1.0%. If a columbium-plus-tantalum alloy in the approximate Cb:Ta ratio of 3:1 is used for stabilizing this grade, the total columbium-plus-tantalum content shall not be less than nine times the carbon content and shall not exceed 1.1%.

[B] For Grade CB30 a copper content of 0.90 to 1.20% is optional.

NOTE 2—Proper heat treatment of these alloys is usually necessary to enhance corrosion resistance and in some cases to meet mechanical properties. Minimum heat treat temperatures are specified; however, it is sometimes necessary to heat treat at higher temperatures, hold for some minimum time at temperature and then rapidly cool the castings in order to enhance the corrosion resistance and meet mechanical properties.

7. Chemical Requirements

7.1 The chemical requirements are shown in Table 2.

8. Repair by Welding

8.1 Repair welding of Grade CA28MWV is not permitted unless by agreement between the manufacturer and the purchaser.

8.2 When methods involving high temperature are used in the removal of discontinuities, castings shall be preheated in accordance with Table 3. Weld repairs shall be subject to the same quality standards as are used to inspect the castings.

8.3 Post weld heat treatment, if required, shall be in accordance with Table 1.

8.3.1 The martensitic grades CA6NM, CA15, CA15M, CB6, and CA40 shall be retempered after weld repairing, except that local tempering will be permitted if, in the opinion of the manufacturer, furnace heat treating will be damaging to the finished surface of a machined casting. Heat treatment, other than tempering, of grades CA6NM, CA15, CA15M, CB6, and CA40 after weld repairing shall be performed only when agreed upon between the manufacturer and the purchaser. Weld repair on Grade CA40F is not recommended because of the risk of local hardening and possible cracking in the heat affected zone.

8.3.2 Post weld heat treatment is not required on the other grades of this specification. When post weld heat treatment is believed necessary for adequate corrosion resistance in the service environment, castings should be ordered in accordance with Specification A 744/A 744M.

TABLE 3 Minimum Preheat Temperatures

Grade	Minimum Preheat Temperatures	
	°F	°C
CA15, CA15M CA40, CA28MWV	400	[205]
Others	50	[10]

9. Product Marking

9.1 Castings shall be marked for material identification with the ASTM specification number (A 743/A 743M) and grade symbol, that is, CF8, CA15, CB30, etc. In addition, the manufacturer's name or identification mark and the pattern number shall be cast or stamped using the low-stress stamps on all castings. Small-size castings may be such that marking must be limited consistent with the available area. The marking of heat numbers on individual castings shall be agreed upon between the manufacturer and the purchaser. Marking shall be in such position as not to injure the usefulness of the casting.

10. Keywords

10.1 corrosion resistant; iron-chromium; iron-chromium-nickel; steel castings

SUPPLEMENTARY REQUIREMENTS

The following supplementary requirements shall not apply unless specified in the purchase order. A list of standardized supplementary requirements for use at the option of the purchaser is included in Specification A 781/A 781M. Those which are ordinarily considered suitable for use with this specification are given below. Others enumerated in A781/A 781M may be used with this specification upon agreement between the manufacturer and purchaser.

S1. Magnetic Particle Examination

S2. Radiographic Examination

S3. Liquid Penetrant Examination

S4. Ultrasonic Examination

S5. Examination of Weld Preparation

S6. Certification

S7. Prior Approval of Major Weld Repairs

S11. Intergranular Corrosion Test

S11.1 An intergranular corrosion test shall be performed in accordance with the appropriate practice for the particular grade involved, as listed in Practices A 262, or as agreed upon with the purchaser. Intergranular corrosion tests on stabilized or 0.03 % carbon maximum grades (CF3, CF3M, CF8C, and CG3M) shall be made on sensitized specimens. On all other grades of chromium-nickel steels, intergranular corrosion tests shall be made on specimens representative of the as-shipped condition.

S12 Tension Test

S12.1 Tensile properties shall be determined from material representing each heat. The bar from which the test specimen is taken shall be heat treated in production furnaces to the same procedure as the castings it represents. The results shall conform to the requirements specified in Table S12.1.

S12.2 Test bars shall be poured in separately cast keel blocks similar to Fig. 1 or Fig. 2 or Fig. 3 of A 781.

S12.3 Tension test specimens may be cut from heat-treated castings, or from as-cast castings if no heat treatment is specified for the castings, instead of from test bars, when agreed upon between the manufacturer and the purchaser.

S12.4 Test specimens shall be machined to the form and dimensions of the standard round 2-in. [50-mm] gage length specimen shown in Fig. 4 and 5 of Test Methods and Definitions A 370, and shall be tested in accordance with Test Methods and Definitions A 370.

S12.5 If the results of the mechanical tests for any heat, lot, or casting do not conform to the requirements specified, retests are permitted as outlined in Test Methods and Definitions A 370. At the manufacturer's option, castings may be reheat-treated and retested. When castings are reheat-treated, they may not be reaustenitized more than three times without the approval of the purchaser. Testing after reheat treatment shall consist of the full number of specimens taken from locations complying with the specification or order.

S12.6 If any test specimen shows defective machining or develops flaws, it may be discarded and another specimen substituted from the same heat.

S13. Post Weld-Heat Treatment

S13.1 Weld repairs shall be considered major in the case of a casting which has leaked on hydrostatic test or when the depth of the cavity after preparation for repair exceeds 20 % of the actual wall thickness, or 1 in. [25 mm], whichever is smaller, or when the extent of the cavity exceeds approximately 10 in.^{2} [65 cm^2]. All other weld repairs shall be considered minor.

S13.2 Grades CF8, CG3M, CG8M, CG12, CF20, CF8M, CF8C, CF16F, CF16Fa, CH10, CH20, CE30, CK20, CF3, CF3M, CF3MN, CN7M, CN7MS, CN3MN, CB30, CC50, CA6N, and CK3MCuN shall be heat treated after major weld repairs, but it is not required after minor repairs except by agreement between the manufacturer and the purchaser.

S14. Hardness Tests

S14.1 Brinell tests on non-austenitic grades shall be conducted. Grades CA15, CA15M, CB30, and CC50 shall have a Brinell hardness of 241 HB maximum. Grade CA6NM shall have a Brinell hardness of 285 HB maximum, Grade CA40 and CA40F, 269 HB maximum, and Grade CA28MWV, 302–352 HB, except for the annealed condition, when the Brinell hardness of this grade shall not exceed 269 HB.

S14.2 The location where the Brinell hardness reading is to be taken and the frequency of such Brinell hardness inspection of the castings shall be established by agreement between the manufacturer and the purchaser.

S15. Low Ferrite in CF8

S15.1 When low ferrite or non-magnetic properties are required, the mechanical property requirements and volume fraction of ferrite as determined by S 31, A 890/A 890M, shall be by agreement between the manufacturer and the purchaser.

TABLE S12.1 Tensile Requirements

Grade	Type	Tensile Strength, min		Yield Strength, min		Elongation in 2 in. [50 mm], min, %^{A}	Reduction of Area, min, %
		ksi	[MPa]	ksi	[MPa]		
CF8	19 Chromium, 9 Nickel	70^{B}	[485]^{B}	30^{B}	[205]^{B}	35	...
CG12	22 Chromium, 12 Nickel	70	[485]	28	[195]	35	...
CF20	19 Chromium, 9 Nickel	70	[485]	30	[205]	30	...
CF8M	19 Chromium, 10 Nickel, with Molybdenum	70	[485]	30	[205]	30	...
CF8C	19 Chromium, 10 Nickel with Columbium	70	[485]	30	[205]	30	...
CF16F and CF16Fa	19 Chromium, 9 Nickel, Free Machining	70	[485]	30	[205]	25	...
CH20 and CH10	25 Chromium, 12 Nickel	70	[485]	30	[205]	30	...
CK20	25 Chromium, 20 Nickel	65	[450]	28	[195]	30	...
CE30	29 Chromium, 9 Nickel	80	[550]	40	[275]	10	...
CA15 and CA15M	12 Chromium	90	[620]	65	[450]	18	30
CB30	20 Chromium	65	[450]	30	[205]	...	...
CC50	28 Chromium	55	[380]	...	...	...	...
CA40	12 Chromium	100	[690]	70	[485]	15	25
CA40F	12 Chromium, Free Machining	100	[690]	70	[485]	12	...
CF3	19 Chromium, 9 Nickel	70	[485]	30	[205]	35	...
CF10SMnN	17 Chromium, 8.5 Nickel with Nitrogen, 9 Nickel	85	[585]	42	[290]	30	...
CF3M	19 Chromium, 10 Nickel, with Molybdenum	70	[485]	30	[205]	30	...
CF3MN	19 Chromium, 10 Nickel, with Molybdenum, and Nitrogen	75	[515]	37	[255]	35	...
CG6MMN	Chromium-Nickel-Manganese-Molybdenum	85	[585]	42	[290]	30	...
CG3M	19 Chromium, 11 Nickel, with Molybdenum	75	[515]	35	[240]	25	. . .
CG8M	19 Chromium, 11 Nickel, with Molybdenum	75	[520]	35	[240]	25	...
CN3M		63	[435]	25	[170]	30	...
CN3MN	21 Chromium, 24 Nickel, with Molybdenum, and Nitrogen	80	[550]	38	[260]	35	...
CN7M	20 Chromium, 29 Nickel, with Copper and Molybdenum	62	[425]	25	[170]	35	...
CN7MS	19 Chromium, 24 Nickel, with Copper and Molybdenum	70	[485]	30	[205]	35	...
CA6NM	12 Chromium, 4 Nickel	110	[755]	80	[550]	15	35
CA6N	11 Chromium, 7 Nickel	140	[965]	135	[930]	15	50
CA28MWV^{C}	12 Chromium, with Molybdenum, Tungsten, and Vanadium	140	[965]	110	[760]	10	24
CK3MCuN	20 Chromium 18 Nickel, with Copper and Molybdenum	80	[550]	38	[260]	35	...
CK35MN	23 Chromium, 21 Nickel, with Molybdenum and Nitrogen	83	[570]	41	[280]	35	...
CB6	16 Chromium, 4 Nickel	115	[790]	85	[580]	16	35

^{A} When ICI test bars are used in tensile testing as provided for in this specification, the gage length to reduced section diameter ratio shall be 4:1.
^{B} For low ferrite or nonmagnetic castings of this grade, the following values shall apply: tensile strength, min, 65 ksi [450 MPa]; yield point, min, 28 ksi [195 MPa].
^{C} These mechanical properties apply only when heat-treatment (1) has been used.

SUMMARY OF CHANGES

Committee A01 has identified the location of selected changes to this standard since the last issue (A 743/A 743M – 98a) that may impact the use of this standard.

(1) UNS numbers were added to Table 2 and removed elsewhere.

(2) Hyphens were deleted from alloy designations.

Designation: A 744/A744M – 00

An American National Standard

Standard Specification for Castings, Iron-Chromium-Nickel, Corrosion Resistant, for Severe Service[1]

This standard is issued under the fixed designation A 744/A744M; 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 iron-chromium-nickel alloy, stainless steel castings intended for particularly severe corrosive applications.

1.2 This specification requires postweld heat-treatment of all weld repairs affecting surfaces intended to be wetted by the corrosive medium. For applications for which postweld heat-treatment is not considered mandatory for retention of acceptable corrosion resistance, refer to Specification A 743/A 743M.

NOTE 1—For general corrosion-resistant alloy castings, reference should be made to Specification A 743/A 743M. For general heat-resistant alloy castings, reference should be made to Specification A 297/A 297M. For nickel-base alloy castings, refer to Specification A 494/A 494M.

1.3 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 must be used independently of the other. Combining values from the two systems may result in nonconformance with the specification. Inch-pound units are applicable for material ordered to Specification A 744 and SI units for material ordered to Specification A 744M.

2. Referenced Documents

2.1 *ASTM Standards:*

A 262 Practices for Detecting Susceptibility to Intergranular Attack in Austenitic Stainless Steels[2]

A 297/A297M Specification for Steel Castings, Iron-Chromium and Iron-Chromium-Nickel, Heat-Resistant, for General Application[3]

A 370 Test Methods and Definitions for Mechanical Testing of Steel Products[2]

A 494/A494M Specification for Castings, Nickel and Nickel Alloy[3]

A 732/A732M Specification for Castings, Investment, Carbon and Low-Alloy Steel for General Application and Cobalt Alloy for High Strength at Elevated Temperatures[3]

A 743/A743M Specification for Castings, Iron-Chromium, Iron-Chromium-Nickel, Corrosion-Resistant, for General Application[3]

A 781/A781M Specification for Castings, Steel and Alloy, Common Requirements, for General Industrial Use[3]

E 29 Practice for Using Significant Digits in Test Data to Determine Conformance With Specifications[4]

2.2 *American Welding Society Standards:*

AWS A5.11 Specification for Nickel and Nickel Alloy Covered Welding Electrodes[5]

AWS A5.14 Specification for Nickel and Nickel Alloy Bare Welding Rods and Electrodes[5]

3. Terminology

3.1 *Definitions of Terms Specific to This Standard:*

3.1.1 *wetted surface, n*—one that contacts a corrosive environment.

4. General Conditions for Delivery

4.1 Material furnished to this specification shall conform to the requirements of Specification A 781/A 781M, including any supplementary requirements that are indicated on the purchase order. Failure to comply with the general requirements of Specification A 781/A 781M constitutes nonconformance with this specification. In case of conflict between the requirements of this specification and Specification A 781/A 781M, this specification shall prevail.

5. Ordering Information

5.1 Orders for material to this specification should include the following, as required, to describe the material adequately:

5.1.1 Description of the casting by pattern number or drawing (dimensional tolerances shall be included on the casting drawing),

5.1.2 Grade,

5.1.3 Heat treatment,

5.1.4 Identify wetted surface(s),

5.1.5 Options in the specification, and

[1] This specification is under the jurisdiction of ASTM Committee A01 on Steel, Stainless Steel, and Related Alloys and is the direct responsibility of Subcommittee A01.18 on Castings.

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[2] *Annual Book of ASTM Standards*, Vol 01.03.

[3] *Annual Book of ASTM Standards*, Vol 01.02.

[4] *Annual Book of ASTM Standards*, Vol 14.02.

[5] Available from American Welding Society, P.O. Box 351040, 550 N.W. LeJeune Rd., Miami, FL 33135.

5.1.6 Supplementary requirements desired, including the standards of acceptance.

6. Process

6.1 Alloys shall be melted by the electric furnace process with or without separate refining, such as argon-oxygen-decarburization (AOD).

7. Heat Treatment

7.1 Castings shall be heat treated in accordance with the requirements in Table 1.

NOTE 2—Proper heat treatment of these alloys is usually necessary to enhance corrosion resistance and in some cases to meet mechanical properties. Minimum heat treat temperatures are specified; however, it is sometimes necessary to heat treat at higher temperatures, hold for some minimum time at temperature and then rapidly cool the castings in order to enhance the corrosion resistance and meet mechanical properties.

8. Chemical Requirements

8.1 The materials shall conform with the chemical requirements prescribed in Table 2.

9. Workmanship, Finish, and Appearance

9.1 Machined welding ends shall be suitably protected against damage during shipping.

10. Repair by Welding

10.1 The composition of the deposited weld metal shall be similar to that of the casting except in grade CK3MCuN. In the case of Grade CK3MCuN, the composition of the deposited metal shall be similar to that of AWS A5.14 ER NiCrMo-3 (UNS NO6625) or AWS A5.11 E NiCrMo-3 (UNS W 86112) when postweld heat treatment is not required, and the composition of the deposited metal shall be either similar to that of the base metal or similar to that of AWS A5.14 ER NiCrMo-3 or AWS A5.11 E NiCrMo-3 when postweld heat treatment is required.

10.1.1 The composition of the deposited weld metal shall be similar to that of the casting except in grade CN3MN. In the case of grade CN3MN, the composition of the deposited weld metal shall be similar to that of AWS A5.14 ER NiCrMo-3 or ER NiCrMo-4 or ER NiCrMo-10, or the composition of the deposited weld metal shall be similar to that of AWS A5.11 E NiCrMo-3 or E NiCrMo-4 or E NiCrMo-10 when postweld heat treatment is or is not required.

10.2 Weld repairs shall be considered major in the case of a casting that has leaked on hydrostatic test or when the depth of the cavity after preparation for repair exceeds 20 % of the actual wall thickness, or 1 in. [25 mm], whichever is smaller, or when the extent of the cavity exceeds approximately 10 in.^{2} [65 cm^2]. All other weld repairs shall be considered minor. Major and minor weld repairs shall be subject to the same quality standards as are used to inspect the castings. When methods involving high temperatures are used in the removal of discontinuities, castings shall be preheated to 50°F [10°C] min.

10.3 Castings shall be postweld heat-treated in accordance with Table 1 after all major weld repairs and after those minor weld repairs involving either of the following conditions: (*1*) welding on a wetted surface, or (*2*) welding that heats a wetted surface to or above 800°F [425°C].

NOTE 3—The maximum wetted surface temperature of 800°F [425°C] permitted on minor weld repairs without subsequent heat treatment for the austenitic grades is necessary to avoid sensitization to intergranular corrosion. Minor repairs of this type can be made by using a low heat input (example, 50 000 J/in.) welding process or by cooling wetted surfaces with water during welding, or both. Wetted surface temperature measurement can be accomplished with temperature-indicating crayon or contact pyrometer.

11. Rejection and Rehearing

11.1 Samples that represent rejected material shall be preserved for two weeks from the date of transmission of the rejection report. In case of dissatisfaction with the results of the tests, the manufacturer may make claim for a rehearing within that time.

12. Product Marking

12.1 Castings shall be marked for material identification with the ASTM specification number (A 744/A 744M) and grade symbol, that is, CF8, CN7M, etc. In addition, the manufacturer's name or identification mark and the pattern number shall be cast or stamped using low-stress stamps on all castings. Small-size castings may be such that marking must be limited consistent with the available area. The marking of heat numbers on individual castings shall be agreed upon by the manufacturer and the purchaser. Marking shall be in such position as not to injure the usefulness of the casting.

TABLE 1 Heat Treatment Requirements

Grade	Heat Treatment
CF8 (J92600), CG8M (J93000), CF8M (J92900), CF8C (J92710), CF3 (J92500), CF3M (J92800), CG3M (J92999)^A	Heat to 1900°F [1040°C] minimum, hold for sufficient time to heat casting to temperature, quench in water or rapid cool by other means.
CN7M (N08007)	Heat to 2050°F [1120°C] minimum, hold for sufficient time to heat casting to temperature, quench in water or rapid cool by other means.
CN7MS (J94650)	Heat to 2100°F [1150°C] min, 2150°F [1180°C] max, hold for sufficient time (2 h min) to heat casting to temperature, and quench in water.
CN3MN J94651	Heat to 2100°F [1150°C] minimum, hold for sufficient time to heat casting to temperature, quench in water or cool rapidly by other means.
CK3MCuN (J93254)	Heat to 2100°F [1150°C] minimum, hold for sufficient time to heat casting to temperature, quench in water or rapid cool by other means .

^{A} For optimum tensile strength, ductility, and corrosion resistance, the solution annealing temperatures for Grades CF8M, CG8M, and CF3M should be in excess of 1900°F [1040°C].

TABLE 2 Chemical Requirements

Grade	Type	Composition, %														
		Carbon, max	Manganese, max	Silicon, max	Phosphorus, max	Sulfur, max	Chromium	Nickel	Molybdenum	Columbium	Copper	Selenium	Tungsten, max	Vanadium, max	Iron, max	Nitrogen
CF8 (J92600)	19 Chromium, 9 Nickel	0.08	1.50	2.0	0.04	0.04	18.0–21.0	8.0–11.0	. . .	. . .	. . .					
CF8M (J92900)	19 Chromium, 10 Nickel with Molybdenum	0.08	1.50	2.0	0.04	0.04	18.0–21.0	9.0–12.0	2.0–3.0	. . .	. . .					
CF8C (J92810)	19 Chromium, 10 Nickel, with Columbium	0.08	1.50	2.0	0.04	0.04	18.0–21.0	9.0–12.0	. . .	[A]	. . .					
CF3 (J92500)	19 Chromium, 9 Nickel	0.03[B]	1.50	2.0	0.04	0.04	17.0–21.0	8.0–12.0	. . .	. . . . . .						
CF3M (J92800)	19 Chromium, 10 Nickel with Molybdenum	0.03[B]	1.50	1.50	0.04	0.04	17.0–21.0	9.0–13.0	2.0–3.0	. . .	. .					
CG3M (J92999)	19 Chromium, 11 Nickel, with Molybdenum	0.03	1.50	1.50	0.04	0.04	18.0–21.0	9.0–13.0	3.0–4.0	. . .	. . .	. . .	. . .	. . .	. . .	. . .
CG8M (J93000)	19 Chromium, 11 Nickel, with Molybdenum	0.08	1.50	1.50	0.04	0.04	18.0–21.0	9.0–13.0	3.0–4.0	. . .	. . .					
CN7M (N08007)	20 Chromium, 29 Nickel, with Copper and Molybdenum	0.07	1.50	1.50	0.04	0.04	19.0–22.0	27.5–30.5	2.0–3.0	. . .	3.0–4.0					
CN7MS (J94650)	19 Chromium, 24 Nickel, with Copper and Molybdenum	0.07	1.0	2.50–3.50	0.04	0.03	18.0–20.0	22.0–25.0	2.5–3.0	. . .	1.5–2.0					
CN3MN (J94651)	21 Chromium, 24 Nickel with Molybdenum and Nitrogen	0.03	2.00	1.00	0.040	0.010	20.0–22.0	23.5–25.5	6.00–7.00	. . .	0.75 max	. . .	. . .	. . .	. . .	0.18–0.26
CK3MCuN (J93254)	20 Chromium, 18 Nickel with Molybdenum and Copper	0.025	1.20	1.00	0.045	0.010	19.5–20.5	17.5–19.5	6.0–7.0	. . .	0.50–1.00	. . .	. . .	. . .	. . .	0.180–0.240

[A] Grade CF8C shall have a columbium content of not less than eight times the carbon content and not more than 1.0 %. If a columbium-plus-tantalum alloy in the approximate Cb:Ta ratio of 3:1 is used for stabilizing this grade, the total columbium-plus-tantalum content shall not be less than nine times the carbon content and shall not exceed 1.1 %.

[B] For purposes of determining conformance with this specification, the observed or calculated value for carbon content shall be rounded to the nearest 0.01 % in accordance with the rounding method of Practice E 29.

13. Keywords

13.1 austenitic stainless steel; corrosion; stainless steel; steel castings

SUPPLEMENTARY REQUIREMENTS

The following supplementary requirements shall not apply unless specified in the purchase order. A list of standard supplementary requirements for use at the option of the purchaser is included in Specification A 781/A 781M. Those which are ordinarily considered for use with this specification are given below. Others enumerated in A 781/A 781M may be used with this specification upon agreement between the manufacturer and the purchaser.

S2. Radiographic Examination

S3. Liquid Penetrant Examination

S5. Examination of Weld Preparation

S6. Certification

S7. Prior Approval of Major Weld Repairs

S21. Intergranular Corrosion Test

S21.1 An intergranular corrosion test shall be performed in accordance with the appropriate practice for the grade involved, as listed in Practices A 262, or as agreed upon with the purchaser. Intergranular corrosion tests on stabilized or 0.03 % carbon maximum grades (CF3, CF3M, CF8C, CG3M, CK3MCuN, and CN3MN) shall be made on sensitized specimens. On all other grades of chromium-nickel steels, intergranular corrosion tests shall be made on specimens representative of the as-shipped condition.

S22. Tension Test

S22.1 Tensile properties shall be determined from material representing each heat. The bar from which the test specimen is taken shall be heat-treated in production furnaces to the same procedure as the casting it represents. The results shall conform to the requirements specified in Table S22.1.

S22.2 Test bars shall be poured in separately cast keel blocks similar to Fig. 1 or Fig. 2 of Specification A 781/A 781M.

S22.3 Tension test specimens may be cut from heat-treated castings, or from as-cast castings if no heat treatment is specified for the castings, instead of from test bars, when agreed upon by the manufacturer and the purchaser.

S22.4 Test specimens shall be machined to the form and

TABLE S22.1 Tensile Requirements

Grade	UNS	Type	Tensile Strength, min		Yield Strength, min		Elongation in 2 in. [50 mm], min, %[A]
			ksi	[MPa]	ksi	[MPa]	
CF8	(J92600	19 Chromium, 9 Nickel	70[B]	[485][B]	30[B]	[205][B]	35
CF8M	(J92900)	19 Chromium, 10 Nickel, with Molybdenum	70	[485]	30	[205]	30
CF8C	(J92710)	19 Chromium, 10 Nickel, with Columbium	70	[485]	30	[205]	30
CF3	(J92500)	19 Chromium, 9 Nickel	70	[485]	30	[205]	35
CF3M	(J92800)	19 Chromium, 10 Nickel, with Molybdenum	70	[485]	30	[205]	30
CG3M	(J92999)	19 Chromium, 11 Nickel, with Molybdenum	75	[515]	35	[240]	25
CG8M	(J93000)	19 Chromium, 11 Nickel, with Molybdenum	75	[520]	35	[240]	25
CN7M	(N08007)	20 Chromium, 29 Nickel, with Copper and Molybdenum	62	[425]	25	[170]	35
CN7MS	(J94650)	19 Chromium, 24 Nickel, with Copper and Molybdenum	70	[485]	30	[205]	35
CN3MN	(J94651)	21 Chromium, 24 Nickel, with Molybdenum and Nitrogen	80	[550]	38	[260]	35
CK3MCuN	(J93254)	20 Chromium, 18 Nickel with Molybdenum and Copper	80	[550]	38	[260]	35

[A] When ICI test bars are used in tensile testing as provided for in this specification, the gage length to reduced section diameter ratio shall be 4:1.
[B] For low ferrite or nonmagnetic castings of this grade, the following values shall apply: Tensile strength, min, 65 ksi [450 MPa]; yield point, min, 28 ksi [195 MPa].

dimensions of the standard round 2-in. [50-mm] gage length specimen shown in Fig. 6 of Test Methods and Definitions A 370, unless the purchase order is for investment castings, in which case, the specimens shall be prepared in accordance with S3.2 of Specification A 732/A 732M. Testing shall be in accordance with Test Methods and Definitions A 370.

S22.5 If the results of the mechanical tests for any heat, lot, or casting do not conform to the requirements specified, retests are permitted as outlined in Test Methods and Definitions A 370. At the manufacturer's option, castings may be reheat-treated and retested. When castings are reheat-treated, they may not be reaustenitized more than three times without the approval of the purchaser. Testing after reheat treatment shall consist of the full number of specimens taken from locations complying with the specification or order.

S23. Surface Carbon Analysis

S23.1 An analysis for carbon shall be made from a casting representative of each heat. The sample for the analysis shall be within 0.010 in. [0.25 mm] of the surface and be taken after removal of scale and other contaminants at a location to be agreed upon between the manufacturer and purchaser. The carbon content shall meet the carbon requirement of the pertinent grade as shown in Table 2. Other sampling depths and surface carbon requirements may be agreed upon between the purchaser and manufacturer.

APPENDIX

(Nonmandatory Information)

X1. RECOMMENDED FILLER METALS FOR CAST STAINLESS STEELS

X1.1 Listed in Table X1.1, for information, are the filler metals most commonly recommended for welding cast stainless steels. Only those materials having AWS designations are included. The standard prefixes designating covered electrodes, bare rod, etc., and the usability suffixes have been intentionally omitted. Special applications or supplier or customer preference may dictate the use of alternate or overmatched filler materials.

TABLE X1.1 Recommended Filler Materials for Cast Stainless Steels

Casting ACI Designation	UNS	Recommended Filler Material (AWS Designation)
CF8	(J92600)	308
CF8M	(J92900)	316, 308Mo
CF8C	(J92710)	309Cb, 347
CF3	(J92500)	308L
CF3M	(J92800)	308MoL 316L
CG3M	(J92999)	317L
CG8M	(J93000)	317
CN3MN	(J94651)	NiCrMo-3 NiCrMo-12
CN7M	(N08007)	320, 320LR
CN7MS	(J94650)	320, 320LR
CK3MCuN	(J93254)	NiCrMo-3 NiCrMo-12

Designation: A 746 – 03

Standard Specification for Ductile Iron Gravity Sewer Pipe[1]

This standard is issued under the fixed designation A 746; 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 4 to 64-in. ductile iron gravity sewer pipe centrifugally cast with push-on joints. This specification may be used for pipe with other types of joints, as may be agreed upon at the time of purchase.

1.2 This specification covers trench load design procedures for both cement-lined pipe and flexible-lined pipe. Maximum depth of cover tables are included for both types of linings.

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:* [2]

D 2847 Classification of Soils for Engineering Purposes (Unified Soil Classification System)

D 3282 Classification of Soils and Soil-Aggregate Mixtures for Highway Construction Purposes

E 8 Test Methods for Tension Testing of Metallic Materials

E 23 Test Methods for Notched Bar Impact Testing of Metallic Materials

2.2 *ANSI/AWWA Standards:*

C104/A21.4 Cement Mortar Lining for Ductile-Iron Pipe and Fittings for Water[3]

C111/A21.11 Rubber-Gasket Joints for Ductile-Iron Pressure Pipe and Fittings[3]

C150/A21.50 Thickness Design of Ductile-Iron Pipe[3]

C600 Installation of Ductile-Iron Water Mains and Their Appurtenances

2.3 *ASCE Standards:*

Manuals and Reports on Engineering Practice, No. 37, (WCPF Manual of Practice No. 9). “Design and Construction of Sanitary and Storm Sewers”[4]

2.4 *AASHTO Standard:*

AASHTO T-99 Standard Method of Test for the Moisture-Density Relations of Soils Using a 5.5 lb (2.5 kg) Rammer and a 12 in. (305 mm) Drop

3. Terminology

3.1 *Symbols:Symbols:*

3.1.1 *A*—outside radius of pipe,

$$ft = \frac{D}{24}$$

$$\left(\text{in metres} = \frac{D}{2000}\right)$$

3.1.2 *a*—conversion factor, lb/ft^2 to psi = 144 (kN/m^2 to kPa = 1)

3.1.3 *B*—1.5 ft (0.457 m)

3.1.4 *b*—Effective pipe length: 36 in. (0.914 m)

3.1.5 *C*—surface load factor, Table 1

3.1.6 *D*—outside diameter, in., Table 2

3.1.7 *E*—modulus of elasticity, 24×10^6 psi (165.5×10^6 kPa)

3.1.8 *E′*—modulus of soil reaction, psi, Table 3

3.1.9 *F*—impact factor, 1.5

3.1.10 *f*—design bending stress, 48 000 psi (331×10^3 kPa)

3.1.11 *H*—depth of cover, ft (m)

3.1.12 K_b— bending moment coefficient, Table 3

3.1.13 K_x— deflection coefficient, Table 3

3.1.14 *P*—wheel load, 16 000 lb (7257 kg)

3.1.15 P_e— earth load, psi (kPa)

3.1.16 P_t— truck load, psi (kPa)

3.1.17 P_v— trench load, psi (kPa) = $P_e + P_t$

3.1.18 *R*—reduction factor which takes into account the fact that the part of the pipe directly below the wheels is aided in carrying the truck load by adjacent parts of the pipe that receive little or no load from the wheels, Table 4

3.1.19 *t*—net thickness, in. (mm)

3.1.20 t_1—minimum manufacturing thickness, in., t + 0.08, (in mm, t + 2.0)

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[1] This specification is under the jurisdiction of ASTM Committee A04 on Iron Castings and is the direct responsibility of Subcommittee A04.12 on Pipes and Tubes.

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[2] 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.

[3] Available from American National Standards Institute, 25 West 43rd Street, 4th Floor, New York, NY 10036.

[4] Available from the American Society of Civil Engineers,1801 Alexander Bell Drive, Reston, VA 20191.

TABLE 1 Surface Load Factors for Single Truck on Unpaved Road

Depth of Cover ft	Pipe Size—in. 3	4	6	8	10	12	14	16	18
	Surface Load Factor—C								
2.5	0.0589	0.0713	0.1020	0.1328	0.1615	0.1901	0.2178	0.2443	0.2698
3	0.0437	0.0530	0.0759	0.0990	0.1207	0.1424	0.1637	0.1843	0.2044
4	0.0265	0.0321	0.0460	0.0602	0.0736	0.0871	0.1005	0.1136	0.1265
5	0.0176	0.0213	0.0306	0.0401	0.0490	0.0581	0.0672	0.0761	0.0849
6	0.0125	0.0151	0.0217	0.0284	0.0348	0.0413	0.0478	0.0542	0.0606
7	0.0093	0.0113	0.0162	0.0212	0.0260	0.0308	0.0357	0.0405	0.0453
8	0.0072	0.0087	0.0125	0.0164	0.0201	0.0238	0.0276	0.0313	0.0350
9	0.0057	0.0069	0.0099	0.0130	0.0160	0.0190	0.0219	0.0249	0.0279
10	0.0046	0.0056	0.0081	0.0106	0.0130	0.0154	0.0179	0.0203	0.0227
12	0.0032	0.0039	0.0056	0.0074	0.0091	0.0108	0.0125	0.0142	0.0159
14	0.0024	0.0029	0.0042	0.0055	0.0067	0.0080	0.0092	0.0105	0.0117
16	0.0018	0.0022	0.0032	0.0042	0.0051	0.0061	0.0071	0.0080	0.0090
20	0.0012	0.0014	0.0020	0.0027	0.0033	0.0039	0.0045	0.0052	0.0058
24	0.0008	0.0010	0.0014	0.0019	0.0023	0.0027	0.0032	0.0036	0.0040
28	0.0006	0.0007	0.0010	0.0014	0.0017	0.0020	0.0023	0.0026	0.0030
32	0.0005	0.0006	0.0008	0.0011	0.0013	0.0015	0.0018	0.0020	0.0023

Depth of Cover ft	Pipe Size—in. 20	24	30	36	42	48	54	60	64
	Surface Load Factor—C								
2.5	0.2941	0.3390	0.3962	0.4437	0.4813	0.5115	0.5366	0.5488	0.5592
3	0.2237	0.2602	0.3085	0.3507	0.3857	0.4153	0.4412	0.4543	0.4657
4	0.1391	0.1635	0.1972	0.2284	0.2559	0.2808	0.3040	0.3164	0.3277
5	0.0936	0.1106	0.1347	0.1576	0.1786	0.1982	0.2173	0.2278	0.2377
6	0.0669	0.0793	0.0970	0.1143	0.1304	0.1458	0.1612	0.1698	0.1781
7	0.0500	0.0594	0.0730	0.0863	0.0988	0.1111	0.1235	0.1306	0.1374
8	0.0387	0.0461	0.0567	0.0672	0.0773	0.0871	0.0973	0.1031	0.1088
9	0.0309	0.0367	0.0453	0.0538	0.0620	0.0700	0.0784	0.0833	0.0880
10	0.0251	0.0299	0.0370	0.0440	0.0507	0.0574	0.0644	0.0685	0.0725
12	0.0176	0.0210	0.0259	0.0309	0.0357	0.0405	0.0456	0.0486	0.0515
14	0.0130	0.0155	0.0192	0.0229	0.0265	0.0301	0.0339	0.0362	0.0384
16	0.0100	0.0119	0.0147	0.0176	0.0204	0.0232	0.0262	0.0279	0.0297
20	0.0064	0.0076	0.0095	0.0113	0.0131	0.0149	0.0169	0.0181	0.0192
24	0.0045	0.0053	0.0066	0.0079	0.0091	0.0104	0.0118	0.0126	0.0134
28	0.0033	0.0039	0.0049	0.0058	0.0067	0.0077	0.0087	0.0093	0.0099
32	0.0025	0.0030	0.0037	0.0044	0.0052	0.0059	0.0067	0.0071	0.0076

3.1.21 *w*—soil weight, 120 lb/ft^3 (18.85 kN/m^3)

3.1.22 ΔX—design deflection, in. (mm),

$$[\Delta X = 0.03\ D], \text{ or } [(\Delta X = 0.05\ D) \text{ for flexible linings}]$$

4. General Requirements

4.1 The pipe shall be ductile iron in accordance with Section 9.

4.2 Push-on joints shall comply with all applicable requirements of ANSI/AWWA C 111/A21.11.

Pipe with other types of joints shall comply with the joint dimensions and weights agreed upon at the time of purchase, but in all other respects shall fulfill the requirements of this specification.

4.3 Unless otherwise specified, pipe shall have a nominal length of 18 or 20 ft (5.5 or 6.1 m). A maximum of 20 % of the total number of pipe of each size specified in an order may be furnished as much as 24 in. (610 mm) shorter than the nominal laying length, and an additional 10 % may be furnished as much as 6 in. (152 mm) shorter than the nominal laying length.

5. Tolerances or Permitted Variations

5.1 *Dimensions*—The spigot end, bell, and socket of the pipe and the accessories shall be gaged with suitable gages at sufficiently frequent intervals to assure that the dimensions comply with the requirements of this specification. The smallest inside diameter (ID) of the sockets and the outside diameter (OD) of the spigot ends shall be tested with circular gauges. Other socket dimensions shall be gauged as may be appropriate.

5.2 *Thickness*— Minus thickness tolerances of pipe shall not exceed those shown in Table 5.

NOTE 1—An additional minus tolerance of 0.02 in. (0.5 mm) shall be permitted along the barrel of the pipe for a distance not to exceed 12 in. (305 mm).

5.3 *Weight*— The weight of any single pipe shall not be less than the tabulated weight by more than 6 % for pipe 12 in. or smaller in diameter, or by more than 5 % for pipe larger than 12 in. in diameter.

TABLE 2 Nominal Thicknesses for Standard Pressure Classes of Ductile-Iron Pipe

Size, in.	Outside Diameter, in. (mm)	Pressure Class				
		150	200	250	300	350
		Nominal Thickness, in. (mm)				
3	3.96 (100.6)	. . .	. . .	. . .	. . .	0.25[A] (6.4)
4	4.80 (121.9)	. . .	. . .	. . .	. . .	0.25[A] (6.4)
6	6.90 (175.3)	. . .	. . .	. . .	. . .	0.25[A] (6.4)
8	9.05 (229.9)	. . .	. . .	. . .	. . .	0.25[A] (6.4)
10	11.10 (281.9)	. . .	. . .	. . .	. . .	0.26 (6.6)
12	13.20 (335.3)	. . .	. . .	. . .	. . .	0.28 (7.1)
14	15.30 (388.6)	. . .	. . .	0.28 (7.1)	0.30 (7.6)	0.31 (7.9)
16	17.40 (442.0)	. . .	. . .	0.30 (7.6)	0.32 (8.1)	0.34 (8.6)
18	19.50 (495.3)	. . .	. . .	0.31 (7.9)	0.34 (8.6)	0.36 (9.1)
20	21.60 (548.6)	. . .	. . .	0.33 (8.4)	0.36 (9.1)	0.38 (9.7)
24	25.80 (655.3)	. . .	0.33 (8.4)	0.37 (9.4)	0.40 (10.2)	0.43 (10.9)
30	32.00 (812.8)	0.34 (8.6)	0.38 (9.7)	0.42 (10.7)	0.45 (11.4)	0.49 (12.4)
36	38.30 (972.8)	0.38 (9.7)	0.42 (10.7)	0.47 (11.9)	0.51 (12.9)	0.56 (14.2)
42	44.50 (1130.3)	0.41 (10.4)	0.47 (11.9)	0.52 (13.2)	0.57 (14.5)	0.63 (16.0)
48	50.80 (1290.3)	0.46 (11.7)	0.52 (13.2)	0.58 (14.7)	0.64 (16.3)	0.70 (17.8)
54	57.56 (1450.3)	0.51 (12.9)	0.58 (14.7)	0.65 (16.5)	0.72 (18.3)	0.79 (20.1)
60	61.61 (1564.9)	0.54 (13.7)	0.61 (15.5)	0.68 (17.3)	0.76 (19.3)	0.83 (21.1)
64	65.67 (1668.0)	0.56 (14.2)	0.64 (16.3)	0.72 (18.3)	0.80 (20.3)	0.87 (22.1)

[A] Calculated thicknesses for these sizes and pressure ratings are less than those shown above. Presently these are the lowest nominal thicknesses available in these sizes.

6. Coating and Lining

6.1 *Outside Coating*—The outside coating for use under normal conditions shall be an asphaltic coating approximately 1 mil (0.025 mm) thick. The coating shall be applied to the outside of all pipe, unless otherwise specified. The finished coating shall be continuous and smooth, neither brittle when cold, nor sticky when exposed to the sun, and shall be strongly adherent to the pipe.

6.2 *Cement-Mortar Linings*—Unless otherwise specified, the lining shall be cement-mortar in accordance with ANSI/AWWA C 104/A21.4.

6.3 *Special Linings*—For severely aggressive wastes, other types of linings may be available. Such special linings shall be specified in the invitation for bids and on the purchase order.

7. Pipe Design

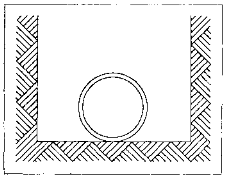
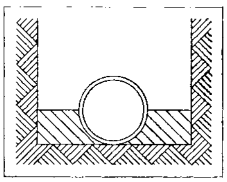
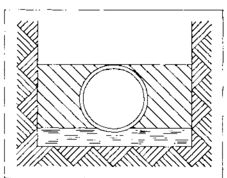
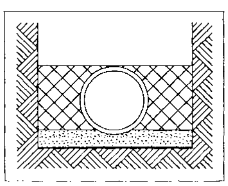
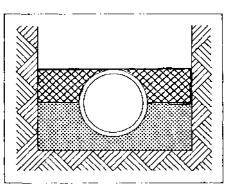
7.1 This section covers the design of ductile iron pipe for trench loads.

7.2 *Determining the Total Calculated Thickness and Standard Thickness*:

7.2.1 Determine the trench load, P_v. Table 6 gives the trench load, including the earth load, P_e, plus the truck load, P_t, for 2.5 to 32 ft (0.76 to 9.75 m) of cover.

7.2.2 Determine the standard laying condition from the descriptions in Table 3 and select the appropriate table for diameter-thickness ratios from Tables 7-11. Each table lists diameter-thickness ratios calculated for both bending and deflection over a range of trench loads.

TABLE 3 Design Values for Standard Laying Conditions [A]

Laying Condition	Description	E′ psi[B]	Bedding Angle, °	K_b	K_x
 Type 1	Flat-bottom trench[C] loose backfill.[D]	150	30	0.235	0.108
 Type 2	Flat-bottom trench[C] Backfill lightly consolidated to centerline of pipe.	300	45	0.210	0.105
 Type 3	Pipe bedded in 4-in. (102 mm) min loose soil[E] Backfill lightly consolidated to top of pipe.	400	60	0.189	0.103
 Type 4	Pipe bedded in sand, gravel, or crushed stone to depth of ⅛ pipe diameter, 4-in. (102 mm) min. Backfill compacted to top of pipe. (Approximately 80 percent Standard Proctor, AASHTO T-99)[F]	500	90	0.157	0.096
 Type 5	Pipe bedded in compacted granular material to centerline of pipe, 4 in. (102 mm) minimum under pipe. Compacted granular[G] or select[E] material to top of pipe. (Approximately 90 percent Standard Proctor, AASHTO T-99)	700	150	0.128	0.085

[A] Consideration of the pipe-zone embedment conditions included in this table may be influenced by factors other than pipe strength. For additional information see ANSI/AWWA C600, Standard for installation of Ductile-Iron Water Mains and Their Appurtenances.

[B] 1 psi = 6.894757 kPa.

[C] Flat-bottom is defined as undisturbed earth.

[D] For pipe 14 in. (350 mm) and larger, consideration should be given to use of laying conditions other than Type 1.

[E] Loose soil or select material is defined as native soil excavated from the trench, free of rocks, foreign materials, and frozen earth.

[F] American Association of State Highway and Transportation Officials, 444 N. Capitol Street, N.W., Suite 225, Washington D.C. 20001.

[G] Granular materials are defined per AASHTO Soil Classification System (Classification D 2487), with the exception that gravel bedding and gravel backfill adjacent to the pipe is limited to 2 in. maximum particle size per ANSI/AWWA C 600.

TABLE 4 Reduction Factors (R) for Truck Load Calculations

Size, in.	Depth of Cover, ft (m)			
	<4 (1.2)	4 to 7 (1.2 to 2.1)	>7 to 10 (2.4 to 3.0)	>10 (3.0)
	Reduction Factor			
3 to 12	1.00	1.00	1.00	1.00
14	0.92	1.00	1.00	1.00
16	0.88	0.95	1.00	1.00
18	0.85	0.90	1.00	1.00
20	0.83	0.90	0.95	1.00
24 to 30	0.81	0.85	0.95	1.00
36 to 64	0.80	0.85	0.90	1.00

TABLE 5 Allowances for Casting Tolerance

Size, in.	Casting Tolerance, in. (mm)
3–8	0.05 (1.3)
10–12	0.06 (1.5)
14–42	0.07 (1.8)
48	0.08 (2.0)
54–64	0.09 (2.3)

7.2.3 For bending-stress design, enter the column headed" Bending-Stress Design" in the appropriate table of Tables 7-11, and locate the tabulated trench load P_v nearest to the calculated P_v nearest to the calculated P_v from Sec. 7.2.1. (If the calculated P_v is halfway between two tabulated values, use the larger P_v value.) Select the corresponding D/t value for this P_v. Divide the pipe's outside diameter D (Table 2) by the D/T value to obtain net thickness t.

7.2.4 For deflection design, enter the column headed" Deflection Design" in the appropriate table of Tables 7-11, and locate the tabulated trench load P_v nearest to the calculated P_v from Sec. 7.2.1. (If the calculated P_v is less than the minimum P_v listed in the table, design for trench load is not controlled by deflection and this determination need not be completed.) If the calculated P_v is halfway between two tabulated values, use the larger P_v value. Select the corresponding D/t_1 value for this P_v. Divide the pipe's outside diameter (Table 2) by the D/t_1 value to obtain minimum manufacturing thickness t_1. Deduct 0.08 in. (2.0 mm) service allowance to obtain the thickness t.

NOTE 2—Service allowance equals 0.08 in. (2.0 mm) for all sizes of ductile-iron pipe.

7.2.5 Compare the net thicknesses from 7.2.3 and 7.2.4 and select the larger of the two. This will be the net thickness, *t*.

7.2.6 Add the service allowance of 0.08 in. (2.0 mm) to the net thickness, *t*. The resulting thickness is the minimum manufacturing thickness, t_1.

7.2.7 Add the casting tolerance from Table 5 to the minimum manufacturing thickness, t_1. The resulting thickness is the total calculated thickness.

7.2.8 In specifying and ordering pipe, use the total calculated thickness from Sec. 7.2.7 to select a standard pressure-class thicknesses from Table 2. When the calculated thickness is between two nominal thicknesses, select the larger of the two. When specifying and ordering pipe, use the pressure-class listed in Table 2 for this nominal thickness.

NOTE 3—On specific projects, manufacturers may be willing to furnish pipe with thicknesses that fall between standard classes.

7.2.9 The appropriate standard pressure class may also be determined by using the Design Equations in Sec. 7.4.

7.3 *Design Example*—Calculate the thickness for 30-in. cement-lined ductile iron pipe bedded in loose soil for a minimum depth of 4 in. (100 mm), backfill lightly consolidated to the top of pipe, Laying Condition Type 3, under 10 ft (3 m) of cover.

Earth load, Table 6, P_e	=	8.3 psi
Truck load, Table 6, P_t	=	0.7 psi
Trench load, $P_v = P_e + P_t$	=	9.0 psi

7.3.1 Entering P_v of 9.0 psi in Table 9, the bending stress design requires *D/t* of 163.

$$\text{Net thickness, } t \text{, for bending stress} = D/(D/t) = 32.00/163 = 0.20$$

7.3.2 Reentering P_v of 9.0 psi in Table 9, the deflection design requires D/t_1 of 136.

Minimum thickness t_1 for deflection design = $D/(D/t_1)$	= 32.00/136
	= 0.24 in.
Deduct service allowance	−0.08 in.
Net thickness *t* for deflection control	= 0.16 in.

7.3.3 The larger net thickness is 0.20 in., obtained by the design for bending stress.

Net thickness	=	0.20 in.
Service allowance	=	0.08 in.
Minimum thickness	=	0.28 in.
Casting Tolerance	=	0.07 in.
Total calculated thickness	=	0.35 in.

TABLE 6 Earth Loads (P_e) Truck Loads (P_t) and Trench Loads (P_v), psi[A]

Depth of Cover, ft (m)	P_e	3-in. Pipe		4-in. Pipe		6-in. Pipe		8-in. Pipe		10-in. Pipe		12-in. Pipe		14-in. Pipe		16-in. Pipe		18-in. Pipe		20-in. Pipe	
		P_t	P_v	P_t	P_v	P_t	P_v	P_t	P_v	P_t	P_v	P_t	P_v	P_t	P_v	P_t	P_v	P_t	P_v	P_t	P_v
2.5 (0.8)	2.1	9.9	12.0	9.9	12.0	9.9	12.0	9.8	11.9	9.7	11.8	9.6	11.7	8.7	10.8	8.2	10.3	7.8	9.9	7.5	9.6
3 (0.9)	2.5	7.4	9.9	7.4	9.9	7.3	9.8	7.3	9.8	7.2	9.7	7.2	9.7	6.6	9.1	6.2	8.7	5.9	8.4	5.7	8.2
4 (1.2)	3.3	4.4	7.7	4.5	7.8	4.4	7.7	4.4	7.7	4.4	7.7	4.4	7.7	4.4	7.7	4.1	7.4	3.9	7.2	3.9	7.2
5 (1.5)	4.2	3.0	7.2	3.0	7.2	3.0	7.2	3.0	7.2	2.9	7.1	2.9	7.1	2.9	7.1	2.8	7.0	2.6	6.8	2.6	6.8
6 (1.8)	5.0	2.1	7.1	2.1	7.1	2.1	7.1	2.1	7.1	2.1	7.1	2.1	7.1	2.1	7.1	2.0	7.0	1.9	6.9	1.9	6.9
7 (2.1)	5.8	1.6	7.4	1.6	7.4	1.6	7.4	1.6	7.4	1.6	7.4	1.6	7.4	1.6	7.4	1.5	7.3	1.4	7.2	1.4	7.2
8 (2.4)	6.7	1.2	7.9	1.2	7.9	1.2	7.9	1.2	7.9	1.2	7.9	1.2	7.9	1.2	7.9	1.2	7.9	1.2	7.9	1.1	7.8
9 (2.7)	7.5	1.0	8.5	1.0	8.5	1.0	8.5	1.0	8.5	1.0	8.5	1.0	8.5	1.0	8.5	1.0	8.5	1.0	8.5	0.9	8.4
10 (3.0)	8.3	0.8	9.1	0.8	9.1	0.8	9.1	0.8	9.1	0.8	9.1	0.8	9.1	0.8	9.1	0.8	9.1	0.8	9.1	0.7	9.0
12 (3.7)	10.0	0.6	10.6	0.6	10.6	0.6	10.6	0.6	10.6	0.5	10.5	0.5	10.5	0.5	10.5	0.5	10.5	0.5	10.5	0.5	10.5
14 (4.3)	11.7	0.4	12.1	0.4	12.1	0.4	12.1	0.4	12.1	0.4	12.1	0.4	12.1	0.4	12.1	0.4	12.1	0.4	12.1	0.4	12.1
16 (4.9)	13.3	0.3	13.6	0.3	13.6	0.3	13.6	0.3	13.6	0.3	13.6	0.3	13.6	0.3	13.6	0.3	13.6	0.3	13.6	0.3	13.6
20 (6.1)	16.7	0.2	16.9	0.2	16.9	0.2	16.9	0.2	16.9	0.2	16.9	0.2	16.9	0.2	16.9	0.2	16.9	0.2	16.9	0.2	16.9
24 (7.3)	20.0	0.2	20.2	0.1	20.1	0.1	20.1	0.1	20.1	0.1	20.1	0.1	20.1	0.1	20.1	0.1	20.1	0.1	20.1	0.1	20.1
28 (8.5)	23.3	0.1	23.4	0.1	23.4	0.1	23.4	0.1	23.4	0.1	23.4	0.1	23.4	0.1	23.4	0.1	23.4	0.1	23.4	0.1	23.4
32 (9.8)	26.7	0.1	26.8	0.1	26.8	0.1	26.8	0.1	26.8	0.1	26.8	0.1	26.8	0.1	26.8	0.1	26.8	0.1	26.8	0.1	26.8

Depth of Cover, ft (m)	P_e	24-in. Pipe		30-in. Pipe		36-in. Pipe		42-in. Pipe		48-in. Pipe		54-in. Pipe		60-in. Pipe		64-in. Pipe	
		P_t	P_v	P_t	P_v	P_t	P_v	P_t	P_v	P_t	P_v	P_t	P_v	P_t	P_v	P_t	P_v
2.5 (0.8)	2.1	7.1	9.2	6.7	8.8	6.2	8.3	5.8	7.9	5.4	7.5	5.0	7.1	4.8	6.9	4.5	6.6
3 (0.9)	2.5	5.4	7.9	5.2	7.7	4.9	7.4	4.6	7.1	4.4	6.9	4.1	6.6	3.9	6.4	3.8	6.3
4 (1.2)	3.3	3.6	6.9	3.5	6.8	3.4	6.7	3.3	6.6	3.1	6.4	3.0	6.3	2.9	6.2	2.8	6.1
5 (1.5)	4.2	2.4	6.6	2.4	6.6	2.3	6.5	2.3	6.5	2.2	6.4	2.1	6.3	2.1	6.3	2.1	6.3
6 (1.8)	5.0	1.7	6.7	1.7	6.7	1.7	6.7	1.7	6.7	1.6	6.6	1.6	6.6	1.6	6.6	1.5	6.5
7 (2.1)	5.8	1.3	7.1	1.3	7.1	1.3	7.1	1.3	7.1	1.2	7.0	1.2	7.0	1.2	7.0	1.2	7.0
8 (2.4)	6.7	1.1	7.8	1.1	7.8	1.1	7.8	1.0	7.7	1.0	7.7	1.0	7.7	1.0	7.7	1.0	7.7
9 (2.7)	7.5	0.9	8.4	0.9	8.4	0.8	8.3	0.8	8.3	0.8	8.3	0.8	8.3	0.8	8.3	0.8	8.3
10 (3.0)	8.3	0.7	9.0	0.7	9.0	0.7	9.0	0.7	9.0	0.7	9.0	0.7	9.0	0.7	9.0	0.7	9.0
12 (3.7)	10.0	0.5	10.5	0.5	10.5	0.5	10.5	0.5	10.5	0.5	10.5	0.5	10.5	0.5	10.5	0.5	10.5
14 (4.3)	11.7	0.4	12.1	0.4	12.1	0.4	12.1	0.4	12.1	0.4	12.1	0.4	12.1	0.4	12.1	0.4	12.1
16 (4.9)	13.3	0.3	13.6	0.3	13.6	0.3	13.6	0.3	13.6	0.3	13.6	0.3	13.6	0.3	13.6	0.3	13.6
20 (8.1)	16.7	0.2	16.9	0.2	16.9	0.2	16.9	0.2	16.9	0.2	16.9	0.2	16.9	0.2	16.9	0.2	16.9
24 (7.3)	20.0	0.1	20.1	0.1	20.1	0.1	20.1	0.1	20.1	0.1	20.1	0.1	20.1	0.1	20.1	0.1	20.1
28 (8.5)	23.3	0.1	23.4	0.1	23.4	0.1	23.4	0.1	23.4	0.1	23.4	0.1	23.4	0.1	23.4	0.1	23.4
32 (9.8)	26.7	0.1	26.8	0.1	26.8	0.1	26.8	0.1	26.8	0.1	26.8	0.1	26.8	0.1	26.8	0.1	26.8

[A] 1 psi = 6.894757 kPa.

TABLE 7 Diameter-Thickness Ratios for Laying Condition Type 1

NOTE 1—E' = 150 psi[A] K_b= 0.235 K_x= 0.108

Trench Load P_v, psi[A]				Trench Load P_v, psi[A]			
Bending Stress Design	Deflection Design 3 %[C] max	Deflection Design 5 %[D] max	D/t[B] or D/t_1	Bending Stress Design	Deflection Design 3 %[C] max	Deflection Design 5 %[D] max	D/t[B] or D/t_1
5.17	3.89	6.48	150	8.86	7.12	11.87	100
5.21	3.91	6.52	149	8.99	7.26	12.11	99
5.26	3.94	6.57	148	9.13	7.41	12.35	98
5.30	3.97	6.62	147	9.27	7.57	12.61	97
5.35	4.00	6.67	146	9.41	7.73	12.88	96
5.40	4.03	6.72	145	9.56	7.89	13.15	95
5.45	4.06	6.77	144	9.71	8.07	13.45	94
5.49	4.09	6.82	143	9.87	8.25	13.75	93
5.54	4.13	6.88	142	10.03	8.44	14.07	92
5.59	4.16	6.94	141	10.20	8.64	14.40	91
5.65	4.20	6.99	140	10.37	8.85	14.74	90
5.70	4.23	7.05	139	10.55	9.06	15.11	89
5.75	4.27	7.12	138	10.74	9.29	15.48	88
5.80	4.31	7.18	137	10.93	9.53	15.88	87
5.86	4.35	7.25	136	11.13	9.78	16.30	86
5.91	4.39	7.31	135	11.34	10.04	16.73	85
5.97	4.43	7.38	134	11.55	10.31	17.19	84
6.03	4.47	7.46	133	11.78	10.60	17.67	83
6.09	4.52	7.53	132	12.01	10.90	18.17	82
6.15	4.56	7.61	131	12.25	11.22	18.70	81
6.21	4.61	7.69	130	12.50	11.56	19.26	80
6.27	4.66	7.77	129	12.76	11.91	19.85	79
6.33	4.71	7.85	128	13.03	12.28	20.46	78
6.40	4.76	7.94	127	13.31	12.67	21.11	77
6.46	4.82	8.03	126	13.60	13.08	21.79	76
6.53	4.87	8.12	125	13.91	13.51	22.52	75
6.60	4.93	8.22	124	14.23	13.97	23.28	74
6.67	4.99	8.32	123	14.56	14.45	24.08	73
6.74	5.05	8.42	122	14.91	14.96	24.93	72
6.82	5.11	8.52	121	15.27	15.50	25.83	71
6.89	5.18	8.63	120	15.65	16.07	26.78	70
6.91	5.25	8.74	119	16.05	16.68	27.79	69
7.05	5.32	8.86	118	16.46	17.32	28.86	68
7.13	5.39	8.98	117	16.89	18.00	30.00	67
7.21	5.46	9.11	116	17.35	18.73	31.21	66
7.29	5.54	9.24	115	17.83	19.50	32.49	65
7.38	5.62	9.37	114	18.33	20.32	33.86	64
7.47	5.71	9.51	113	18.85	21.19	35.32	63
7.56	5.79	9.65	112	19.40	22.12	36.87	62
7.65	5.88	9.80	111	19.98	23.12	38.53	61
7.75	5.97	9.96	110	20.59	24.18	40.30	60
7.85	6.07	10.12	109	21.23	25.32	42.20	59
7.95	6.17	10.20	108	21.91	26.54	44.23	58
8.05	6.27	10.46	107	22.63	27.85	46.42	57
8.16	6.38	10.63	106	23.38	29.26	48.76	56
8.27	6.49	10.82	105	24.18	30.77	51.28	55
8.38	6.61	11.01	104	25.02	32.39	53.99	54
8.49	6.73	11.22	103	25.92	34.15	56.92	53
8.61	6.86	11.43	102	26.86	36.05	60.08	52
8.74	6.99	11.64	101	27.87	38.10	63.50	51
28.94	40.32	67.20	50	46.84	83.54	139.23	39
30.07	42.73	71.22	49	49.30	90.28	150.47	38
31.28	45.35	75.58	48	51.96	97.80	163.00	37
32.57	48.20	80.34	47	54.86	106.20	177.00	36
33.95	51.31	85.52	46				
35.42	54.72	91.19	45	58.02	115.62	192.70	35

TABLE 7 *Continued*

Trench Load P_v, psi[A]				Trench Load P_v, psi[A]			
Bending Stress Design	Deflection Design 3 %[C] max	Deflection Design 5 %[D] max	D/t[B] or D/t_1	Bending Stress Design	Deflection Design 3 %[C] max	Deflection Design 5 %[D] max	D/t[B] or D/t_1
37.00	58.44	97.40	44	61.46	126.21	210.36	34
38.69	62.53	104.22	43	65.23	138.18	230.29	33
40.50	67.03	111.71	42	69.36	151.73	252.88	32
42.46	71.99	119.98	41	73.92	167.15	278.58	31
				78.94	184.77	307.96	30
44.56	77.47	129.11	40				

[A] 1 psi = 6.894757 kPa.

[B] The D/t for the tabulated P_v nearest to the calculated P_v is selected. When the calculated P_v is halfway between two tabulated values, the smaller D/t should be used.

[C] Maximum 3 % deflection is recommended for rigid or semirigid linings such as cement mortar.

[D] Maximum 5 % deflection is recommended for flexible linings such as asphaltic and plastic.

TABLE 8 Diameter-Thickness Ratios for Laying Condition Type 2

NOTE 1—$E' = 300$ psi[A] $K_b = 0.210$ $K_x = 0.105$

Trench Load P_v, psi[A]				Trench Load P_v, psi[A]			
Bending Stress Design	Deflection Design 3 %[C] max	Deflection Design 5 %[D] max	D/t[B] or D/t_1	Bending Stress Design	Deflection Design 3 %[C] max	Deflection Design 5 %[D] max	D/t[B] or D/t_1
7.42	6.61	11.02	150	12.01	9.94	16.57	100
7.48	6.64	11.06	149	12.16	10.09	16.81	99
7.54	6.67	11.11	148	12.31	10.24	17.06	98
7.61	6.70	11.16	147	12.46	10.40	17.33	97
7.67	6.73	11.21	146	12.62	10.56	17.60	96
7.74	6.76	11.27	15	12.79	10.73	17.89	95
7.80	6.79	11.32	144	12.96	10.91	18.19	94
7.87	6.83	11.38	143	13.13	11.10	18.50	93
7.94	6.86	11.43	142	13.31	11.29	18.82	92
8.01	6.89	11.49	141	13.49	11.50	19.17	91
8.08	6.93	11.55	140	13.68	11.71	19.52	90
8.15	6.97	11.61	139	13.88	11.94	19.89	89
8.22	7.01	11.68	138	14.08	12.17	20.28	88
8.29	7.05	11.74	137	14.30	12.42	20.69	87
8.37	7.09	11.81	135	14.51	12.67	21.12	86
8.44	7.13	11.88	135	14.74	12.94	21.57	85
8.52	7.17	11.95	134	14.97	13.22	22.04	84
8.59	7.22	12.03	133	15.21	13.52	22.53	83
8.67	7.26	12.10	132	15.46	13.83	23.05	82
8.75	7.31	12.18	131	15.72	14.16	23.60	81
8.83	7.36	12.26	130	15.99	14.50	24.17	80
8.91	7.41	12.35	129	16.28	14.86	24.77	79
8.99	7.46	12.43	128	16.57	15.24	25.40	78
9.07	7.51	12.52	127	16.87	15.64	26.07	77
9.16	7.57	12.62	126	17.19	16.06	26.77	76
9.25	7.63	12.71	125	17.52	16.51	27.52	75
9.33	7.69	12.81	124	17.86	16.98	28.30	74
9.42	7.75	12.91	123	18.22	17.48	29.13	73
9.51	7.81	13.02	122	18.59	18.00	30.00	72
9.60	7.87	13.12	121	18.98	18.56	30.93	71
9.70	7.94	13.24	120	19.39	19.14	31.91	70
9.79	8.01	13.35	119	19.82	19.77	32.95	69
9.89	8.08	13.47	118	20.27	20.43	34.05	68
9.99	8.16	13.60	117	20.73	21.13	35.22	67
10.09	8.23	13.72	116	21.23	21.87	36.46	66
10.19	8.31	13.86	115	21.74	22.67	37.78	65
10.29	8.40	13.99	114	22.28	23.51	39.18	64
10.40	8.48	14.14	113	22.85	24.41	40.68	63
10.51	8.57	14.29	112	23.45	25.37	42.28	62
10.62	8.66	14.44	111	24.07	26.39	43.99	61
10.73	8.76	14.60	110	24.74	27.49	45.81	60
10.84	8.86	14.76	109	25.43	28.66	47.76	59
10.96	8.96	14.93	108	26.17	29.91	49.86	58
11.08	9.07	15.11	107	26.95	31.26	52.10	57
11.21	9.18	15.30	106	27.77	32.71	54.521	56
11.33	9.29	15.49	105	28.64	34.26	57.10	55
11.46	9.41	15.69	104	29.56	35.93	59.89	54
11.59	9.54	15.89	103	30.53	37.74	62.90	53
11.73	9.67	16.11	102	31.57	39.69	66.15	52
11.87	9.80	16.33	101	32.67	41.80	69.67	51
33.84	44.09	73.48	50	51.06	82.29	137.16	40
35.08	46.56	77.61	49	53.57	88.54	147.57	39
36.41	49.26	82.10	48	56.30	95.48	159.13	38
37.83	52.19	86.99	47	59.25	103.21	172.02	37
39.34	55.40	92.33	46	62.46	111.85	186.42	36
40.96	58.89	98.16	45	65.96	121.54	202.56	35
42.70	62.73	104.54	44	69.79	132.44	220.73	34

TABLE 8 *Continued*

Trench Load P_v, psi[A]				Trench Load P_v, psi[A]			
Bending Stress Design	Deflection Design 3 %[C] max	Deflection Design 5 %[D] max	D/t[B] or D/t_1	Bending Stress Design	Deflection Design 3 %[C] max	Deflection Design 5 %[D] max	D/t[B] or D/t_1
44.57	66.93	111.55	43	73.98	144.74	241.23	33
46.57	71.56	119.26	42	78.57	158.68	264.46	32
48.73	76.66	127.76	41	83.64	174.54	290.90	31
				89.23	192.67	321.11	30

[A] 1 psi = 6.894757 kPa.

[B] The D/t for the tabulated P_v nearest to the calculated P_v is selected. When the calculated P_v is halfway between two tabulated values, the smaller D/t should be used.

[C] Maximum 3 % deflection is recommended for rigid or semirigid linings such as cement mortar.

[D] Maximum 5 % deflection is recommended for flexible linings such as asphaltic and plastic.

TABLE 9 Diameter-Thickness Ratios for Laying Condition Type 3

NOTE 1—E' = 400 psi[A] K_b= 0.189 K_x= 0.103

Trench Load P_v, psi[A]				Trench Load P_v, psi[A]			
Bending Stress Design	Deflection Design 3 %[C] max	Deflection Design 5 %[D] max	D/t[B] or D/t_1	Bending Stress Design	Deflection Design 3 %[C] max	Deflection Design 5 %[D] max	D/t[B] or D/t_1
10.00	8.52	14.19	150	15.39	11.91	19.85	100
10.08	8.54	14.24	149	15.55	12.06	20.10	99
10.16	8.57	14.29	148	15.71	12.21	20.35	98
10.24	8.60	14.34	147	15.88	12.37	20.62	97
10.33	8.64	14.39	146	16.06	12.54	20.90	96
10.41	8.67	14.45	145	16.23	12.72	21.20	95
10.49	8.70	14.50	144	16.42	12.90	21.50	94
10.58	8.73	14.56	143	16.61	13.09	21.82	93
10.66	8.77	14.62	142	16.80	13.29	22.15	92
10.75	8.81	14.68	141	17.00	13.50	22.50	91
10.83	8.84	14.74	140	17.21	13.72	22.86	90
10.92	8.88	14.80	139	17.42	13.95	23.24	89
11.01	8.92	14.87	138	17.64	14.18	23.64	88
11.10	8.96	14.93	137	17.86	14.43	24.06	87
11.19	9.00	15.00	136	18.10	14.70	24.49	86
11.28	9.04	15.07	135	18.34	14.97	24.95	85
11.37	9.09	15.15	134	18.59	15.26	25.43	84
11.46	9.13	15.22	133	18.85	15.56	25.93	83
11.56	9.18	15.30	132	19.12	15.88	26.46	82
11.65	9.23	15.38	131	19.40	16.21	27.01	81
11.75	9.28	15.46	130	19.68	16.56	27.60	80
11.84	9.33	15.55	129	19.99	16.93	28.21	79
11.94	9.38	15.64	128	20.30	17.31	28.86	78
12.04	9.44	15.73	127	20.62	17.72	29.54	77
12.14	9.49	15.82	126	20.96	18.15	30.26	76
12.25	9.55	15.92	125	21.31	18.61	31.01	75
12.35	9.61	16.02	124	21.68	19.09	31.81	74
12.45	9.67	16.12	123	22.07	19.59	32.65	73
12.56	9.74	16.23	122	22.47	20.13	33.55	72
12.67	9.80	16.34	121	22.88	20.69	34.49	71
12.78	9.87	16.45	120	23.32	21.29	35.49	70
12.89	9.94	16.57	119	23.78	21.93	36.55	69
13.00	10.02	16.69	118	24.26	22.60	37.67	68
13.11	10.09	16.82	117	24.76	23.32	38.86	67
13.23	10.17	16.95	116	25.29	24.08	40.13	66
13.34	10.25	17.09	115	25.85	24.88	41.47	65
13.46	10.34	17.23	114	26.43	25.74	42.91	64
13.58	10.42	17.37	113	27.04	26.66	44.43	63
13.71	10.51	17.52	112	27.68	27.64	46.06	62
13.83	10.61	17.68	111	28.36	28.68	47.80	61
13.96	10.71	17.84	110	29.08	29.80	49.66	60
14.09	10.81	18.01	109	29.83	30.99	51.65	59
14.22	10.91	18.18	108	30.63	32.27	53.78	58
14.36	11.02	18.37	107	31.47	33.64	56.07	57
14.50	11.13	18.55	106	32.36	35.12	58.53	56
14.64	11.25	18.75	105	33.31	36.70	61.17	55
14.78	11.37	18.95	104	34.30	38.41	64.02	54
14.93	11.50	19.16	103	35.37	40.25	67.08	53
15.08	11.63	19.38	102	36.49	42.24	70.40	52
15.23	11.77	19.61	101	37.69	44.39	73.98	51
38.97	46.72	77.86	50	57.84	85.67	142.78	40
40.33	49.25	82.08	49	60.61	92.04	153.39	39
41.78	51.99	86.65	48	63.61	99.11	165.18	38
43.33	54.98	91.64	47	66.86	106.99	178.32	37
44.98	58.25	97.08	46	70.40	115.80	193.00	36
				74.27	125.67	209.46	35

TABLE 9 *Continued*

Trench Load P_v, psi[A]				Trench Load P_v, psi[A]			
Bending Stress Design	Deflection Design 3 %[C] max	Deflection Design 5 %[D] max	D/t[B] or D/t_1	Bending Stress Design	Deflection Design 3 %[C] max	Deflection Design 5 %[D] max	D/t[B] or D/t_1
46.76	61.81	103.02	45	78.49	136.78	227.97	34
48.66	65.72	109.53	44	83.11	149.32	248.87	33
50.71	70.01	116.68	43	88.19	163.54	272.56	32
52.91	74.72	124.54	42	93.79	179.71	299.51	31
55.28	79.92	133.20	41	99.97	198.18	330.31	30

[A] 1 psi = 6.894757 kPa.

[B] The *D/t* for the tabulated P_v nearest to the calculated P_v is selected. When the calculated P_v is halfway between two tabulated values, the smaller *D/t* should be used.

[C] Maximum 3 % deflection is recommended for rigid or semirigid linings such as cement mortar.

[D] Maximum 5 % deflection is recommended for flexible linings such as asphaltic and plastic.

TABLE 10 Diameter-Thickness Ratios for Laying Condition Type 4

NOTE 1—E' = 500 psi[A] K_b= 0.157 K_x= 0.096

Trench Load P_v, psi[A]				Trench Load P_v, psi[A]			
	Deflection Design				Deflection Design		
Bending Stress Design	3 %[C] max	5 %[D] max	D/t[B] or D/t_1	Bending Stress Design	3 %[C] max	5 %[D] max	D/t[B] or D/t_1
16.34	11.04	18.40	150	22.49	14.68	24.47	100
16.45	11.07	18.46	149	22.66	14.84	24.74	99
16.55	11.11	18.51	148	22.83	15.01	25.02	98
16.65	11.14	18.56	147	23.01	15.18	25.30	97
16.76	11.17	18.62	146	23.20	15.36	25.61	96
16.86	11.21	18.68	145	23.38	15.55	25.92	95
16.96	11.24	18.74	144	23.58	15.75	26.25	94
17.07	11.28	18.80	143	23.78	15.95	26.59	93
17.18	11.31	18.86	142	23.99	16.17	26.94	92
17.28	11.35	18.92	141	24.20	16.39	27.32	91
17.39	11.39	18.99	140	24.42	16.62	27.71	90
17.50	11.43	19.06	139	24.64	16.87	28.11	89
17.60	11.48	19.13	138	24.88	17.12	28.54	88
17.71	11.52	19.20	137	25.12	17.39	28.99	87
17.82	11.56	19.27	136	25.37	17.67	29.45	86
17.93	11.61	19.35	135	25.63	17.97	29.95	85
18.04	11.66	19.43	134	25.90	18.28	30.46	84
18.15	11.71	19.51	133	26.18	18.60	31.00	83
18.26	11.76	19.59	132	26.47	18.94	31.57	82
18.37	11.81	19.68	131	26.77	19.30	32.16	81
18.49	11.86	19.77	130	27.09	19.67	32.79	80
18.60	11.92	19.86	129	27.42	20.07	33.45	79
18.72	11.97	19.95	128	27.76	20.48	34.14	78
18.83	12.03	20.05	127	28.11	20.92	34.87	77
18.95	12.09	20.15	126	28.49	21.38	35.64	76
19.06	12.15	20.26	125	28.87	21.87	36.45	75
19.18	12.22	20.36	124	29.28	22.38	37.31	74
19.30	12.28	20.47	123	29.70	22.93	38.21	73
19.42	12.35	20.59	122	30.15	23.50	39.17	72
19.54	12.42	20.71	121	30.62	24.11	40.18	71
19.66	12.50	120.83	120	31.11	24.75	41.25	70
19.78	12.57	120.96	119	31.62	25.43	42.39	69
19.91	12.65	21.09	118	32.16	26.16	43.59	68
20.04	12.73	21.22	117	32.72	26.92	44.87	67
20.16	12.82	21.36	116	33.32	27.74	46.23	66
20.29	12.91	21.51	115	33.95	28.60	47.67	65
20.42	13.00	21.66	114	34.61	29.53	49.21	64
20.55	13.09	21.82	113	35.30	30.51	50.85	63
20.69	13.19	21.98	112	36.04	31.56	52.60	62
20.82	13.29	22.15	111	36.81	32.68	54.47	61
20.96	13.39	22.32	110	37.63	33.88	56.46	60
21.10	13.50	22.50	109	38.50	35.16	58.60	59
21.24	13.61	22.69	108	39.42	36.53	60.88	58
21.39	13.73	22.88	107	40.39	38.00	63.34	57
21.54	13.85	23.08	106	41.42	39.58	65.97	56
21.69	13.98	23.29	105	42.51	41.28	68.81	55
21.84	14.11	23.51	104	43.67	43.12	71.86	54
22.00	14.24	23.74	103	44.91	45.09	75.15	53
22.16	14.38	23.97	102	46.22	47.22	78.71	52
22.32	14.53	24.22	101	47.62	49.53	82.55	51
49.11	52.03	86.72	50	71.39	93.82	156.37	40
50.70	54.74	91.24	49	74.67	100.65	167.75	39
52.41	57.69	96.15	48	78.24	108.24	180.40	38
54.23	60.90	101.50	47	82.11	116.70	194.50	37
56.18	64.40	107.33	46	86.33	126.15	210.25	36
				90.93	136.74	227.91	35

TABLE 10 *Continued*

Trench Load P_v, psi[A]				Trench Load P_v, psi[A]			
Bending Stress Design	Deflection Design 3 %[C] max	Deflection Design 5 %[D] max	D/t[B] or D/t_1	Bending Stress Design	Deflection Design 3 %[C] max	Deflection Design 5 %[D] max	D/t[B] or D/t_1
58.27	68.23	113.71	45	95.97	148.66	247.77	34
60.52	72.42	120.70	44	101.49	162.12	270.20	33
62.93	77.02	128.36	43	107.56	177.37	295.61	32
65.54	82.08	136.80	42	114.25	194.72	324.53	31
68.35	87.66	146.09	41	121.65	214.54	357.57	30

[A] 1 psi = 6.894757 kPa.

[B] The D/t for the tabulated P_v nearest to the calculated P_v is selected. When the calculated P_v is halfway between two tabulated values, the smaller D/t should be used.

[C] Maximum 3

[D] Maximum 5 % deflection is recommended for flexible linings such as asphaltic and plastic.

TABLE 11 Diameter-Thickness Ratios for Laying Condition Type 5

NOTE 1—E' = 700 psi[A] K_b= 0.128 K_x= 0.085

Trench Load P_v, psi[A]				Trench Load P_v, psi[A]			
Bending Stress Design	Deflection Design 3 %[C] max	Deflection Design 5 %[D] max	D/t[B] or D/t_1	Bending Stress Design	Deflection Design 3 %[C] max	Deflection Design 5 %[D] max	D/t[B] or D/t_1
30.21	16.78	27.96	150	36.54	20.89	34.82	100
30.34	16.81	28.02	149	36.69	21.07	35.12	99
30.48	16.85	28.08	148	36.85	21.26	35.43	98
30.61	16.89	28.14	147	37.01	21.45	35.76	97
30.74	16.92	28.20	146	37.17	21.66	36.10	96
30.87	16.96	28.27	145	37.34	21.87	36.45	95
30.99	17.00	28.34	144	37.52	22.09	36.82	94
31.12	17.04	28.40	143	37.70	22.32	37.20	93
31.25	17.09	28.48	142	37.89	22.56	37.61	92
31.38	17.13	28.55	141	38.08	22.82	38.03	91
31.50	17.17	28.62	140	38.28	23.08	38.47	90
31.63	17.22	28.70	139	38.49	23.36	38.93	89
31.76	17.27	28.78	138	38.71	23.65	39.41	88
31.88	17.32	28.86	137	38.93	23.95	39.91	87
32.01	17.37	28.94	136	39.17	24.27	40.44	86
32.13	17.42	29.03	135	39.41	24.60	41.00	85
32.25	17.47	29.12	134	39.67	24.95	41.58	84
32.38	17.53	29.21	133	39.94	25.31	41.29	83
32.50	17.58	29.30	132	40.22	25.70	42.83	82
32.62	17.64	29.40	131	40.51	26.10	43.50	81
32.75	17.70	29.50	130	40.82	26.52	44.21	80
32.87	17.76	29.61	129	41.14	26.97	44.95	79
32.99	17.83	29.71	128	41.48	27.44	45.73	78
33.11	17.89	29.82	127	41.84	27.93	46.56	77
33.23	17.96	29.94	126	42.21	28.46	47.43	76
33.35	18.03	30.05	125	42.60	29.01	48.34	75
33.47	18.11	30.18	124	43.02	29.59	49.31	74
33.59	18.18	30.30	123	43.45	30.20	50.33	73
33.71	18.26	30.43	122	43.92	30.85	51.41	72
33.83	18.34	30.56	121	44.40	31.53	52.56	71
33.95	18.42	30.70	120	44.91	32.26	53.77	70
34.07	18.51	30.85	119	45.46	33.03	55.05	69
34.19	18.60	30.99	118	46.03	33.85	56.41	68
34.31	18.69	31.15	117	46.64	34.71	57.85	67
34.43	18.78	31.31	116	47.28	35.63	59.39	66
34.55	18.88	31.47	115	47.96	36.61	61.02	65
34.68	18.98	31.64	114	48.68	37.65	62.76	64
34.80	19.09	31.82	113	49.44	38.77	64.61	63
34.92	19.20	32.00	112	50.25	39.95	66.58	62
35.05	19.31	32.19	111	51.11	41.21	68.69	61
35.17	19.43	32.39	110	52.02	42.57	70.94	60
35.30	19.55	32.59	109	52.99	44.01	73.36	59
35.43	19.68	32.80	108	54.02	45.56	75.94	58
35.56	19.81	33.02	107	55.12	47.23	78.71	57
35.69	19.95	33.25	106	56.28	49.01	81.69	56
35.83	20.09	33.48	105	57.53	50.93	84.89	55
35.96	20.24	33.73	104	58.86	53.00	88.34	54
36.10	20.39	33.99	103	60.28	55.23	92.05	53
36.25	20.55	34.25	102	61.79	57.64	96.07	52
36.39	20.72	34.53	101	63.41	60.25	100.41	51
65.14	63.07	105.12	50	91.47	110.27	183.78	40
67.00	66.13	110.22	49	95.40	117.98	196.64	39
68.99	69.46	115.77	48	99.67	126.56	210.93	38
71.12	73.09	121.81	47	104.32	136.11	226.84	37
73.41	77.04	128.40	46	109.40	146.78	244.63	36
75.88	81.36	135.61	45	114.94	158.75	264.58	35

TABLE 11 *Continued*

Trench Load P_v, psi[A]				Trench Load P_v, psi[A]			
Bending Stress Design	Deflection Design 3 %[C] max	Deflection Design 5 %[D] max	D/t[B] or D/t_1	Bending Stress Design	Deflection Design 3 %[C] max	Deflection Design 5 %[D] max	D/t[B] or D/t_1
78.54	86.10	143.49	44	121.02	172.21	287.01	34
81.40	91.29	152.15	43	127.69	187.41	312.34	33
84.50	97.01	161.68	42	135.03	204.63	341.04	32
87.85	103.31	172.18	41	143.14	224.22	373.70	31
				152.11	246.61	411.02	30

[A] 1 psi = 6.894757 kPa.
[B] The *D/t* for the tabulated P_v nearest to the calculated P_v is selected. When the calculated P_v is halfway between two tabulated values, the smaller *D/t* should be used.
[C] Maximum 3 % deflection is recommended for rigid or semirigid linings such as cement mortar.
[D] Maximum 5 % deflection is recommended for flexible linings such as asphaltic and plastic.

7.3.4 The total calculated thickness of 0.35 in. is larger than 0.34 in., Class 150, in Table 2. Therefore, Class 200 is selected for specifying and ordering.

7.4 *Design Method:*

7.4.1 Calculations are made for the thicknesses required to resist the bending stress and the deflection caused by trench load. The larger of the two is selected as the thickness required to resist trench load.

7.4.2 To this net thickness is added a service allowance to obtain the minimum manufacturing thickness and a casting tolerance to obtain the total calculated thickness.

7.4.3 The thickness for specifying and ordering is selected from a table of standard pressure-class thicknesses. (Table 2)

7.4.4 The reverse of the above procedure is used to determine the maximum depth of cover for pipe of a given pressure-class.

7.4.5 *Trench Load, P_v*—Trench load is expressed as vertical pressure, psi, and is equal to the sum of earth load, P_e, and truck load, P_t.

7.4.6 *Earth Load, P_e*—Earth load is computed by Eq 3 for the weight of the unit prism of soil with a height equal to the distance from the top of the pipe to the ground surface. The unit weight of backfill soil is taken to be 120 lb/ft^3 (18.85 kN/m^3). If the designer anticipates additional loads, the design load should be increased accordingly.

7.4.7 *Truck Load, P_t*—The truck loads shown in Table 6 were computed by Eq 4 using the surface load factors in Table 1 and the reduction factors R from Table 4 for a single AASHTO H-20 truck on an unpaved road or flexible pavement, 16 000-lbf (71 kN) wheel load and 1.5 impact factor. The surface load factors in Table 1 were calculated by Eq 5 for a single concentrated wheel load centered over an effective pipe length of 3 ft (0.91 m).

7.4.8 *Design for Trench Load*—Tables 7-11, the diameter-thickness ratios tables used to design for trench load, were computed by Eqs 1 and Eqs 2. Equation 1 is based on the bending stress at the bottom of the pipe. The design bending stress, *f*, is 48 000 psi (331 MPa) which provides at least a 1.5 safety factor based on minimum ring yield strength and 2.0 safety factor based on ultimate strength. Equation 2 is based on the deflection of the pipe ring section. The design deflection Δ_x is 3 % of the outside diameter of the pipe for cement-lined pipe and 5 % for pipe with flexible linings. Design values of the trench parameters, E', K_b, and K_x are given in Table 3.

7.4.9 Tables similar to Tables 7-11 may be compiled for laying conditions other than those shown in this specification by calculating the trench loads, P_v, for a series of diameter-thickness ratios, D/t and D/t_1, using Eqs 1 and Eqs 2 with values of E', K_b, and K_x appropriate to the bedding and backfill conditions.

7.5 *Design Equations*:

$$P_v = \frac{f}{3\left(\frac{D}{t}\right)\left(\frac{D}{t}-1\right)\left[K_b - \frac{K_x}{\frac{8E}{E'\left(\frac{D}{t}-1\right)^3}+0.732}\right]} \quad (1)$$

$$P_v = \frac{\frac{\Delta X}{D}}{12K_x}\left[\frac{8E}{\left(\frac{D}{t_1}-1\right)^3}+.732\,E'\right] \quad (2)$$

$$P_e = \frac{wH}{a} \quad (3)$$

$$P_t = RF\frac{CP}{bD} \quad (4)$$

$$C = 1 - \frac{2}{3}\ \arcsin\left[H\sqrt{\frac{A^2+B^2+H^2}{(A^2+H^2)(H^2+B^2)}}\right] + \frac{2}{\pi}\left(\frac{A\cdot H\cdot B}{\sqrt{A^2+H^2+B^2}}\right)\left(\frac{1}{A^2+H^2}+\frac{1}{B^2+H^2}\right) \quad (5)$$

NOTE 4—In Eq 5, angles are in radians.

8. Hydrostatic Test

8.1 Each pipe shall be subjected to a hydrostatic test of not less than 500 psi (3.45 MPa). This test may be performed either before or after the outside coating and inside coating have been applied, but shall be performed before the application of cement-mortar lining or of a special lining.

8.2 The pipe shall be under the full test pressure for at least 10 s. Suitable controls and recording devices shall be provided so that the test pressure and duration are adequately ascertained. Any pipe that leaks or does not withstand the test pressure shall be rejected.

8.3 In addition to the hydrostatic test before application of a cement-mortar lining or special lining, the pipe may be retested, at the manufacturer's option, after the application of such a lining.

9. Acceptance Tests

9.1 The standard acceptance tests for the physical characteristics of the pipe shall be as follows:

9.2 *Tension Test*—Unless otherwise specified by the purchaser, a tension test specimen shall be cut longitudinally or circumferentially from the midsection of the pipe wall. In case of dispute, the test specimen shall be cut longitudinally. This specimen shall be machined and tested in accordance with Fig. 1 and Test Methods E 8. The yield strength shall be determined by the 0.2 % offset, halt-of-pointer, or extension-under-load methods. If check tests are to be made, the 0.2 % offset method shall be used. All specimens shall be tested at room temperature 70 ± 10°F (21 ± 6°C).

9.2.1 *Acceptable Values*—The acceptance values for test specimens shall be as follows:

Grade of Iron:	60–42–10
Minimum tensile strength, psi (MPa)	60 000 (413.7)
Minimum yield strength, psi (MPa):	42 000 (289.6)
Minimum elongation, %:	10

9.3 *Charpy Impact Test*—Tests shall be made in accordance with Test Methods E 23, except that dimensions of the specimens shall be 0.500 in. (12.70 mm) by full thickness of pipe wall. Unless otherwise specified by the purchaser, the Charpy notched impact test specimen shall be in accordance with Fig. 2 except that it may be cut circumferentially. In case of dispute, the specimen shall be cut in accordance with Fig. 2. If the pipe wall thickness exceeds 0.40 in. (10.2 mm), the Charpy impact specimen may be machined to a nominal thickness of 0.40 in. In all tests, impact values are to be corrected to a standard wall thickness, t_s = 0.40 in., by calculation as follows:

$$\text{Impact value (corrected)} = \frac{t_s}{t} \times \text{impact value (actual)}$$

where: t = the thickness of the specimen, in. (mm).

The Charpy impact test machine anvil shall not be moved to compensate for the variation of cross-section dimensions of the test specimens.

9.3.1 *Acceptance Value*—The corrected acceptance value for notched impact test specimens shall be a minimum of 7 ft·lbf (9.49 J) for tests conducted at 70 ± 10°F (21 ± 6°C).

9.4 *Sampling*— At least one tension sample shall be taken during each casting period of approximately 3 h. At least one 70 ± 10°F (21 ± 6°C) Charpy impact sample shall be taken during each operating hour. Samples shall be selected to properly represent extremes of pipe diameters and wall thicknesses.

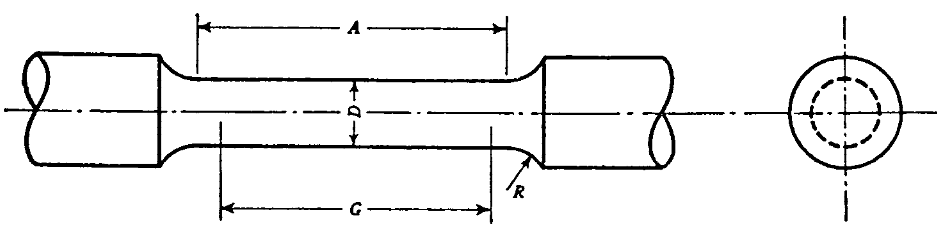
10. Additional Control Tests by Manufacturer

10.1 An additional low-temperature impact test shall be made from at least 10 % of the sample coupons taken for the required 70 ± 10°F (21 ± 6°C) Charpy impact test specified in 9.4 to check compliance with a minimum corrected value of 3

NOTE 1—The reduced section (*A*) may have a gradual taper from the ends toward the center with the ends not more than 0.005 in. [11] (0.13 min) larger in diameter than the center on the standard specimen and not more than 0.003 in. (0.08 mm) larger in diameter than the center on the small size specimens.

NOTE 2—If desired, on the small size specimens the length of the reduced section may be increased to accommodate an extensometer. However, reference marks for the measurement of elongation should nevertheless be spaced at the indicated gage length (*G*).

NOTE 3—The gage length and fillets shall be as shown, but the ends may be of any form to fit the holders of the testing machine in such a way that the load shall be axial. If the ends are to be held in grips it is desirable, if possible to make the length of the grip section great enough to allow the specimen to extend into the grips a distance equal to two thirds or more of the length of the grips.

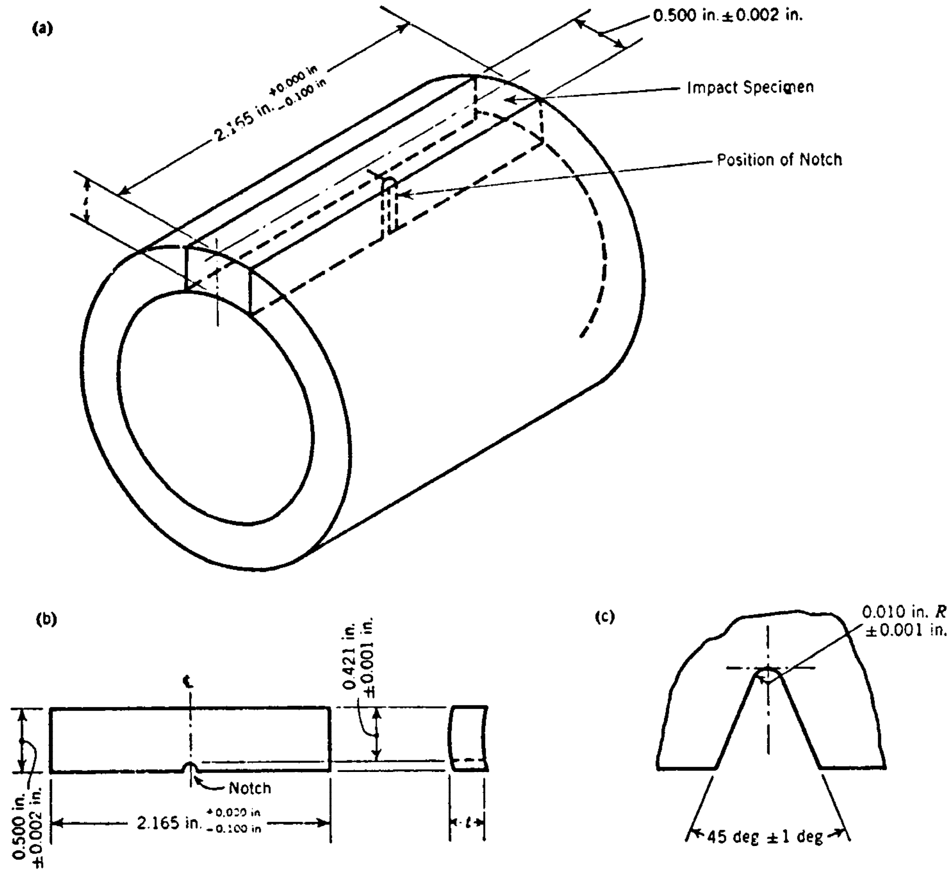


Dimension	Standard Specimen 0.50–in (12.7–mm) Round		0.350-in. (8.89-mm) Round		0.250-in. (6.35-mm) Round		0.175-in. (4.45-mm) Round		0.125-in. (3.18-mm) Round	
	Dimensions, in. (mm)									
G	2.000 ± 0.005	(50.80 ± 0.13)	1.400 ± 0.005	(35.56 ± 0.13)	1.000 ± 0.005	(25.40 ± 0.13)	0.700 ± 0.005	(12.78 ± 0.13)	0.500 ± 0.005	(12.70 ± 0.13)
D	0.500 ± 0.010	(12.70 ± 0.25)	0.350 ± 0.007	(8.89 ± 0.18)	0.250 ± 0.005	(6.35 ± 0.13)	0.175 ± 0.005	(4.44 ± 0.13)	0.125 ± 0.005	(3.18 ± 0.13)
R,min	3 / 8	(9.5)	1 / 4	(6.4)	3 / 16	(4.8)	3 / 32	(2.4)	3 / 32	(2.4)
A,min	2 1 / 4	(57.2)	1 3 / 4	(44.4)	1 1 / 4	(31.8)	3 / 4	(19)	5 / 8	(15.9)
T[A]	0.71 and greater	(18.0)	0.50 to 0.70	(12.2 to 17.8)	0.35 to 0.49	(8.9 to 12.4)	0.25 to 0.34	(6.4 to 8.6)	0.18 to 0.24	(4.6 to 6.1)

[A] Thickness of the section from the wall of the pipe from which the tension specimen is to be machined.

FIG. 1 Tension Test Specimen

NOTE 1—t = pipe-wall thickness.



Test Specimen Detail		Notch Detail	
in.	mm	in.	mm
−0.100	−2.54	0.100	2.54
+0.000	+0.00	0.421	10.69
0.001	0.03	0.500	12.70
0.002	0.05	2.165	54.99
0.010	0.25		

FIG. 2 Impact Test Specimen

ft·lbf (4 J) for tests conducted at −40°F ± 2°F (−40°C ± 1°C). Test specimens shall be prepared and tested in accordance with 9.3.

10.2 In addition, the manufacturer shall conduct such other tests as may be necessary to ensure compliance with this specification.

11. Additional Tests Required by Purchaser

11.1 When tests other than those required in this specification are required by the purchaser, such tests shall be specified in the purchaser's specifications.

12. Inspection and Certification by Manufacturer

12.1 The manufacturer shall establish the necessary quality-control and inspection practice to ensure compliance with this specification.

12.2 The manufacturer shall, if required on the purchaser's specifications, furnish a sworn statement that the inspection and all of the specified tests have been made and that all results thereof comply with the requirements of this specification.

12.3 All pipes shall be without defects that could impair service. Repairing of defects by welding or other methods shall not be allowed if such repairs could adversely affect the serviceability of the pipe or its capability to meet strength requirements of this specification.

13. Defective Specimens and Retests

13.1 When any mechanical test specimen shows defective machining or lack of continuity of metal, it shall be discarded and replaced by another specimen. When any sound test specimen fails to meet the specified mechanical property requirements, the lot of pipe from which the specimen was obtained shall be separated from acceptable pipe. The lot may be either retested, re-heat treated as necessary and retested, or rejected. A retest shall be made on two additional sound test specimens taken from the same lot as the specimen that failed. Pipe that are heat-treated, or retested, or both, shall meet the requirements of 5.1, 9, and 10.

14. Inspection by Purchaser

14.1 If the purchaser desires to inspect pipe at the manufacturer's plant, the purchaser shall so state in the purchaser's specifications and describe the conditions (such as time and the extent of inspection) under which the inspection shall be made.

14.2 The purchaser's representative shall have free access to those areas of the manufacturer's plant that are necessary to determine compliance with this specification. The manufacturer shall make available for the use of the purchaser's representative such gages as are necessary for inspection. The manufacturer shall provide the purchaser's representative with assistance as necessary for handling of pipe.

15. Delivery and Acceptance

15.1 All pipe and accessories shall comply with this specification. Pipe and accessories not complying with this specification shall be replaced by the manufacturer at the agreed point of delivery. The manufacturer shall not be liable for shortages or damaged pipe after acceptance at the agreed point of delivery, except as recorded on the delivery receipt or similar document by the carrier's agent. See Tables 12-14.

16. Foundry Records

16.1 The results of the acceptance tests (Section 9) and low-temperature impact tests (Section 10) shall be recorded and retained for 1 year, and shall be available to the purchaser at the foundry. Written transcripts shall be furnished, if required by the purchaser's specification.

17. Rejection of Pipe

17.1 If the results of any physical acceptance test fail to meet the requirements of Sections 9, 10, or 13, all pipe cast in the same period shall be rejected, except as provided in Section 18.

18. Determining Rejection

18.1 The manufacturer may determine the amount of pipe to be rejected by making similar additional tests of pipe, of the same size as the rejected pipe, until the rejected lot is bracketed, in order of manufacture, by an acceptable test at each end of the interval in question. When pipe of one size is rejected from a casting period, the acceptability of pipe of different sizes from that same period may be established by developing the acceptance tests for these sizes as specified in Section 9.

19. Marking Pipe

19.1 The weight, class, or nominal thickness, and casting period shall be shown on each pipe. The manufacturer's mark, the country where cast, the year in which the pipe was produced, and the letters "DI" or "DUCTILE" shall be cast or metal stamped on the pipe and letters and numbers on pipe sizes 14 in. (356 mm) and larger shall be not less than ½ in. (13 mm) in height. When required in the purchaser's specifications, initials not exceeding four in number shall be cast or stamped on the pipe. All required markings shall be clear and legible, and all cast or metal stamped marks shall be on or near the bell.

20. Weighing Pipe

20.1 Each pipe shall be weighed before the application of any lining or coating other than the asphaltic coating and the weight shown on the outside or inside of the bell or spigot end.

21. Keywords

21.1 ductile iron sewer pipe; elongation; laying conditions; mechanical properties; tensile strength; yield strength

TABLE 12 Pipe Selection Table (Cement-Lined Pipe)

NOTE 1—Ring deflection limited to 3 %, minimum safety factor of 2.
NOTE 2—Earth load (P_e) of 120 pcf.

Pipe Size, in.	Pressure Class	Nominal Thickness, in.	Laying Condition				
			Type 1	Type 2	Type 3	Type 4	Type 5
			Maximum Depth of Cover, ft[A]				
3	350	0.25	78	88	99	[B]	[B]
4	350	0.25	53	61	69	85	[B]
6	350	0.25	26	31	37	47	65
8	350	0.25	16	20	25	34	50
10	350	0.26	11[C]	15	19	28	45
12	350	0.28	10[C]	15	19	28	44
14	250	0.28	[D]	11[C]	15	23	36
	300	0.30		13	17	26	42
	350	0.31		14	19	27	44
16	250	0.30	[D]	11[C]	15	24	34
	300	0.32		13	17	26	39
	350	0.34		15	20	28	44
18	250	0.31	[D]	10[C]	14	22	31
	300	0.34		13	17	26	36
	350	0.36		15	19	28	41
20	250	0.33	[D]	10	14	22	30
	300	0.36		13	17	26	35
	350	0.38		15	19	28	38
24	200	0.33	[D]	8[C]	12	17	25
	250	0.37		11	15	20	29
	300	0.40		13	17	24	32
	350	0.43		15	19	28	37
30	150	0.34	[D]	. . .	9	14	22
	200	0.38		8[C]	12	16	24
	250	0.42		11	15	19	27
	300	0.45		12	16	21	29
	350	0.49		15	19	25	33
36	150	0.38	[D]	. . .	9	14	21
	200	0.42		8[C]	12	15	23
	250	0.47		10	14	18	25
	300	0.51		12	16	20	28
	350	0.56		15	19	24	32
42	150	0.41	[D]	. . .	9	13	20
	200	0.47		8	12	15	22
	250	0.52		10	14	17	25
	300	0.57		12	16	20	27
	350	0.63		15	19	23	32
48	150	0.46	[D]	. . .	9	13	20
	200	0.52		8	11	15	22
	250	0.58		10	13	17	24
	300	0.64		12	15	19	27
	350	0.70		15	18	22	30
54	150	0.51	[D]	. . .	9	13	20
	200	0.58		8	11	14	22
	250	0.65		10	13	16	24
	300	0.72		13	15	19	27
	350	0.79		15	18	22	30
60	150	0.54	[D]	5[C]	9	13	20
	200	0.61		8	11	14	22
	250	0.68		10	13	16	24
	300	0.76		13	15	19	26
	350	0.83		15	18	22	30
64	150	0.56	[D]	5[C]	9	13	20
	200	0.64		8	11	14	21
	250	0.72		10	13	16	24
	300	0.80		12	15	19	26
	350	0.87		15	17	21	29

[A] These pipes are adequate for depths of cover from 2.5 ft up to the maximum shown including an allowance for a single H-20 truck with 1.5 impact factor unless noted.
[B] Calculated maximum depth of cover exceeds 100 ft.
[C] Minimum allowable depth of cover is 3 ft.
[D] For pipe 14 in. and larger, consideration should be given to the use of laying conditions other than Type 1.

TABLE 13 Pipe Selection Table (Pipe with Flexible Lining)

NOTE 1—Examples of flexible linings include polyethylene, epoxy, asphaltic, etc.
NOTE 2—Ring deflection limited to 5 %, minimum safety factor of 2.
NOTE 3—Earth load (P_e) of 120 pcf.

Pipe Size, in.	Pressure Class	Nominal Thickness, in.	Laying Condition				
			Type 1	Type 2	Type 3	Type 4	Type 5
			Maximum Depth of Cover, ft[A]				
3	350	0.25	78	88	99	[B]	[B]
4	350	0.25	53	61	69	85	[B]
6	350	0.25	26	31	37	47	65
8	350	0.25	16	20	25	34	50
10	350	0.26	11[C]	15	19	28	45
12	350	0.28	10[C]	15	19	28	44
14	250	0.28	[D]	11[C]	15	23	41
	300	0.30		13	17	26	43
	350	0.31		14	19	27	44
16	250	0.30	[D]	11[C]	15	24	41
	300	0.32		13	17	26	43
	350	0.34		15	20	28	45
18	250	0.31	[D]	10 [C]	14	23	40
	300	0.34		13	17	26	43
	350	0.36		15	19	28	45
20	250	0.33	[D]	10	14	23	40
	300	0.36		13	17	26	43
	350	0.38		15	19	28	44
24	200	0.33	[D]	8[C]	12	20	37
	250	0.37		11	15	23	41
	300	0.40		13	17	26	43
	350	0.43		15	19	28	45
30	150	0.34	[D]	. . .	9	17	33
	200	0.38		8[C]	12	20	37
	250	0.42		11	15	23	40
	300	0.45		12	16	25	42
	350	0.49		15	19	28	44
36	150	0.38	[D]	. . .	9	17	33
	200	0.42		8[C]	12	20	37
	250	0.47		10	14	23	40
	300	0.51		12	17	25	42
	350	0.56		15	19	28	45
42	150	0.41	[D]	. . .	9	16	32
	200	0.47		8	12	20	37
	250	0.52		10	14	23	40
	300	0.57		12	17	25	42
	350	0.63		15	19	28	45
48	150	0.46	[D]	. . .	9	17	33
	200	0.52		8	12	20	37
	250	0.58		10	14	23	40
	300	0.64		12	17	25	42
	350	0.70		15	19	28	44
54	150	0.51	[D]	. . .	9	17	33
	200	0.58		8	12	20	37
	250	0.65		10	14	23	40
	300	0.72		13	17	25	43
	350	0.79		15	19	28	45
60	150	0.54	[D]	5[C]	9	17	33
	200	0.61		8	12	20	37
	250	0.68		10	14	23	40
	300	0.76		13	17	25	43
	350	0.83		15	19	28	45
64	150	0.56	[D]	5[C]	9	17	33
	200	0.64		8	12	20	36
	250	0.72		10	15	23	40
	300	0.80		13	17	26	43
	350	0.87		15	19	28	45

[A] These pipes are adequate for depths of cover from 2.5 ft up to the maximum shown including an allowance for a single H-20 truck with 1.5 impact factor unless noted.
[B] Calculated maximum depth of cover exceeds 100 ft.
[C] Minimum allowable depth of cover is 3 ft.
[D] For pipe 14 in. and larger, consideration should be given to the use of laying conditions other than Type 1.

TABLE 14 Standard Dimensions and Weights of Push-on Joint Ductile Iron Pipe

Pipe Size, in.	Pressure Class	Thickness, in.	OD,[A] in.	Weight of Barrel per ft, lb	Weight of Bell,[B] lb	18-ft Laying Length		20-ft Laying Length	
						Weight per Length,[C] lb	Average Weight per ft,[D] lb	Weight per Length,[C] lb	Average Weight per ft,[D] lb
3	350	0.25	3.96	8.9	7.0	165	9.3	185	9.2
4	350	0.25	4.80	10.9	9.0	205	11.4	225	11.3
6	350	0.25	6.90	16.0	11.0	300	16.6	330	16.6
8	350	0.25	9.05	21.1	17.0	395	22.0	440	22.0
10	350	0.26	11.10	27.1	24.0	510	28.4	565	28.3
12	350	0.28	13.20	34.8	29.0	655	36.4	725	36.3
14	250	0.28	15.30	40.4	45.0	770	42.9	855	42.7
	300	0.30	15.30	43.3	45.0	825	45.8	910	45.6
	350	0.31	15.30	44.7	45.0	850	47.2	940	47.0
16	250	0.30	17.40	49.3	54.0	940	52.3	1040	52.0
	300	0.32	17.40	52.5	54.0	1000	55.5	1105	55.2
	350	0.34	17.40	55.8	54.0	1060	58.8	1170	58.5
18	250	0.31	19.50	57.2	59.0	1090	60.5	1205	60.2
	300	0.34	19.50	62.6	59.0	1185	65.9	1310	65.6
	350	0.36	19.50	66.2	59.0	1250	69.5	1385	69.2
20	250	0.33	21.60	67.5	74.0	1290	71.6	1425	71.2
	300	0.36	21.60	73.5	74.0	1395	77.6	1545	77.2
	350	0.38	21.60	77.5	74.0	1470	81.6	1625	81.2
24	200	0.33	25.80	80.8	95.0	1550	86.1	1710	85.6
	250	0.37	25.80	90.5	95.0	1725	95.8	1905	95.3
	300	0.40	25.80	97.7	95.0	1855	103.0	2050	102.5
	350	0.43	25.80	104.9	95.0	1985	110.2	2195	109.7
30	150	0.34	32.00	103.5	139.0	2000	111.2	2210	110.5
	200	0.38	32.00	115.5	139.0	2220	123.2	2450	122.5
	250	0.42	32.00	127.5	139.0	2435	135.2	2690	134.5
	300	0.45	32.00	136.5	139.0	2595	144.2	2870	143.5
	350	0.49	32.00	148.4	139.0	2810	156.1	3105	155.3
36	150	0.38	38.30	138.5	184.0	2675	148.7	2955	147.7
	200	0.42	38.30	152.9	184.0	2935	163.1	3240	162.1
	250	0.47	38.30	170.9	184.0	3260	181.1	3600	180.1
	300	0.51	38.30	185.3	184.0	3520	195.5	3890	194.5
	350	0.56	38.30	203.2	184.0	3840	213.4	4250	212.4
42	150	0.41	44.50	173.8	289.0	3415	189.9	3765	188.3
	200	0.47	44.50	198.9	289.0	3870	215.0	4265	213.3
	250	0.52	44.50	219.9	289.0	4245	236.0	4685	234.3
	300	0.57	44.50	240.7	289.0	4620	256.8	5105	255.2
	350	0.63	44.50	265.7	289.0	5070	281.8	5605	280.2
48	150	0.46	50.80	222.6	354.0	. . .	. . .	4805	240.3
	200	0.52	50.80	251.3	354.0	. . .	. . .	5380	269.0
	250	0.58	50.80	280.0	354.0	. . .	. . .	5955	297.7
	300	0.64	50.80	308.6	354.0	. . .	. . .	6525	326.3
	350	0.70	50.80	337.1	354.0	. . .	. . .	7095	354.8
54	150	0.51	57.56	279.7	439.0	. . .	. . .	6035	301.7
	200	0.58	57.56	317.7	439.0	. . .	. . .	6795	339.7
	250	0.65	57.56	355.6	439.0	. . .	. . .	7550	377.5
	300	0.72	57.56	393.4	439.0	. . .	. . .	8305	415.3
	350	0.79	57.56	431.1	439.0	. . .	. . .	9060	453.1
60	150	0.54	61.61	317.0	588.0	. . .	. . .	6930	346.4
	200	0.61	61.61	357.7	588.0	. . .	. . .	7740	387.1
	250	0.68	61.61	398.3	588.0	. . .	. . .	8555	427.7
	300	0.76	61.61	444.6	588.0	. . .	. . .	9480	474.0
	350	0.83	61.61	485.0	588.0	. . .	. . .	10 290	514.4
64	150	0.56	65.67	350.5	670.0	. . .	. . .	7680	384.0
	200	0.64	65.67	400.1	670.0	. . .	. . .	8670	433.6
	250	0.72	65.67	449.6	670.0	. . .	. . .	9660	483.1
	300	0.80	65.67	496.9	670.0	. . .	. . .	10 650	532.4
	350	0.87	65.67	542.0	670.0	. . .	. . .	11 510	575.5

[A] Tolerance of OD of spigot end: 3–12 in., ±0.06 in.; 14–24 in., +0.05 in., −0.08 in.; 30–48 in., +0.08 in., −0.06 in.; 54–64 in., +0.04 in., −0.10 in.

[B] The bell weights shown above are adequate for 350-psi (2413-kPa) operating pressure. Bell weights vary due to differences in push-on-joint design. The manufacturer shall calculate pipe weights using standard barrel weights and weights of bells being produced.

[C] Including bell; calculated weight of pipe rounded off to nearest 5 lb.

[D] Including bell; average weight per foot based on calculated weight of pipe before rounding.

Designation: A 747/A747M – 99

Standard Specification for Steel Castings, Stainless, Precipitation Hardening[1]

This standard is issued under the fixed designation A 747/A747M; 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 iron-chromium-nickel-copper corrosion-resistant steel castings, capable of being strengthened by precipitation hardening heat treatment.

1.2 These castings may be used in services requiring corrosion resistance and high strengths at temperatures up to 600°F [315°C]. They may be machined in the solution-annealed condition and subsequently precipitation hardened to the desired high-strength mechanical properties specified in Table S14.1 with little danger of cracking or distortion.

1.3 The material is not intended for use in the solution-annealed condition.

NOTE 1—If the service environment in which the material is to be used is considered conducive to stress-corrosion cracking, precipitation hardening should be performed at a temperature that will minimize the susceptibility of the material to this type of attack.

1.4 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 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 370 Test Methods and Definitions for Mechanical Testing of Steel Products[2]

A 732/A732M Specification for Castings, Investment, Carbon and Low Alloy Steel for General Application, and Cobalt Alloy for High Strength at Elevated Temperatures[3]

A 781/A781M Specification for Castings, Steel and Alloy, Common Requirements, for General Industrial Use[3]

E 38 Methods for Chemical Analysis of Nickel-Chromium and Nickel-Chromium-Iron Alloys[4]

E 353 Test Methods for Chemical Analysis of Stainless, Heat-Resisting, Maraging, and Other Similar Chromium-Nickel-Iron Alloys[4]

2.2 *ASME Standard:*

ASME Boiler and Pressure Vessel Code, Supplementary Requirements S6, S14, and S27[5]

3. General Conditions for Delivery

3.1 Material furnished to this specification shall conform to the requirements of Specification A 781/A 781M, including any supplementary requirements that are indicated in the purchase order. Failure to comply with the general requirements of Specification A 781/A 781M constitutes nonconformance with this specification. In case of conflict between the requirements of this specification and Specification A 781/A 781M, this specification shall prevail.

4. Ordering Information

4.1 Orders for material to this specification should include the following:

4.1.1 Specification number and grade (Table 1),

4.1.2 Heat treatment condition (SA, H900, etc.), Table 2,

4.1.3 Drawing or pattern,

4.1.4 Options in the specification, if any, in accordance with 5.2, 6.3, and Section 7, and

4.1.5 Supplementary requirements, if any, including the standards of acceptance.

4.1.6 Notice when the castings are to be used in equipment covered by the ASME Boiler and Pressure Vessel Code, Supplementary Requirements S6, S14, and S27 are mandatory and must be specified in the purchase order.

5. Materials and Manufacture

5.1 The steel shall be made by the electric furnace process with or without separate refining such as argon-oxygen decarburization (AOD).

5.2 *Heat Treatment*—Castings may be given a homogenization heat treatment in accordance with 5.2.1 at the producer's option or when specified by the purchaser (see S26) prior to solution heat treatment. All castings, whether homogenized or

[1] This specification is under the jurisdiction of ASTM Committee A-1 on Steel, Stainless Steel, and Related Alloys and is the direct responsibility of Subcommittee A01.18 on Castings.

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[2] *Annual Book of ASTM Standards*, Vol 01.03.

[3] *Annual Book of ASTM Standards*, Vol 01.02.

[4] *Annual Book of ASTM Standards*, Vol 03.05.

[5] Available from American Society of Mechanical Engineers, 345 E. 47th St., New York, NY 10017.

TABLE 1 Chemical Requirements[A]

	CB7Cu-1	CB7Cu-2
Carbon	0.07	0.07
Manganese	0.70	0.70
Phosphorus	0.035	0.035
Sulfur	0.03	0.03
Silicon	1.00	1.00
Chromium	15.50–17.70	14.0–15.50
Nickel	3.60–4.60	4.50–5.50
Copper	2.50–3.20	2.50–3.20
Columbium	0.15–0.35[B]	0.15–0.35[B]
Nitrogen[C]	0.05	0.05

[A] Limits are percent maximum unless shown as a range or stated otherwise.
[B] See 6.2. When the H900 condition is ordered the minimum columbium content shall not apply.
[C] To be determined and reported when specified by the order or contract.

TABLE 2 Precipitation Hardening Heat Treatment[A,B]

Condition	PH[C] Temperature, °F[°C]	Time, h and min	Cooling Treatment
SA	Not precipitation hardened (see 5.2.3)		
H900	900 [480]	1.5	air cool
H925	925 [495]	1.5	air cool
H1025	1025 [550]	4.0	air cool
H1075	1075 [580]	4.0	air cool
H1100	1100 [595]	4.0	air cool
H1150	1150 [620]	4.0	air cool
H1150M	1400 [760]	2.0	air cool
	1150 [620]	4.0	air cool
H1150 DBL	1150 [620]	4.0	air cool
	1150 [620]	4.0	air cool

[A] The furnace and controls used shall be calibrated and capable of uniformity of heating in order to ensure consistent results.
[B] See Note.
[C] ± 25°F [15°C].

not, shall be given a solution treatment in accordance with 5.2.2 and unless ordered in the solution-annealed condition shall be precipitation hardened to the ordered condition (Table 2).

5.2.1 Homogenization heat treatment shall consist of heating the castings and test material to a minimum of 1900°F [1040°C], holding for a minimum of 1½h, and cooling to below 90°F [30°C].

5.2.2 Solution annealing heat treatment shall consist of heating the castings and test material to 1925°F [1050°C] ± 50°F [30°C], holding the 30 min/in. [1.2 min/mm] of section but not less than 30 min, and cooling to below 90°F [30°C].

5.2.3 Temperature used for precipitation hardening shall be maintained within the range of ± 25°F [± 15°C] of that listed in Table 2 for the heat treatment condition ordered. (See Note.)

5.2.4 When the order of contract specifies a minimum columbium content, the minimum precipitation hardening temperature shall be 925°F [495°C].

6. Chemical Composition

6.1 The steel shall conform to the requirements as to chemical composition prescribed in Table 1.

6.2 When the H900 condition is ordered, the minimum columbium content (Table 1) shall not apply. It is recommended that columbium other than that in revert material not be added.

6.3 *Methods of Analysis*—Analytical procedures for nitrogen analysis are not included in Methods E 38 or Test Methods E 353, so if the contract or order specifies that the nitrogen content is to be reported, the method of analysis shall be agreed upon by purchaser and producer.

7. Repair by Welding

7.1 Repairs shall be made only in one of the following conditions: homogenized, solution annealed, H1100, H1150, H1150M, H1150DBL, or stress relieved at 1150°F ± 25°F [620°C ± 15°C] for a minimum of 4 h.

7.2 Castings welded in one of the aged conditions noted in 7.1 shall be post weld heat treated by the same aging treatment used prior to welding, or, where necessary to meet mechanical property requirements, shall be solution annealed and aged after welding. Castings welded in the stress-relieved condition shall receive the specification heat-treatment after welding.

8. Keywords

8.1 steel castings; stainless steel; precipitation hardening stainless steel

SUPPLEMENTARY REQUIREMENTS

A list of standardized supplementary requirements for use at the option of the purchaser is described in Specification A 781/A 781M. Those that are considered suitable for use with this specification are listed below by title only. Additional supplementary requirements suitable for use with this specification at the option of the purchaser are described below. One or more of the supplementary requirements indicated below may be included in the purchaser's order or contract. When so included, a supplementary requirement shall have the same force as if it were in the body of the specification. Supplementary Requirements details not fully described shall be agreed upon between the purchaser and the supplier, but shall not negate any of the requirements in the body of the specification.

S1. Magnetic Particle Examination

NOTE —When CB7CU-1 alloy is inspected by magnetic particle method, false indications may be caused by ferrite stingers or traces of retained austenite in the microstructure. Liquid penetrant methods may be used to confirm the presence or absence of a discontinuity when such indications are noted.

S2. Radiographic Examination

S3. Liquid Penetrant Examination.

S5. Examination of Weld Preparation

S6. Certification

S13. Hardness Test

S13.1 Brinell hardness test shall be made from each heat treatment load for each heat. The results shall conform to the requirements in Table S14.1 and shall be reported to the purchaser or his representative.

S13.2 The test may be made on the end of the tension specimen unless the order requires it to be made on a casting, in which case, where possible, the test shall be made on a boss or extension located on the casting suitable for testing in the Brinell tester.

S13.3 The test shall be conducted in accordance with Test Methods and Definitions A 370.

S14. Tension Test

S14.1 Tensile properties shall be determined from material representing each heat. The bar from which the test specimen is taken shall be heat treated with production castings to the same procedure as the castings it represents, unless the castings are ordered in the solution-annealed condition (5.2.2). The results shall conform to the requirements specified in Table S14.1 and shall be reported to the purchaser or his representative.

S14.2 When the contract or order specifies that the castings are to be furnished in the solution annealed condition, the manufacturer shall test specimens representing the castings which have been given the precipitation heat treatment specified by the purchaser in accordance with Table 2.

TABLE S14.1 Mechanical Properties

Alloy Type	PH Heat Treatment	Hardness, HB	Yield Strength 0.2 % Offset, min, ksi [MPa]	Tensile Strength, ksi [MPa]	Elongation in 2 in. [51 mm], min, %[A]
CB7Cu-1	H900	375 min	145 [1000]	170 [1170]	5
	H925	375 min	150 [1035]	175 [1205]	5
	H1025	311 min	140 [965]	150 [1035]	9
	H1075	277 min	115 [795]	145 [1000]	9
	H1100	269 min	110 [760]	135 [930]	9
	H1150	269 min	97 [670]	125 [860]	10
	H1150M	310 max	...	...	...
	H1150 DBL	310 max	...	...	...
CB7Cu-2	H900	375 min	145 [1000]	170 [1170]	5
	H925	375 min	150 [1035]	175 [1205]	5
	H1025	311 min	140 [965]	150 [1035]	9
	H1075	277 min	115 [795]	145 [1000]	9
	H1100	269 min	110 [760]	135 [930]	9
	H1150	269 min	97 [670]	125 [860]	10
	H1150M	310 max	...	...	...
	H1150 DBL	310 max	...	...	...

[A] If sub-size tension test bars are used, the gage length/gage diameter ratio must be 4 to 1 to assure elongation values comparable to those of the standard test specimen.

S14.3 Test coupons and tests shall be made in accordance with Test Methods and Definitions A 370. Where possible, the standard 2-in. [50-mm] gage length specimens shall be used, unless the purchase order is for investment castings. Standard subsize specimens may be used when a 2-in. gage length specimen is not feasible. When subsize specimens are used, the gage length shall be four times the gage diameter. When investment castings are ordered, the specimens shall be prepared in accordance with S3.2 of Specification A 732/A 732M.

S14.4 If any test specimen shows defective machining or develops flaws, it may be discarded and another specimen substituted from the same lot. A retest shall be allowed if the percentage elongation of any tension test specimen is less than that specified in Table S14.1, or if any part of the fracture is more than 3/4 in. [19 mm] from the center of a standard 2-in. [50-mm] gage length established by scribe scratches on the untested specimen.

S26. Homogenization Heat Treatment

S26.1 The homogenization heat treatment shall consist of heating the castings and test material to a minimum of 1900°F [1040°C], holding for a minimum of 1 1/2 h, and cooling to below 90°F [30°C].

S27. Product Marking

S27.1 The manufacturer's name or identification mark and the pattern number shall be cast or stamped on all castings except those of such small size as to make such marking impractical. To minimize small defects caused by dislodged particles of molding sand, the number of cast identification marks should be minimized. When further specified, the heat numbers shall be marked on individual castings.

S27.2 When the castings are too small to mark individually, a symbol traceable to the lot shall be placed on the castings and the required identification then placed on a tag affixed to the container in which these castings are shipped.

Designation: A 748/A 748M – 87 (Reapproved 2003)

Standard Specification for Statically Cast Chilled White Iron-Gray Iron Dual Metal Rolls for Pressure Vessel Use[1]

This standard is issued under the fixed designation A 748/A 748M; 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 statically cast dual metal rolls with the outer layer of the roll body being chilled white iron of different chemical composition than the core and journals of the roll which is gray cast iron. The castings are suitable for pressure containing parts, the design strength of which is based on the gray iron portion of the cylinder. The castings are suitable for service at temperatures up to 450°F [232°C].

1.2 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 must be used independent of the other. Combining values from the two systems may result in nonconformance with the specification.

1.3 The following safety hazards statement pertains only to the test method portion, 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 278 Specification for Gray Iron Castings for Pressure-Containing Parts for Temperatures Up to 650°F (350°C)[2]

A 278M Specification for Gray Iron Castings for Pressure-Containing Parts for Temperatures Up to 345°C [Metric][3]

A 667/A667M Specification for Centrifugally Cast Dual Metal (Gray and White Cast Iron) Cylinders[2]

3. Ordering Information

3.1 Orders for material under this specification shall include the following information:

3.1.1 ASTM designation and year of issue,

3.1.2 Dimensions of dual rolls,

3.1.3 Class of gray iron in the roll core (see 4.2),

3.1.4 Inspection requirements, if different (see 10.1),

3.1.5 Certification, if required (see 11.1), and

3.1.6 Special position of marking information, if required (see 12.1).

3.2 Any additional requirements not covered in this specification are subject to agreement between the manufacturer and purchaser.

4. Materials and Manufacture

4.1 The melting procedure shall be optional with the foundry.

4.2 The chilled white iron exterior of the roll body shall be made to a minimum hardness of 60 Scleroscope "C". The gray iron portion of the roll shall conform to the applicable class of Specifications A 278 and A 278M, as determined by design requirements. The scope of this specification shall include Nos. 20, 25, 30, and 35 of Specification A 278 [Nos. 150, 175, 200, and 250 of Specification A 278M].

4.3 The casting process shall be controlled to produce a metallurgical bond between the chilled white iron exterior and gray iron interior of the roll body.

5. Test Requirements

5.1 *Tensile Requirements*—Tensile bars removed from a prolongation at one end of the roll journal, in accordance with Specifications A 278 and A 278M, shall have a tensile strength not less than 80 % of that specified by the applicable class of Specifications A 278 and A 278M.

5.2 *Thickness of Chilled White Iron*:

5.2.1 The thickness of the clear chilled white iron plus the mottled iron at the roll face shall not be more than 30 % of the total finished wall thickness.

[1] This specification is under the jurisdiction of ASTM Committee A04 on Iron Castings and is the direct responsibility of Subcommittee A04.01 on Grey and White Iron Castings.

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[2] *Annual Book of ASTM Standards*, Vol 01.02.

[3] Discontinued. Replaced by A 278/A 278M. See 2000 *Annual Book of ASTM Standards*, Vol 01.02.

5.2.2 The thickness of the chilled white iron exterior of the roll body shall be determined by measuring the chill depth at the ends of the roll face.

6. Finish

6.1 All surfaces shall be machined or ground, or both, prior to the rolls being placed into service.

7. Number of Tests

7.1 The number of tension tests shall be in accordance with Specifications A 278 and A 278M.

8. Specimen Preparation

8.1 Test bars representing the gray iron portion of the roll shall be made from a prolongation at one end of the roll journal in accordance with Specifications A 278 and A 278M. Tension test specimens machined from this prolongation shall conform to the dimensions shown for Specimen "C" in Specifications A 278 and A 278M.

9. Test Method

9.1 Tension test specimens shall fit the holders of the testing machine in such a way that the load shall be axial. The use of self-aligning shackles is suggested. After reaching a stress equivalent to 15 000 psi [100 MPa], the speed of the moving head of the testing machine shall not exceed ⅛ in. [3.2 mm]/min.

10. Inspection

10.1 The inspector representing the purchaser shall have free 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 manufacturer 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 tests and inspections shall be made at the place of manufacture prior to the shipment, and shall be so conducted as not to interfere unnecessarily with the operation of the works.

11. Acceptance and Certification

11.1 Final acceptance of the casting shall follow complete machining of the casting. Upon request of the purchaser and when so specified in the purchase order, a certification shall be made on the basis of acceptance of the material. This shall consist of a copy of the manufacturer's test report or a statement by the supplier, accompanied by a copy of the test results, that the material has been sampled, tested, and inspected in accordance with the provisions of this specification. Each certification so furnished shall be signed by an authorized agent of the supplier or manufacturer.

12. Product Marking

12.1 Pressure-containing castings made in accordance with this specification shall have the name of the manufacturer or his recognized trademark and the class of iron to which it conforms, cast or indelibly stamped on the surface indicated by the purchaser or in such a position as not to injure the usefulness of the casting.

Standard Specification for Steel Castings, Ferritic and Martensitic, for Pressure-Containing and Other Applications, for Low-Temperature Service[1]

This standard is issued under the fixed designation A 757/A757M; 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 carbon and alloy steel castings for pressure-containing and other applications intended primarily for petroleum and gas pipelines in areas subject to low-ambient temperatures. Castings shall be heat treated by normalizing and tempering or liquid quenching and tempering. All classes are weldable under proper conditions. Hardenability of some grades may limit usable section size.

1.2 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 must be used independently of the other. Combining values from the two systems may result in nonconformance with the specification. Inch-pound units are applicable for material ordered to Specification A 757 and SI units for material ordered to Specification A 757M.

2. Referenced Documents

2.1 *ASTM Standards:*

A 370 Test Methods and Definitions for Mechanical Testing of Steel Products[2]

A 488/A488M Practice for Steel Castings, Welding, Qualifications of Procedures and Personnel[3]

A 703/A703M Specification for Steel Castings, General Requirements, for Pressure-Containing Parts[3]

A 919 Terminology Relating to Heat Treatment of Metals[3]

E 29 Practice for Using Significant Digits in Test Data to Determine Conformance with Specifications[4]

E 30 Test Methods for Chemical Analysis of Steel, Cast Iron, Open-Hearth Iron, and Wrought Iron[5]

E 38 Methods for Chemical Analysis of Nickel-Chromium and Nickel-Chromium-Iron Alloys[5]

E 94 Guide for Radiographic Testing[6]

E 125 Reference Photographs for Magnetic Particle Indications on Ferrous Castings[6]

E 142 Method for Controlling Quality of Radiographic Testing[6]

E 165 Test Method for Liquid Penetrant Examination[6]

E 186 Reference Radiographs for Heavy-Walled (2 to 4 1/2 -in. (51 to 114-mm)) Steel Castings[6]

E 208 Test Method for Conducting Drop-Weight Test to Determine Nil-Ductility Transition Temperature of Ferritic Steels[7]

E 280 Reference Radiographs for Heavy-Walled (4 1/2 to 12-in. (114 to 305-mm)) Steel Castings[6]

E 350 Test Methods for Chemical Analysis of Carbon Steel, Low-Alloy Steel, Silicon Electrical Steel, Ingot Iron, and Wrought Iron[5]

E 353 Test Methods for Chemical Analysis of Stainless, Heat-Resisting, Maraging, and Other Similar Chromium-Nickel-Iron Alloys[5]

E 390 Reference Radiographs for Steel Fusion Welds[6]

E 446 Reference Radiographs for Steel Castings up to 2 in. (51 mm) in Thickness[6]

E 709 Guide for Magnetic Particle Examination[6]

2.2 *American Society of Mechanical Engineers:*

ASME Boiler and Pressure Vessel Code[8]

2.3 *Manufacturers Standardization Society of the Valve and Fittings Industry Standards:*

MSS SP-53 Quality Standard for Steel Castings for Valves, Flanges and Fittings, and Other Piping Components (Dry Powder Magnetic Particle Inspection Method)[9]

MSS SP-54 Quality Standard for Steel Casting for Valves, Flanges and Fittings, and Other Piping Components (Radiographic Inspection Method)[9]

MSS SP-55 Quality Standard for Steel Castings for Valves, Flanges and Fittings, and Other Piping Components (Visual Method)[9]

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[1] This specification is under the jurisdiction of ASTM Committee A-1 on Steel, Stainless Steel, and Related Alloys and is the direct responsibility of Subcommittee A01.18 on Castings.

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[2] *Annual Book of ASTM Standards*, Vol 01.03.

[3] *Annual Book of ASTM Standards*, Vol 01.02.

[4] *Annual Book of ASTM Standards*, Vol 14.02.

[5] *Annual Book of ASTM Standards*, Vol 03.05.

[6] *Annual Book of ASTM Standards*, Vol 03.03.

[7] *Annual Book of ASTM Standards*, Vol 03.01.

[8] Available from the American Society of Mechanical Engineers, 345 E. 47th St., New York, NY 10017.

[9] Available from the Manufacturers' Standardization Society of the Valve and Fittings Industry, 127 Park St., North East Vienna, VA 22180.

3. Terminology

3.1 *Definitions:*

3.1.1 Definitions in Test Methods and Definitions A 370 and Terminology A 919 are applicable to this specification.

3.1.2 Definition of nominal thickness, *T*, applies to quenched and tempered castings with a thickness exceeding 2 in. [50 mm]. Nominal thickness, *T*, is the maximum thickness of the pressure-containing wall of the casting exclusive of padding added for directional solidification, flanges, appendages, and sections designated by the designer as noncritical.

4. Ordering Information

4.1 Orders for material to this specification should include the following, as required, to describe the material adequately:

4.1.1 Description of the casting by pattern number or drawing (dimensional tolerances shall be included on the casting drawing),

4.1.2 Grade,

4.1.3 Options in the specification,

4.1.4 Detailed drawing including areas that are suitable for marking, the proposed nondestructive testing techniques and areas to be so tested, and the test dimension, *T* (see 3.1.2), and

4.1.5 Supplementary requirements desired, if any, including standards of acceptance.

5. Materials and Manufacture

5.1 *Melting Process*—The steel shall be made by the electric furnace process or other primary processes approved by the purchaser. The primary melting may incorporate separate degassing or refining and may be followed by secondary melting.

5.2 *Heat Treatment*:

5.2.1 All castings shall be heat treated by either normalizing and tempering or quenching and tempering. Tempering temperature shall be 1100°F [595°C] minimum, except grades B4N and B4Q, which shall be tempered at 1050°F [565°C] minimum.

5.2.2 E3N castings shall be heat-treated by heating to 1850°F [1010°C] minimum, and air cooling to 200°F [95°C] maximum before any optional intermediate temper, but shall cool to 100°F [40°C] maximum before the final temper, which shall be between 1050 and 1150°F [565 and 620°C].

5.2.3 Furnace temperatures for heat treating shall be controlled by pyrometers.

5.2.4 Castings shall be allowed to cool below the transformation range directly after pouring and solidification before they are reheated for normalizing or liquid quenching.

6. Chemical Composition

6.1 *Heat Analysis*—An analysis of each heat shall be made by the manufacturer to determine the percentages of the elements specified in Table 1. The analysis shall be made from a test sample preferably taken during the pouring of the heat. When drillings are used, they shall be taken not less than ¼ in. [6.4 mm] beneath the surface. The chemical composition thus determined shall be reported to the purchaser or his representative, and shall conform to the requirements specified in Table 1 for the grade being poured.

6.2 *Product Analysis*—A product analysis may be made by the purchaser from material representing each heat, lot, or casting. The analysis shall be made on representative material. Due to the possibility of decarburization, samples for carbon analysis shall be taken no closer than ¼ in. [6.4 mm] to a cast surface, except that castings too thin for this shall be analyzed

TABLE 1 Chemical Requirements (Maximum Percent Unless Range is Given)

Grade	A1Q	A2Q	B2N B2Q	B3N B3Q	B4N B4Q	C1Q	D1N1 D1Q1 D1N2 D1Q2 D1N3 D1Q3	E1Q	E2N, E2Q	E3N
Type	Carbon	Carbon-Manganese	2 ½Nickel	3½ Nickel	4½Nickel	Nickel Molybdenum	Chromium Molybdenum	Nickel Chromium Molybdenum	Nickel Chromium Molybdenum	Martensitic Chromium Nickel
Carbon	0.30	0.25^{A}	0.25	0.15	0.15	0.25	0.20	0.22	0.20	0.06
Manganese	1.00	1.20^{A}	0.50/0.80	0.50/0.80	0.50/0.80	1.20	0.40/0.80	0.50/0.80	0.40/0.70	1.00
Phosphorus	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.020	0.030
Sulfur	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.020	0.030
Silicon	0.60	0.60	0.60	0.60	0.60	0.60	0.60	0.60	0.60	1.00
Nickel	—	—	2.0/3.0	3.0/4.0	4.0/5.0	1.5/2.0	—	2.5/3.5	2.75/3.90	3.5/4.5
Chromium	—	—	—	—	—	—	2.0/2.75	1.35/1.85	1.50/2.0	11.5/14.0
Molybdenum	—	—	—	—	—	0.15/0.30	0.90/1.20	0.35/0.60	0.40/0.60	0.40/1.0
Specified Residual Elements:										
Vanadium	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	—
Copper	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50
Nickel	0.50	0.50	—	—	—	—	0.50	—	—	—
Chromium	0.40	0.40	0.40	0.40	0.40	0.40	—	—	—	—
Molybdenum	0.25	0.25	0.25	0.25	0.25	—	—	—	—	—
Tungsten	—	—	—	—	—	—	0.10	—	0.10	0.10
Total residuals (maximum %)^{B}	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.70	0.70	0.50

^{A}For each 0.01 % of reduction in carbon below the maximum specified, an increase of 0.04 % manganese over the maximum specified will be permitted up to 1.40 %.

^{B}Total residuals includes phosphorus and sulfur.

on representative material. When a product analysis is performed, the chemical composition thus determined may vary from the specified limits in Table 1 by the amounts shown in Table 2. When the analysis exceeds the permitted variance specified in Table 2, the material shall be subject to rejection by the purchaser.

6.3 *Referee Analysis*—Test Methods E 350 or Test Methods E 353 shall be used for referee purposes. Test Methods E 30 or E 38 shall be used if Test Methods E 350 or Test Methods E 353 do not include a method for some element present in the material. When a comparison is made between the heat analysis and the referee analysis, the reproducibility data, R 2, in the precision statement of Test Methods E 350 or Test Methods E 353 shall be used as a guide.

6.4 *Rounding*—Chemical analysis results shall be rounded, in accordance with Practice E 29, to the nearest unit in the last right-hand place of values in the table of chemical requirements.

7. Tensile Requirements

7.1 One tension test shall be made from each heat. The mechanical properties thus determined shall conform to the requirements specified in Table 3. The bar from which the tension specimen is machined shall be in accordance with Section 12.

TABLE 2 Product Analysis Tolerances

Element	Range,[A] %	Tolerances[B,C] Over Maximum or Under Minimum Limit, %
C	up to 0.65	0.03 × % C_L+ 0.02
	above 0.65	0.04
Mn	up to 1	0.08 × % Mn_L+ 0.01
	above 1	0.09
Si	up to 0.60	0.22 × % Si_L− 0.01
	above 0.60	0.15
P	all	0.13 × % P_L+ 0.005
S	all	0.36 × % S_L+ 0.001
Ni	up to 2	0.10 × % Ni_L+ 0.03
	above 2	0.25
Cr	up to 2	0.07 × % Cr_L+ 0.04
	above 2	0.18
Mo	up to 0.6	0.04 × % Mo_L+ 0.03
	above 0.6	0.06
V	up to 0.25	0.23 × % V_L+ 0.004
	above 0.25	0.06
W	up to 0.10	0.08 × % W_L+ 0.02
	above 0.10	0.02
Cu	up to 0.15	0.18 × % Cu_L+ 0.02
	above 0.15	0.05
A1	up to 0.10	0.08 × % Al_L+ 0.02
	above 0.10	0.03

[A]The range denotes the composition limits up to which tolerances are computed by the equation and above which the tolerances are given by a constant.

[B]The subscript *L* for the elements in each equation indicates that the limits of the element specified by the applicable specification are to be inserted into the equation to calculate the tolerance for the upper limit and the lower limit (if applicable), respectively. Examples of computing tolerances are presented in the Footnote *C* below.

[C]To illustrate, consider the manganese limits 0.50 to 0.80 % of E 1Q. According to Table 4, the maximum permissible deviation of a product analysis below the lower limit 0.50 is 0.05 % = (0.08 × 0.50 + 0.01). The lowest acceptable product analysis of E 1Q, therefore, is 0.45 %. Similarly, the maximum permissible deviation above the upper limit of 0.80 % is 0.074 % = (0.08 × 0.80 + 0.01). The highest acceptable product analysis of E 1Q, therefore, is 0.874 %. For A 2Q, the maximum manganese content is 1.40 % if the carbon content is 0.20 % or lower. In this case, the highest acceptable product analysis is 1.49 % = (1.40 + 0.09).

7.2 Tension test specimens shall be machined to the form and dimensions shown in Fig. 2 of Test Methods and Definitions A 370 and tested in accordance with Test Methods and Definitions A 370.

7.3 If a specimen is machined improperly or flaws are revealed, the specimen may be discarded and another substituted from the same heat.

7.4 To determine conformance with the tension test requirements, an observed value or calculated value shall be rounded off in accordance with Practice E 29 to the nearest 500 psi [5 MPa] for yield and tensile strengths and to the nearest 1 % for elongation and reduction of area.

8. Impact Requirements

8.1 Impact properties shall be determined on each heat by testing a set of three Charpy V-notch specimens. The bar from which the impact specimens are machined shall be prepared in accordance with Section 12. The longitudinal axis of the Charpy specimens shall be parallel to the longitudinal axis of the tensile bar. Testing shall be in accordance with Test Methods and Definitions A 370 using the Charpy V-notch Type A specimen.

8.2 Test temperature and absorbed energy requirements for the grade shall be as specified in Table 4, except for those grades that have no values specified, in which case, impact energy values and test temperatures shall be agreed upon between the manufacturer and the purchaser. The average energy value of three specimens shall not be less than the minimum average specified, with only one value permitted below the minimum average specified and this value not permitted to fall below the minimum specified for a single specimen. Supplementary Requirement S8 may be specified if lateral expansion or percent shear area, or both, are desired by the purchaser.

8.3 Impact properties shall also be determined on both the heat-affected zone of the base metal and the weld metal of the welding procedure qualification test. Test temperature, energy absorption, specimen type, and test method shall be the same as specified for the base material.

8.3.1 *Coupons Representing the Weld Deposits*—Impact specimens shall be located so that the longitudinal axis of the specimen is at least one fourth of the thickness of the weld test plate, *t*, from the surface of the test assembly and is transverse to the longitudinal axis of the weld with the area of the notch located in the weld metal. The length of the notch of the Charpy specimen shall be normal to the surface of the weld (see Fig. 1).

8.3.2 *Coupons Representing the Heat-Affected Zone*:

8.3.2.1 Impact specimens in test plate thicknesses greater than ⅝ in. [16 mm] shall be from coupons removed from a location as near as practical to a point midway between the surface and center thickness. Heat-affected zone coupons for impact specimens shall be taken transverse to the weld and etched to define the heat-affected zone. The notch shall be cut normal to the material surface in the heat-affected zone to include as much heat-affected zone as possible in the resulting fracture (see Fig. 2).

TABLE 3 Tensile Requirements

Grade	Heat Treatment[A,B]	Tensile Strength,[C] min, ksi [MPa]	Yield Strength (0.2 % offset), min, ksi [MPa]	Elongation in 2 in. [50 mm], min, %	Reduction of Area, min, %
A1Q	QT	65 [450]	35 [240]	24	35
A2Q	QT	70 [485]	40 [275]	22	35
B2N, B2Q	NT/QT[D]	70 [485]	40 [275]	24	35
B3N, B3Q	NT/QT	70 [485]	40 [275]	24	35
B4N, B4Q	NT/QT	70 [485]	40 [275]	24	35
C1Q	QT	75 [515]	55 [380]	22	35
D1N1, D1Q1	NT/QT	85 [585] 115 [795]	55 [380]	20	35
D1N2, D1Q2	NT/QT	95 [655] 125 [860]	75 [515]	18	35
D1N3, D1Q3	NT/QT	105 [725] 135 [930]	85 [585]	15	30
E1Q	QT	90 [620]	65 [450]	22	40
E2N1, E2Q1	NT/QT	90 [620] 120 [825]	70 [485]	18	35
E2N2, E2Q2	NT/QT	105 [725] 135 [930]	85 [585]	15	30
E2N3, E2Q3	NT/QT	115 [795] 145 [1000]	100 [690]	13	30
E3N	NT	110 [760]	80 [550]	15	35

[A]QT = Quenched and tempered.
[B]NT = Normalized and tempered.
[C] Minimum ksi (MPa), unless range is given.
[D]NT/QT indicates that either a normalized and tempered or quenched and tempered heat treatment may be used.

TABLE 4 Charpy V-Notch Energy Requirements for Standard Size (10 mm by 10 mm) Specimens[A]

Grade	Heat Treatment[B,C]	Effective Section Size, max, in. [mm]	Test Temperature		Energy value, ft·lbf [J], min value for two specimens and min average of three specimens	Energy Value, ft·lbf [J], min for single specimen
			°F	[°C]		
A1Q	QT	1 1/4 [32]	−50	[−46]	13 [17]	10 [14]
A2Q	QT	3 [75]	−50	[−46]	15 [20]	12 [16]
B2N, B2Q	NT/QT[D]	5 [125]	−100	[−73]	15 [20]	12 [16]
B3N, B3Q	NT/QT	1 1/4 [32]	−150	[−101]	15 [20]	12 [16]
B4N, B4Q	NT/QT	1 1/4 [32]	−175	[−115]	15 [20]	12 [16]
C1Q	QT	5 [125]	−50	[−46]	15 [20]	12 [16]
D1N1, D 1Q1	NT/QT	[E]	[E]	[E]	[E]	[E]
D1N2, D 1Q2	NT/QT	[E]	[E]	[E]	[E]	[E]
D1N3, D 1Q3	NT/QT	[E]	[E]	[E]	[E]	[E]
E1Q	QT	[E]	−100	[−73]	30 [41]	25 [34]
E2N1, E 2Q1	NT-QT	5 [125]	−100	[−73]	30 [41]	25 [34]
E2N2, E 2Q2	NT-QT	1 1/4 [32]	−100	[−73]	20 [27]	15 [20]
E2N3, E 2Q3	NT/QT	1 1/4 [32]	−100	[−73]	15 [20]	12 [16]
E3N	NT	1 1/4 [32]	−100	[−73]	20 [27]	15 [20]

[A]Hardenability and residual elements (primarily P & S levels) in some of the grades may limit the maximum section size in which these impact values can be obtained.
[B]QT = Quenched and tempered.
[C]NT = Normalized and tempered.
[D]NT/QT indicates that either a normalized and tempered or quenched and tempered heat treatment may be used.
[E]Requirements shall be subject to agreement between the manufacturer and the purchaser.

8.3.2.2 Where the material thickness permits, the axis of a specimen may be inclined to allow the root of the notch to align parallel to the fusion line (see Fig. 2).

8.4 Test temperature and impact values for section thickness in excess of those specified in Table 4 may be agreed upon between the manufacturer and the purchaser, in which case, Supplementary Requirement S 22 shall be specified. Castings shall be marked with this test temperature in accordance with 17.2.

9. Workmanship, Finish, and Appearance

9.1 Castings shall conform to the shapes, tolerances, and sizes indicated by patterns or drawings submitted by the purchaser.

10. Quality

10.1 The surface of the casting shall be examined visually and shall be free of adhering sand, scale, cracks, and hot tears. Other surface discontinuities shall meet the visual acceptance standards specified in the order. Visual Method MSS SP-55 or other visual standards may be used to define acceptable surface discontinuities and finish. Unacceptable visual surface discontinuities shall be removed and their removal verified by visual examination of the resultant cavities. When methods involving high temperatures are used in the removal of discontinuities, the casting shall be preheated to at least the minimum temperatures in Table 5.

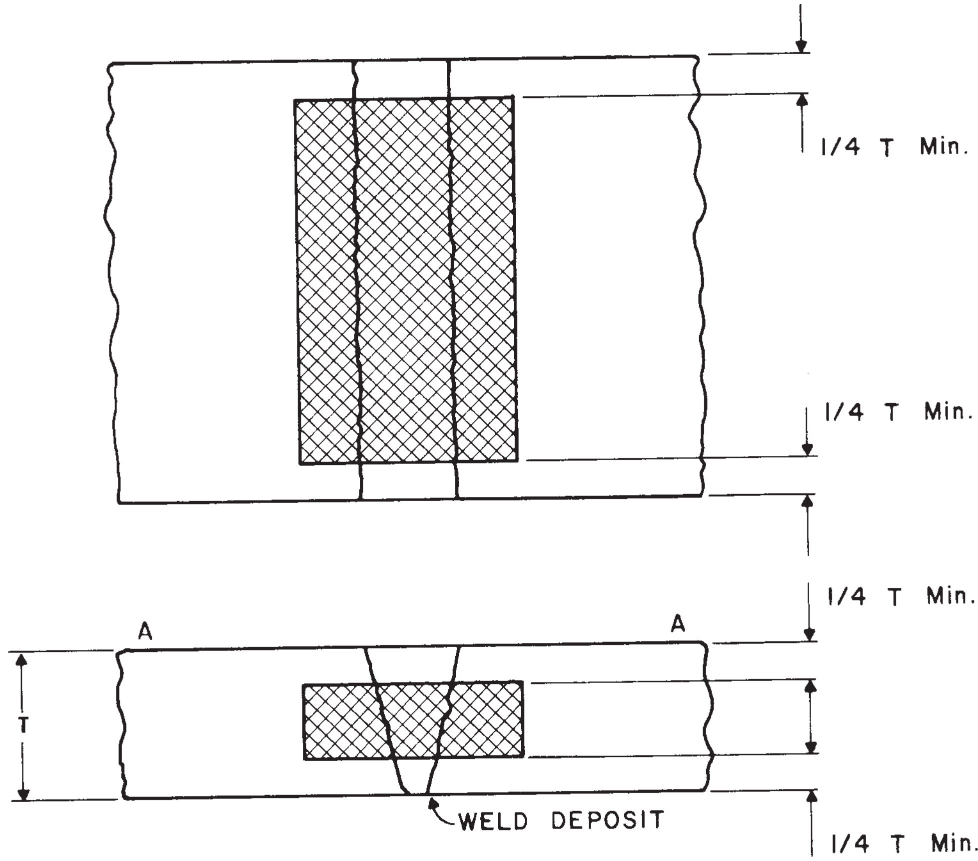

FIG. 1 Charpy V-Notch Specimen Must Be Within Cross-Hatched Zone With Notch in the Weld Metal Perpendicular to Surface A-A

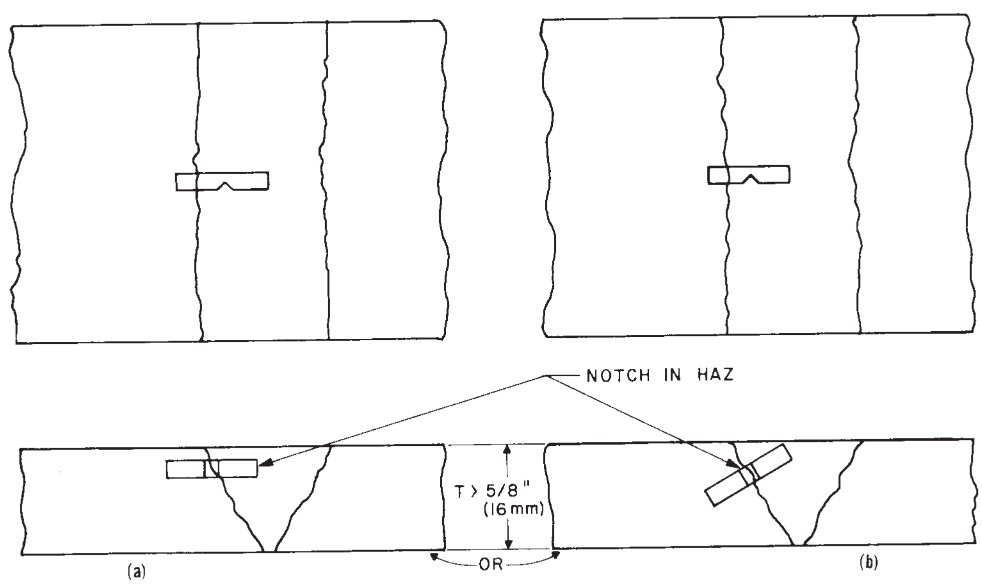

FIG. 2 Location of Notch in Charpy Specimens Shall Be In HAZ Midway Between Center and Surface

10.2 When additional inspection is desired, Supplementary Requirements, S4, S5, and S10 may be ordered.

11. Retests

11.1 If the results of the mechanical tests for any heat, lot, or casting do not conform to the requirements specified, retests are permitted as outlined in Test Methods and Definitions A 370. At the manufacturer's option, castings may be reheat-treated and retested. When castings are reheat-treated, they may not be reaustenitized more than three times without the approval of the purchaser. Testing after reheat treatment shall

TABLE 5 Minimum Preheat Temperatures

Grade	Minimum Preheat Temperature	
	°F	[°C]
A1Q	50	[10]
A2Q	50	[10]
B2N, B 2Q	300	[150]
B3N, B 3Q	300	[150]
B4N, B 4Q	300	[150]
C1Q	300	[150]
D1N, D 1Q	400	[200]
E1Q	300	[150]
E2N, E 2Q	400	[200]
E3N	50	[10]

consist of the full number of specimens taken from locations complying with the specification or order.

12. Test Coupons and Specimen Location

12.1 Test blocks may be cast integrally with the casting or as separate blocks. Test coupons shall be heat treated in production furnaces to the same procedure as the castings they represent.

12.2 *Normalized and Tempered Castings*— Test blocks shall be similar to those shown in Fig. 2 and Table 2 in Specification A 703/A 703M.

12.3 *Quenched and Tempered Castings T ≤ 2 in.* [*50 mm*]—Requirements in 12.2apply.

12.4 *Quenched and Tempered Castings T > 2 in.* [*350 mm*]—Requirements of 12.2 may be applied when agreed upon between the manufacturer and the purchaser, in place of 12.4.1, 12.4.2, 12.4.3, and 12.4.4, one of which otherwise shall apply.

12.4.1 The longitudinal centerline of the tensile test specimen shall be taken at least ¼*T* from the *T* dimension surface and all of the gage length must be at least 1*T* from any other heat-treated surface, exclusive of the surface opposite the *T* dimension surface. For cylindrical castings, the longitudinal centerline of the specimens shall be taken at least ¼*T* from the outside or inside and all of the gage length must be at least *T* from the as-heat-treated end (see Fig. 3).

12.4.2 Where separately cast test coupons are used, the dimension shall not be less than 3*T* by 3 *T* by *T* and each specimen shall meet the requirements of 12.4.1. The test coupon shall be of the same heat of steel and shall receive substantially the same casting practices as the production casting it represents. Centrifugal castings may be represented by statically cast coupons (see Fig. 4).

12.4.3 Where specimens are to be removed from the body of the casting, either the requirements of 12.4.1 shall be met or a steel thermal buffer pad or thermal insulation or other thermal barriers shall be used during heat treatment. Steel thermal buffer pad shall be a minimum of *T* by *T* by 3 *T* in length and shall be joined to the casting surface by a partial penetration weld completely sealing the buffered surface. Test specimens shall be removed from the casting in a location adjacent to the center third of the buffer pad. They shall be located at a minimum distance of ½in. [13 mm] from the buffered surface and ¼*T* from other heat-treated surfaces (see Fig. 5). When thermal insulation is used, it shall be applied adjacent to the casting surface where the test specimens are to be removed. The producer shall demonstrate that the cooling rate of the test specimen location is no faster than that of specimens taken by the method described in 12.4.1.

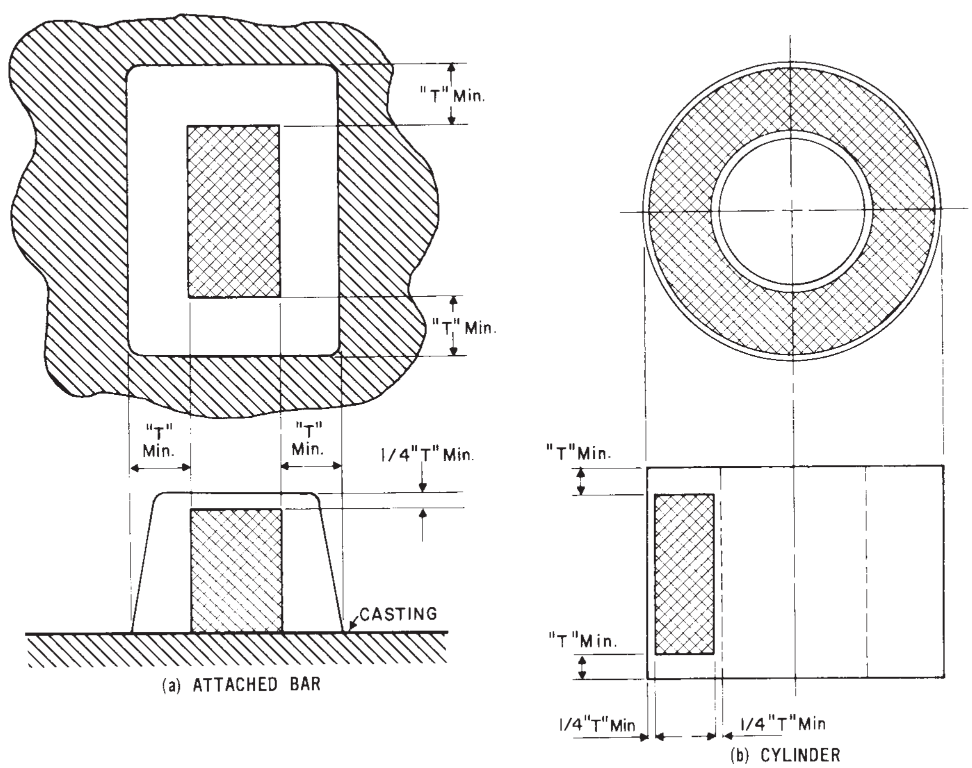

FIG. 3 Longitudinal Axis and Gage Length of Test Specimen Must Be Within Cross-Hatched Zone

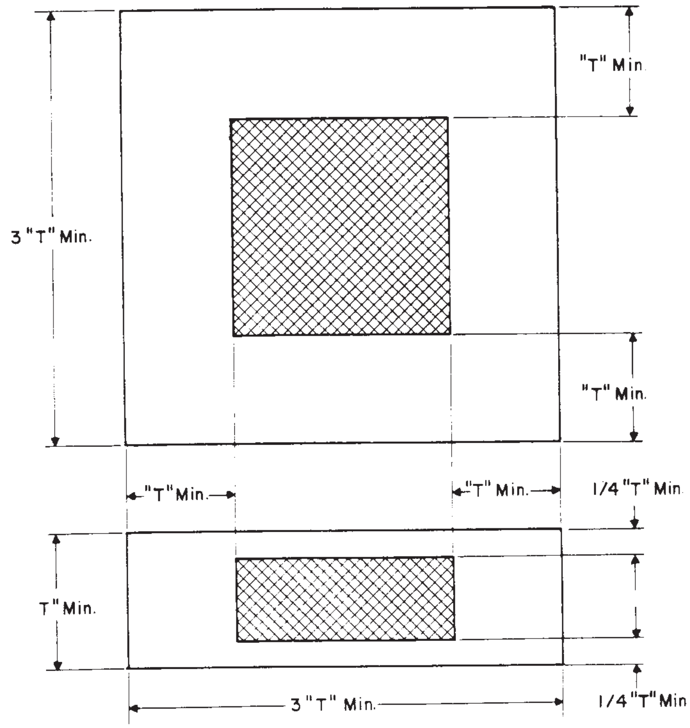

FIG. 4 Longitudinal Axis and Gage Length of Test Specimen Must Be Within Cross-Hatched Zone

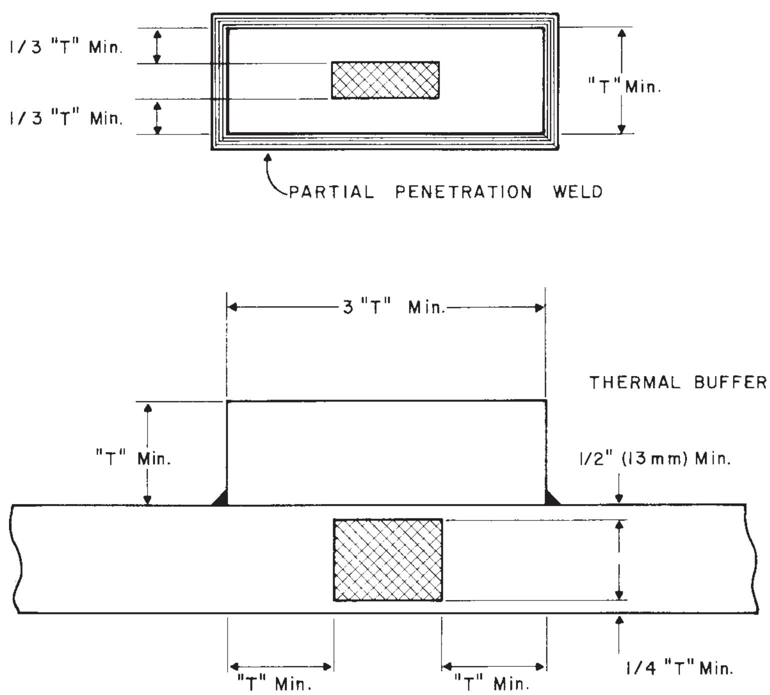

FIG. 5 Thermal Buffer Pads—Longitudinal Axis and Gage Length of Test Specimen Must be Within Cross-Hatched Zone

12.4.4 *Test Specimens From Castings*—When agreed upon by the manufacturer and the purchaser, castings that are cast or machined to essentially the finished configuration prior to heat treatment shall have test specimens removed from a prolongation or other stock on the casting at a location below the nearest heat-treated surface indicated on the order. The specimen location shall be at a distance below the nearest heat-treated surface equivalent to at least the greatest distance that the indicated high-tensile-stress surface will be from the nearest heat-treated surface and a minimum of twice this distance from a second heat-treated surface, except that the test specimens shall be no nearer than ¾in. [19 mm] to a heat-treated surface and 1½ in. [38 mm] from a second heat-treated surface (see Fig. 6).

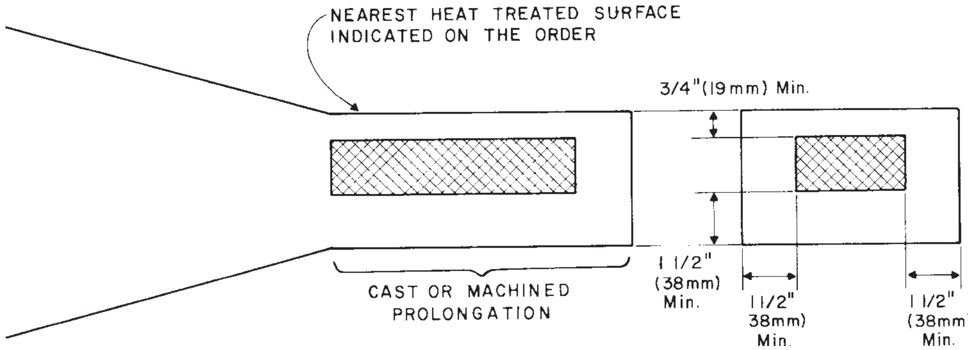

FIG. 6 Prolongation Test Specimen—Longitudinal Axis and Gage Length of Test Specimen Must Be Within Cross-Hatched Zone

13. Hydrostatic Tests for Pressure-Containing Castings

13.1 After machining, each pressure-containing casting shall be tested by the organization specified and to the test pressure requirements specified on the drawing or the purchase order and shall not leak.

13.2 It is realized that the foundry may be unable to perform the hydrostatic test prior to shipment, or that the purchaser may wish to defer testing until additional work or machining has been performed on the casting. Castings ordered in the rough state for final machining by the purchaser may be tested hydrostatically prior to shipment by the manufacturer at pressures to be agreed upon with the purchaser. However, the foundry is responsible for the satisfactory performance of the castings under the final test required in 13.1.

14. Repair by Welding

14.1 *Qualification*—Repairs shall be made using procedures and welders qualified under Practice A 488/A 488M or in accordance with the ASME Boiler and Pressure Vessel Code, Section IX.

14.2 *Inspection*—Weld repairs shall be inspected to the same quality standards as used to inspect the casting, except when radiography (see Supplementary Requirement S 5) is specified in the order for the original casting. Radiography of weld repairs shall be performed only for the examination of major repairs (see 14.3).

14.3 *Major Weld Repairs*—Weld repairs shall be considered major when the depth of the cavity prepared for welding exceeds 20 % of the wall thickness or 1 in. [25 mm] whichever is smaller, or when the extent of cavity exceeds approximately 10 in. [65 cm], or when a pressure-containing casting leaks on hydrostatic test.

14.4 *Postweld Heat Treatment*—All castings with repair welds shall be thermally stress relieved or reheat-treated completely in accordance with 5.2 and the welding procedure qualification used.

15. Inspection

15.1 The manufacturer shall afford the purchaser's inspector all reasonable facilities necessary to satisfy that the material is being produced and furnished in accordance with this specification. Foundry inspection by the purchaser shall not interfere unnecessarily with the manufacturer's operations. All tests and inspections, with the exception of product analysis and hydrostatic tests, shall be made at the place of manufacture unless otherwise agreed.

16. Rejection and Rehearing

16.1 Any rejection based on the manufacturer's test report or product analysis shall be reported to the manufacturer within 30 days from receipt of the test reports by the purchaser.

16.2 Castings that show unacceptable discontinuities subsequent to their acceptance at the manufacturer's works will be rejected, and the manufacturer shall be notified within 30 days after discovery of the rejectable condition.

16.3 Product analysis samples (6.2) representing material that does not comply with this specification shall be held for two weeks from the date of transmission of the test report. In case of dissatisfaction with the results of the tests, the manufacturer may claim for a rehearing within that time.

17. Product Marking

17.1 Castings shall be marked with the manufacturer's name or identification mark, and for material identification with the grade symbol, that is, A1Q, B2N, C1Q, etc. If stamped, low-stress stamps shall be used on a raised pad. A heat number, or a serial number that is traceable to the heat number, shall be marked individually on all castings weighing 50 lb [25 kg] or more. Castings weighing less than 50 lb shall be marked with either the heat number or a lot number that will identify the casting as to the month in which it was poured. When lot number identification is used, test reports shall show both the heat number and the lot number, and shall carry a certification that castings marked with the lot number meet all the requirements of the specification. Marking shall be in such positions as not to injure the usefulness of the casting.

17.2 Marking shall also include the test temperature, if it is other than the standard test temperature or if no test temperature is specified in Table 4. A prefix O to the test temperature shall indicate a less than 0° value.

18. Keywords

18.1 alloy steel; carbon steel; ferritic; low temperature service; martensitic stainless steel; pressure containing; stainless steel; steel castings

SUPPLEMENTARY REQUIREMENTS

Supplementary requirements shall be applied when specified by the purchaser. Details of these supplementary requirements shall be agreed upon between the manufacturer and the purchaser. The specified tests shall be made by the manufacturer before shipment of the castings.

S1. Unspecified Elements

S1.1 Limits may be established for elements not specified for the grade ordered by agreement between the manufacturer and the purchaser. The results of the analysis for the agreed-upon elements shall be reported.

S4. Magnetic Particle Examination

S4.1 Castings shall be examined for surface and near surface discontinuities by magnetic particle test method. The examination shall be in accordance with Guide E 709, and the types and degrees of discontinuities considered may be judged by Reference Photographs E 125. The extent of examination and the basis for acceptance shall be agreed upon. A specification that may be used as a basis for such agreement is MSS SP-53.

S5. Radiographic Examination

S5.1 Castings shall be examined for internal defects by means of X rays or gamma rays. The procedure shall be in accordance with Guide E 94 and Method E 142, and the types and degrees of discontinuities considered may be judged by the Reference Radiographs E 446, E 186, or E 280, except that repair welds shall be judged by Reference Radiographs E 390. The extent of coverage and the basis for acceptance shall be agreed upon. A specification that may be used as a basis for such agreement is MSS SP-54.

S5.2 Radiography may be performed prior to heat treatment and shall be performed at the stage of manufacture defined in this subparagraph.

S5.3 Castings may be radiographed prior to finish machining at limiting thickness as follows: thicknesses less than 6 in. [150 mm] shall be radiographed within 20 % of the finished thickness, and thicknesses 6 in. [150 mm] and over shall be radiographed within 10 % of the finished thickness. Penetrameters shall be based on final thickness.

S5.4 Radiographic examination of castings for pumps and valves may be performed in the as-cast or rough-machined thickness as follows; for thicknesses over 2 in. [50 mm], acceptance shall be based on Reference Radiographs for the next lesser thickness range (for example, if the section being radiographed exceeds 4½ in. [114 mm] use Reference Radiographs E 186). The penetrameters shall be based on the thickness of the section being radiographed. For thicknesses 2 in. [50 mm] or less, Reference Radiographs E 446 shall be used with penetrameters based on the final section thickness.

S5.5 Weld ends for a minimum distance of t or ½ in. [13 mm], whichever is more (where t is the design section thickness of the weld), from the final welding end shall be radiographed at a thickness within the limits given in S 5.3. As an alternative, the weld ends may be radiographed in the as-cast or rough-machined thickness in accordance with S 5.4. Penetrameters shall be based on the final section thickness.

S8. Lateral Expansion and Percent Shear Area

S8.1 The test temperature, specimen location, and method of testing shall be as stated in Section 8.

S8.2 *Lateral Expansion:*

S8.2.1 Lateral expansion shall be determined and reported for information, if no minimum is specified.

S8.2.2 The lateral expansion value shall be agreed upon. The value determined shall meet the specified value and shall be reported to the purchaser.

S8.3 *Percent Shear Area:*

S8.3.1 Percent shear area shall be determined and reported for information, if no minimum is specified.

S8.3.2 The percent shear area value shall be agreed upon. The value determined shall meet the specified value and shall be reported to the purchaser.

S9. Drop Weight Test

S9.1 Drop weight test properties shall be determined from each heat by preparing and testing either Type P1, P2, or P3 specimens in accordance with Test Method E 208. The crack starter weld shall be deposited on the specimen surface that was nearest to and less than ½in. [13 mm] from the as-cast surface. Each test shall consist of at least two specimens tested at a temperature agreed upon. Each specimen shall exhibit a "no break" performance.

S10. Examination of Weld Preparation

S10.1 Magnetic particle or liquid penetrant examination of the cavities prepared for welding shall be performed to verify removal of those discontinuities found unacceptable by the inspection method specified for the casting. The method of performing magnetic particle or liquid penetrant examination shall be in accordance with Guide E 709 or Test Method E 165. Unless other degrees of shrinkage or types of discontinuities found in the cavities are specified, Type II, Internal Shrinkage, of Reference Photographs E 125, of Degree 2 in sections up to 2 in. [50 mm] thick and of Degree 3 in sections over 2 in. thick shall be acceptable.

S11. Certification

S11.1 The manufacturer's certification shall be furnished to the purchaser stating that the material was manufactured, sampled, tested, and inspected in accordance with the material specification (including year date) and was found to meet the requirements.

S11.2 The test report shall contain the results of the actual chemical analysis, tension and impact tests, and other tests ordered by the purchaser.

S11.3 The test report shall be signed by an authorized agent of the seller or manufacturer.

S11.4 The test report shall be furnished within five working days of shipment of the castings.

S12. Prior Approval of Major Weld Repairs

S12.1 Major weld repairs shall be subject to the prior approval of the purchaser.

S13. Hardness Test

S13.1 Hardness measurements at specified locations of the castings shall be made in accordance with Test Methods and Definitions A 370 and reported.

S14. Tension Test from Each Heat and Heat Treatment Charge

S14.1 One tension test shall be made for each heat and heat treatment charge.

S15. Heat Treatment Furnace Records

S15.1 Heat treatment furnace records showing a plot of time and temperature shall be submitted to the purchaser.

S17. Tension Test from Castings

S17.1 This supplementary requirement is intended where heavy section properties are to be guaranteed. In addition to the tensile test required in Section 7, test material shall be cut from heat treated castings instead of test coupons. The mechanical properties and location for the test material shall be agreed upon.

S18. Heat Treatment

S18.1 Test specimens shall be heat treated together with the castings they represent. Heat-treated specimens shall be tested and shall meet the tensile and impact properties specified.

S18.2 The remaining test specimens from S 18.1 representing the casting shall be treated thermally after the final (foundry) heat treatment to simulate heat treatments below the critical temperature which the casting may receive during fabrication, and then tested for mechanical properties. Time, temperature, and cooling rate shall be as stated in the order. In the case of post-weld heat treatment, the total time at temperature or temperatures for the test material shall be at least 80 % of the total time at temperature or temperatures during actual postweld heat treatment of the fabrication of which the casting or castings are a part. The total time at temperature or temperatures for the test material may be performed in a single cycle. When this supplementary requirement is specified, the welding qualification test metal must be processed in the same manner.

S20. Magnetic Particle Inspection after Liquid Quench

S20.1 Castings that are liquid quenched shall be examined by magnetic particle inspection for quench cracks. Examination shall be in accordance with Supplementary Requirement S 4.

S22. Charpy Impact Test

S22.1 Impact properties at temperatures other than specified in Table 3, or impact properties for grades that do not have specified test temperatures or impact values, shall be determined on each heat by testing a set of three Charpy V-notch specimens. It is preferable to select temperatures in 25°F [14°C] increments with standard test temperatures being −25°F, −50°F, −75°F, and −100°F [−32°C, −46°C, −59°C, and −73°C], etc.

S22.2 All requirements specified in Section 8 shall apply, including impact requirements for welding procedure qualification test at the specified temperature. Castings shall be marked with the lowest test temperature at which the material met the impact requirements in accordance with Section 17.

S24. Welding Materials

S24.1 Each lot or batch of welding material used shall be tested and shall conform to the ultimate tensile strength and impact property requirements of the base material.

S24.2 Test specimens shall be prepared from locations in the test coupons prepared as required by Specifications SFA-5.1 or SFA-5.5, as applicable, of ASME, Section II, Part C. Test coupons shall be postweld heat treated in the same manner as required by the welding procedure. One all-weld-metal tensile test shall be made and shall meet the tensile strength requirements of the base material specification.

S24.3 When impact tests are required for the base material, all-weld-metal impact tests shall be made and the results shall meet the requirements of the base material. When five specimens are used, the average value shall be computed by discarding the extreme lowest value and extreme highest value.

S24.4 Tests performed on welding material in the qualification of weld procedures will satisfy the test requirements for the lot, heat, or combination of heat and batch of welding material used, provided the tests meet the requirements.

S28. Weld Charts

S28.1 Major weld repairs shall be documented by means of sketches showing location and extent of the weld. Documentation shall be submitted to the purchaser at the completion of the order.

INTERNATIONAL

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Standard Specification for Castings, Steel and Alloy, Common Requirements, for General Industrial Use[1]

This standard is issued under the fixed designation A 781/A 781M; 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 a group of requirements that are mandatory requirements of the following steel casting specifications issued by ASTM. If the product specification specifies different requirements, the product specification shall prevail.

ASTM Designation	Title of Specification
A 27/A 27M	Steel Castings, Carbon, for General Application
A 128/A 128M	Steel Castings, Austenitic Manganese
A 148/A 148M	Steel Castings, High-Strength, for Structural Purposes
A 297/A 297M	Steel Castings, Iron Chromium and Iron-Chromium-Nickel, Heat Resistant for General Application
A 447/A 447M	Steel Castings, Chromium-Nickel-Iron Alloy (25-12 Class), for High-Temperature Service
A 486/A 486M	Steel Castings, for Highway Bridges
A 494/A 494M	Castings, Nickel and Nickel Alloy
A 560/A 560M	Castings, Chromium-Nickel Alloy
A 743/A 743M	Castings, Iron-Chromium, Iron-Chromium-Nickel, Corrosion Resistant, for General Application
A 744/A 744M	Castings, Iron-Chromium-Nickel, Corrosion Resistant, for Severe Service
A 747/A 747M	Steel Castings, Stainless, Precipitation Hardening
A 890/A 890M	Castings, Iron-Chromium-Nickel-Molybdenum Corrosion-Resistant, Duplex (Austenitic/Ferritic) for General Application
A 915/A 915M	Steel Castings, Carbon and Alloy, Chemical Requirements Similar to Standard Wrought Grades
A 958	Steel Castings, Carbon and Alloy, with Tensile Requirements, Chemical Requirements Similiar to Standard Wrought Grades
A 1002	Castings, Nickel-Aluminum Ordered Alloy

1.2 This specification also covers a group of supplementary requirements that may be applied to the above specifications as indicated therein. These are provided for use when additional testing or inspection is desired and apply only when specified individually by the purchaser in the order.

1.3 The requirements of the individual material specification, and this general specification shall prevail in the sequence named.

1.4 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 must be used independently of the other. Combining values from the two systems may result in nonconformance with the specification. Inch-pound units are applicable for material ordered to Specification A 781 and SI units for material ordered to Specification A 781M.

[1] This specification is under the jurisdiction of ASTM Committee A01 on Steel, Stainless Steel and Related Alloys and is the direct responsibility of Subcommittee A01.18 on Castings.

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

2. Referenced Documents

2.1 *ASTM Standards:* [2]

A 27/A27M Specification for Steel Castings, Carbon, for General Application
A 128/A128M Specification for Steel Castings, Austenitic Manganese
A 148/A148M Specification for Steel Castings, High Strength, for Structural Purposes
A 297/A297M Specification for Steel Castings, Iron-Chromium and Iron-Chromium-Nickel, Heat Resistant, for General Application
A 370 Test Methods and Definitions for Mechanical Testing of Steel Products
A 380 Practice for Cleaning, Descaling, and Passivation of Stainless Steel Parts, Equipment, and Systems
A 447/A 447M Specification for Steel Castings, Chromium-Nickel-Iron Alloy (25-12 Class), for High-Temperature Service
A 486/A 486M Specification for Steel Castings for Highway Bridges[3]
A 488/A 488M Practice for Steel Castings, Welding, Qualifications of Procedures and Personnel
A 494/A 494M Specification for Castings, Nickel and Nickel Alloy
A 560/A 560M Specification for Castings, Chromium-Nickel Alloy
A 609/A 609M Practice for Castings, Carbon, Low-Alloy, and Martensitic Stainless Steel, Ultrasonic Examination Thereof
A 743/A 743M Specification for Castings, Iron-Chromium, Iron-Chromium-Nickel, Corrosion-Resistant, for General Application
A 744/A 744M Specification for Castings, Iron-Chromium-Nickel, Corrosion Resistant, for Severe Service
A 747/A 747M Specification for Steel Castings, Stainless, Precipitation Hardening
A 751 Test Methods, Practices, and Terminology for Chemical Analysis of Steel Products
A 800/A 800M Practice for Steel Castings, Austenitic Alloy, Estimating Ferrite Content Thereof
A 802/A 802M Practice for Steel Castings, Surface Acceptance Standards, Visual Examination
A 890/A 890M Specification for Castings, Iron-Chromium-Nickel-Molybdenum Corrosion-Resistant, Duplex (Austenitic/Ferritic) for General Application
A 915/A 915M Specification for Steel Castings, Carbon and Alloy, Chemical Requirements Similar to Standard Wrought Grades
A 941 Terminology Relating to Steel, Stainless Steel, Related Alloys, and Ferroalloys
A 958 Specification for Steel Castings, Carbon and Alloy, with Tensile Requirements, Chemical Requirements Similar to Standard Wrought Grades
A 967 Specification for Chemical Passivation Treatments for Stainless Steel Parts
A 991/A 991M Test Method for Conducting Temperature Uniformity Surveys of Furnaces Used to Heat Treat Steel Products
A 1002 Specification for Castings, Nickel-Aluminum Ordered Alloy
E 94 Guide for Radiographic Examination
E 125 Reference Photographs for Magnetic Particle Indications on Ferrous Castings
E 165 Test Method for Liquid Penetrant Examination
E 186 Reference Radiographs for Heavy-Walled (2 to 4½-in. (51 to 114-mm)) Steel Castings
E 280 Reference Radiographs for Heavy-Walled (4½ to 12-in. (114 to 305-mm)) Steel Castings
E 340 Test Method for Macroetching Metals and Alloys
E 353 Test Methods for Chemical Analysis of Stainless, Heat-Resisting, Maraging, and Other Similar Chromium-Nickel-Iron Alloys
E 354 Test Methods for Chemical Analysis of High-Temperature, Electrical, Magnetic, and Other Similar Iron, Nickel, and Cobalt Alloys
E 446 Reference Radiographs for Steel Castings Up to 2 in. (51 mm) in Thickness
E 709 Guide for Magnetic Particle Examination

3. Terminology

3.1 *Definitions:*

3.1.1 The definitions in Test Methods and Definitions A 370, Test Methods, Practices, and Terminology A 751, and Terminology A 941 are applicable to this specification and those listed in 1.1.

4. Materials and Manufacture

4.1 *Melting Process*—The steel shall be made by open-hearth or electric furnace process with or without separate refining such as argon-oxygen-decarburization (AOD) unless otherwise specified in the individual specification.

4.2 *Heat Treatment*

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[2] 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.

[3] Withdrawn.

4.2.1 Castings shall be heat treated in the working zone of a furnace that has been surveyed in accordance with Test Method A 991/A 991M.

4.2.2 When castings are heat treated at temperatures above 2000°F (1100°C), then the working zone shall have been established by a survey performed at not more than 25°F (15°C) below nor more than 200°F (110°C) above the minimum heat treatment temperature specified for the grade. If a minimum heat treatment temperature is not specified for the grade, then the survey temperature shall be not more than 50°F (30°C) below nor more than 175°F (100°C) above the furnace set point used.

4.2.3 The maximum variation in measured temperature as determined by the difference between the highest temperature and the lowest temperature shall be as agreed between the purchaser and producer except that during production heat treatment no portion of the furnace shall be below the minimum specified temperature nor above the maximum specified temperature for the grade being processed.

5. Chemical Composition

5.1 *Chemical Analysis*—Chemical analysis of materials covered by this specification shall be in accordance with Test Methods, Practices, and Terminology A 751.

5.2 *Heat Analysis*—An analysis of each heat shall be made by the manufacturer to determine the percentages of the elements specified in the individual specification for the grade being poured. The analysis shall be made from a test sample preferably taken during the pouring of the heat. When drillings are used, they shall be taken not less than ¼ in. [6.4 mm] beneath the surface. The chemical composition thus determined shall conform to the requirements in the individual specification for the grade being poured.

5.3 *Product Analysis*—A product analysis may be made by the purchaser from material representing each heat, lot, or casting. The analysis shall be made on representative material. Samples for carbon analysis of carbon and alloy steel shall be taken no closer than ¼ in. to a cast surface, except that castings too thin for this shall be analyzed on representative material. The chemical composition thus determined shall meet the requirements specified in the applicable specification for the grade involved, or shall be subject to rejection by the purchaser, except that the chemical composition determined for carbon and low alloy steel castings may vary from the specified limits by the amounts shown in Table 1. The product analysis tolerances of Table 1 are not applicable as acceptance criteria for heat analysis by the casting manufacturer. When comparing product and heat analysis for other than

TABLE 1 Product Analysis Tolerances

Element	Range, %[A]	Tolerances[B],[C] Over Maximum or Under Minimum Limit, %
C	up to 0.65	$0.03 \times \%\ C_L + 0.02$
	above 0.65	0.04
Mn	up to 1	$0.08 \times \%\ Mn_L + 0.01$
	above 1	0.09
Si	up to 0.60	$0.22 \times \%\ Si_L - 0.01$
	above 0.60	0.15
P	all	$0.13 \times \%\ P_L + 0.005$
S	all	$0.36 \times \%\ S_L + 0.001$
Ni	up to 2	$0.10 \times \%\ Ni_L + 0.03$
	above 2	0.25
Cr	up to 2	$0.07 \times \%\ Cr_L + 0.04$
	above 2	0.18
Mo	up to 0.6	$0.04 \times \%\ Mo_L + 0.03$
	above 0.6	0.06
V	up to 0.25	$0.23 \times \%\ V_L + 0.004$
	above 0.25	0.06
W	up to 0.10	$0.08 \times \%\ W_L + 0.02$
	above 0.10	0.02
Cu	up to 0.15	$0.18 \times \%\ Cu_L + 0.02$
	above 0.15	0.05
Al	up to 0.10	$0.08 \times \%\ Al_L + 0.02$
	above 0.10	0.03

[A] The range denotes the composition limits up to which tolerances are computed by the equation, and above which the tolerances are given by a constant.

[B] The subscript $_L$ for the elements in each equation indicates that the limits of the element specified by the applicable specification are to be inserted into the equation to calculate the tolerance for the upper limit and the lower limit (if applicable), respectively. Examples of computing tolerances are presented in footnote C.

[C] To illustrate the computation of the tolerance, consider the manganese maximum of 0.70 for an 0.30 carbon grade 65–35 in Specification A 27/A 27M. The maximum permissible deviation is $(0.08 \times 0.70 + 0.01) = 0.066$. Therefore, the highest acceptable product analysis is 0.766. Similarly, for an 0.20 carbon grade 70–40 in Specification A 27/A 27M, the maximum manganese content is 1.40; thus, the highest acceptable product analysis is $(1.40 + 0.09) = 1.49$.

carbon and low alloy steels, the reproducibility Data R_2, in Test Methods E 353 or E 354, as applicable, shall be taken into consideration.

5.4 *Unspecified Elements*—When chemical analysis for elements not specified for the grade ordered is desired, Supplementary Requirement S13 may be specified.

5.4.1 Grade substitution, for stainless steel or nickel base alloy castings, is not permitted. Grade substitution occurs when the material supplied:

(1) contains an element, other than nitrogen, that is not specified in the ordered grade; and,

(2) the amount of that element equals or exceeds the minimum requirement for the element in another grade for which it is specified.

For this requirement, a grade is defined as an alloy described individually in a table of chemical requirements within any specification listed within the scope of A 781/A 781M.

6. Mechanical Test Requirements

6.1 The individual product specifications vary as to whether mechanical tests are required; for this reason, and to determine specific test requirements, the individual product specification should be reviewed.

6.2 Unless otherwise specified by the purchaser, when mechanical properties are required by the product specification, test coupons may be cast integrally with the castings, or as separate blocks, in accordance with Fig. 1, Fig. 2, or Fig. 3 except when Supplementary Requirement S15 is specified. The test coupon in Fig. 3 shall be employed only for austenitic alloy castings with cross sections less than 2½ in.[4]

7. Workmanship, Finish, and Appearance

7.1 All castings shall be made in a workmanlike manner and shall conform to the dimensions on drawings furnished by the purchaser before manufacture is started. If the pattern is supplied by the purchaser, the dimensions of the casting shall be as predicated by the pattern.

8. Quality

8.1 The surface of the casting shall be free of adhering sand, scale, cracks, and hot tears as determined by visual examination. Other surface discontinuities shall meet the visual acceptance standards specified in the order. Practice A 802/A 802M or other visual standards may be used to define acceptable surface discontinuities and finish. Unacceptable visual surface discontinuities shall be removed and their removal verified by visual examination of the resultant cavities.

8.2 When additional inspection is desired, Supplementary Requirements S1, S2, S3, S4, or S5 may be specified.

8.3 The castings shall not be peened, plugged or impregnated.

9. Repair

9.1 Repair by welding shall be in accordance with the requirements of the individual specification using procedures and welders qualified in accordance with Practice A 488/A 488M.

10. Inspection

10.1 The manufacturer shall afford the purchaser's inspector all reasonable facilities necessary to satisfy that the material is being produced and furnished in accordance with the applicable specification. Foundry inspection by the purchaser shall not interfere unnecessarily with the manufacturer's operations. All tests and inspections, with the exception of product analysis (5.3), shall be made at the place of manufacture unless otherwise agreed.

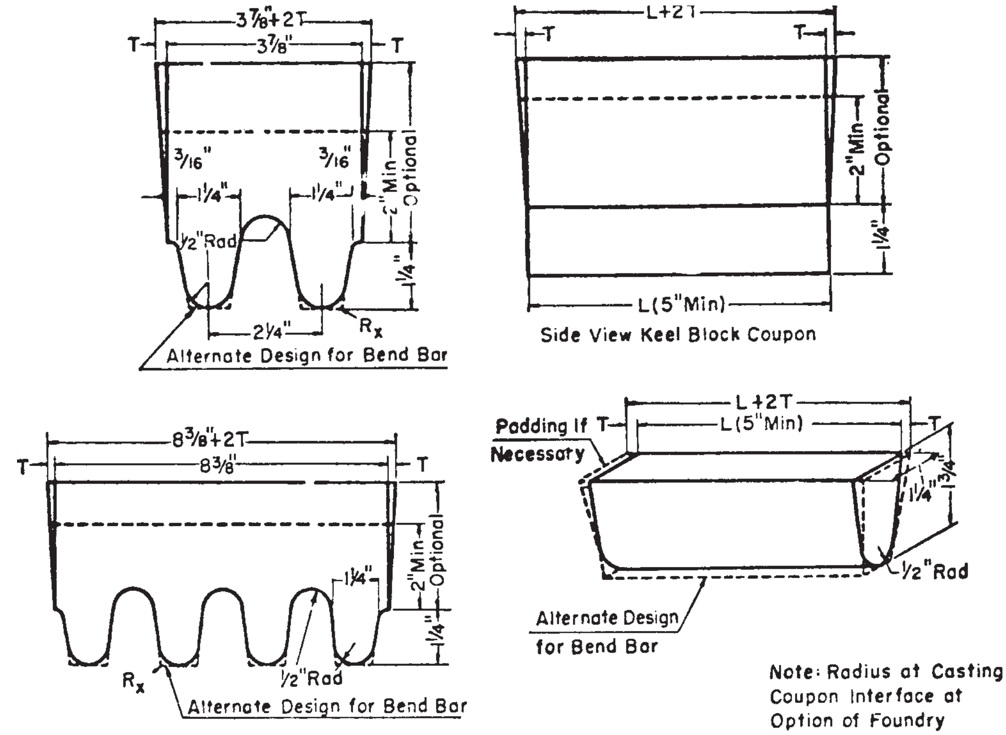
11. Rejection

11.1 Subsequent to acceptance at the manufacturer's works, material which is found to be unacceptable as determined by requirements specified in the order may be rejected by the purchaser. The manufacturer should be notified of such rejection. If the manufacturer is dissatisfied with the results of any tests performed by the purchaser, he may make claim for a rehearing.

12. Keywords

12.1 castings; common requirements; steel and alloy

[4] Information on the relationship of mechanical properties determined on test coupons obtained as specified in 6.2 with those obtained from the casting may be found in "The Steel Casting Handbook," Fifth Edition, Steel Founders' Society of America, pp. 15–35 through 15–43, 1980.



Metric Equivalents

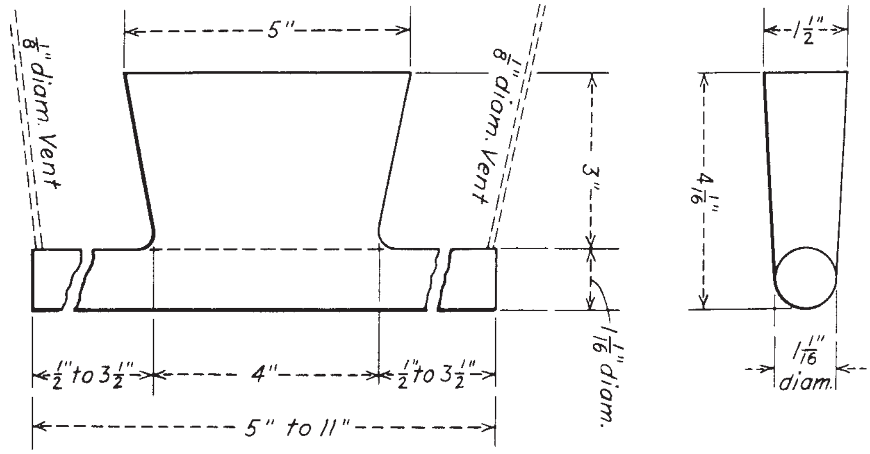
in.	3/16	½	1¼	1¾	2	2¼	3⅞	5	8⅜
[mm]	[4.8]	[13]	[32]	[45]	[51]	[57]	[98]	[127]	[213]

	Leg Design [125 mm]		Riser Design
1. *L* (length)	A 5 in. [125 mm] minimum length will be used. This length may be increased at the option of the foundry to accommodate additional test bars (see Note 1).	1. *L* (length)	The length of the riser at the base will be the same as the top length of the leg. The length of the riser at the top therefore depends on the amount of taper added to the riser.
2. End Taper	Use of and size of end taper is at the option of the foundry.	2. Width	The width of the riser at the base of a multiple-leg coupon shall be *n* (2¼) [57 mm] − ⅝ [16 mm] where *n* equals the number of legs attached to the coupon. The width of the riser at the top is therefore dependent on the amount of taper added to the riser.
3. Height	1¼ in. [32 mm]		
4. Width (at top)	1¼ [32 mm] (see Note 1).		
5. Radius (at bottom)	½ in. [13 mm], max		
6. Spacing between legs	A ½-in. [13-mm] radius will be used between the legs.		
7. Location of test bars	The tensile, bend, and impact bars will be taken from the lower portion of the leg (see Note 2).		
8. Number of legs	The number of legs attached to the coupon is at the option of the foundry providing they are equi-spaced according to Item 6.	3. *T*(riser taper) Height	Use of and size is at the option of the foundry. The minimum height of the riser shall be 2 in. [51 mm]. The maximum height is at the option of the foundry for the following reasons: (*a*) many risers are cast open. (*b*) different compositions may require variation in risering for soundness. (*c*) different pouring temperatures may require variation in risering for soundness.
9 R_s	Radius from 0 to approximately 1/16 in. [2 mm].		

NOTE 1—*Test Coupons for Large and Heavy Steel Castings:* The test coupons in Fig. 1 are to be used for large and heavy steel castings. However, at the option of the foundry the cross-sectional area and length of the standard coupon may be increased as desired.

NOTE 2—*Bend Bar:* If a bend bar is required, an alternate design (as shown by dotted lines in Fig. 1) is indicated.

FIG. 1 Test Coupons for Castings with Details of Design

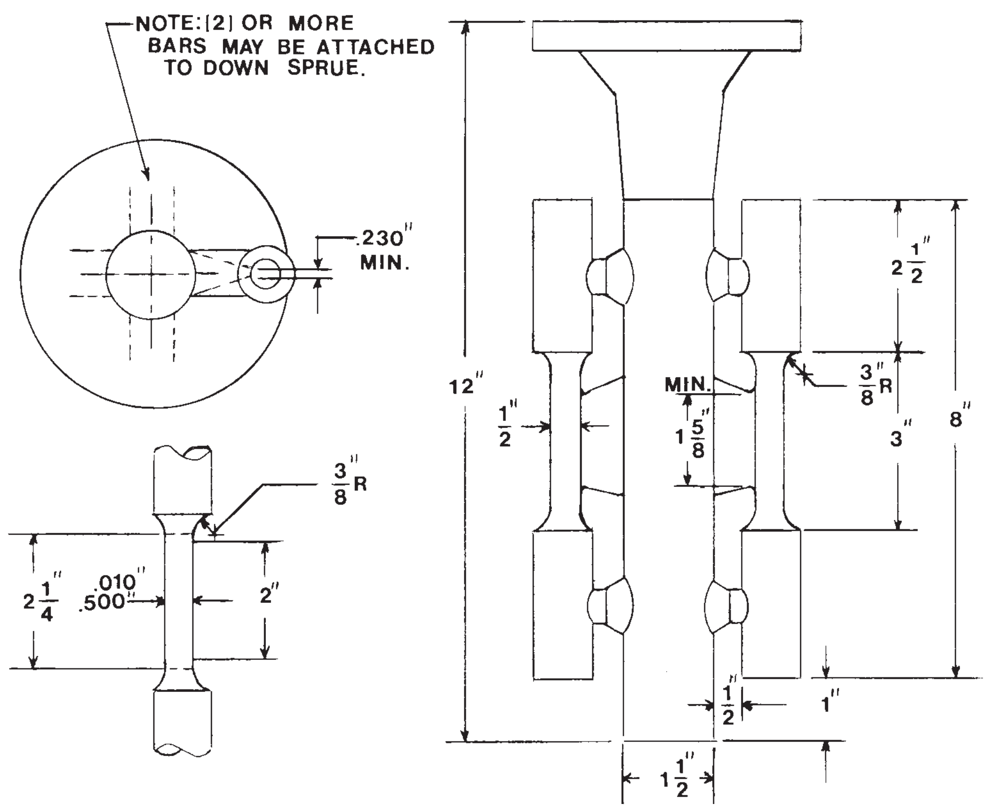


Metric Equivalents

in.	[mm]	in.	[mm]
⅛	[3.2]	3½	[88.9]
½	[12.7]	4	[101.6]
1¹⁄₁₆	[27.0]	4¹⁄₁₆	[103.2]
1½	[38.1]	5	[127.0]
3	[76.2]	11	[279.4]

NOTE—Pour through head; cover molten head with powdered charcoal, coke dust, and so forth, immediately after pouring, in order to keep head fluid as long as possible.

FIG. 2 Test Block for Tension Test Specimen



NOTE—Coupons produced in this manner are suitable for austenitic alloys only. The mold may be preheated for pouring to produce a sound coupon.

FIG. 3 Cast-To-Shape Test Coupon for Tension Specimen

SUPPLEMENTARY REQUIREMENTS

Supplementary requirements shall be applied only when specified by the purchaser. Details of the supplementary requirements shall be agreed upon by the manufacturer and purchaser. The specified tests shall be performed by the manufacturer prior to shipment of the castings.

S1. Magnetic Particle Examination

S1.1 Castings shall be examined for surface and near surface discontinuities by magnetic particle examination. The examination shall be in accordance with Guide E 709. Extent of examination and the basis for acceptance shall be agreed upon between the manufacturer and purchaser.

S2. Radiographic Examination

S2.1 Castings shall be examined for internal defects by means of X rays or gamma rays. The procedure shall be in accordance with Guide E 94, and types and degrees of discontinuities considered shall be judged by Reference Radiographs E 446, E 186, or E 280. Extent of examination and basis for acceptance shall be agreed upon between the manufacturer and purchaser.

S3. Liquid Penetrant Examination

S3.1 Castings shall be examined for surface discontinuities by means of liquid penetrant examination. The examination shall be in accordance with Test Method E 165. Areas to be inspected, methods and types of liquid penetrants to be used, developing procedure, and basis for acceptance shall be agreed upon between the manufacturer and purchaser.

S4. Ultrasonic Examination

S4.1 Castings shall be examined for internal defects by means of ultrasonic examination. The examination procedure shall be in accordance with Practice A 609/A 609M. Extent of examination, methods of testing, and basis for acceptance shall be agreed upon between the manufacturer and purchaser.

S5. Examination of Weld Preparation

S5.1 Magnetic particle or liquid penetrant examination of cavities prepared for welding shall be performed to verify removal of those discontinuities found unacceptable by the examination method specified for the casting. Unless other degrees of shrinkage or types of discontinuities found in the cavities are specified, Type II, Internal Shrinkage, of Reference Photographs E 125, of Degree 2 in sections up to 2 in. [50.8 mm] thick and of Degree 3 in sections over 2 in. thick shall be acceptable.

S6. Certification

S6.1 The manufacturer's certification shall be furnished to the purchaser stating that the material was manufactured, sampled, tested, and inspected in accordance with the material specification (including year date) and was found to meet the requirements.

S6.2 A manufacturer's certification 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 provided it conforms to any existing EDI agreement between the purchaser and the supplier.

S7. Prior Approval of Major Weld Repairs

S7.1 Major weld repairs as defined and agreed upon between the manufacturer and purchaser shall be subject to the prior approval of the purchaser.

S8. Marking

S8.1 The manufacturer's name or identification mark and the pattern number shall be cast or stamped on all castings. When further specified, the heat numbers or serial numbers shall be marked on individual castings.

S9. Charpy Impact Test

S9.1 Charpy impact test properties shall be determined by testing a set of three Charpy V-notch specimens made from each heat at a test temperature agreed upon by the manufacturer and purchaser. The material from which the test specimens are prepared shall be cast in accordance with 6.2. The acceptance requirements shall be either energy absorbed, lateral expansion, or percent shear area, or all three, and shall be that agreed upon between the manufacturer and purchaser. Test specimens shall be prepared as Type A and tested in accordance with Test Methods and Definitions A 370.

S9.2 *Absorbed Energy*—Average energy value of three specimens shall be not less than specified, with not more than one value permitted to fall below the minimum specified and no value permitted below the minimum specified for a single specimen.

S9.3 *Lateral Expansion*—Lateral expansion value shall be agreed upon between the manufacturer and purchaser.

S9.4 *Percent Shear Area*—Percent shear area shall be agreed upon between the manufacturer and purchaser.

S10. Hardness Test

S10.1 Hardness measurements at specified locations of the castings shall be made in accordance with Test Methods and Definitions A 370 and reported.

S11. Specified Ferrite Content Range

S11.1 The chemical composition of the heat shall be controlled such that the ferrite content, as determined by the chemical composition procedure of Practice A 800/A 800M, shall be in conformance with the specified ferrite content range.

S11.2 The specified ferrite content range shall be as agreed upon between the manufacturer and the purchaser. The minimum specified ferrite content range shall be 10 % with the minimum ferrite content being no lower than the percent necessary to achieve the minimum mechanical properties required for the alloy.

S11.3 Should the purchaser wish to have the ferrite content determined by either magnetic response or metallographic methods, the purchaser should impose Supplementary Requirement S1 or S2 of Practice A 800/A 800M.

S12. Test Report

S12.1 The manufacturer shall supply a test report to the purchaser giving the results of all tests performed including chemical analysis.

S13. Unspecified Elements

S13.1 Chemical analysis and limits for elements not specified for the grade ordered shall be as agreed upon between the manufacturer and purchaser.

S14. Tension Test from Castings

S14.1 In addition to the tension test required by the material specification, test material shall be cut from the casting. The mechanical properties and location for the test material shall be agreed upon by the manufacturer and purchaser.

S15. Alternate Mechanical Test Coupons and Specimen Locations for Castings (in lieu of Test Bars Poured from Special Blocks)

S15.1 Test blocks may be cast integrally with the castings or as separate blocks. Test blocks shall be heat-treated together with the castings they represent.

S15.2 In the following, the casting thickness, *T*, is the maximum thickness of the casting exclusive of padding added for directional solidification, flanges, appendages, and sections designated by the designer as noncritical. The order, inquiry, and drawing shall designate what the test dimension, *T*, is for the casting.

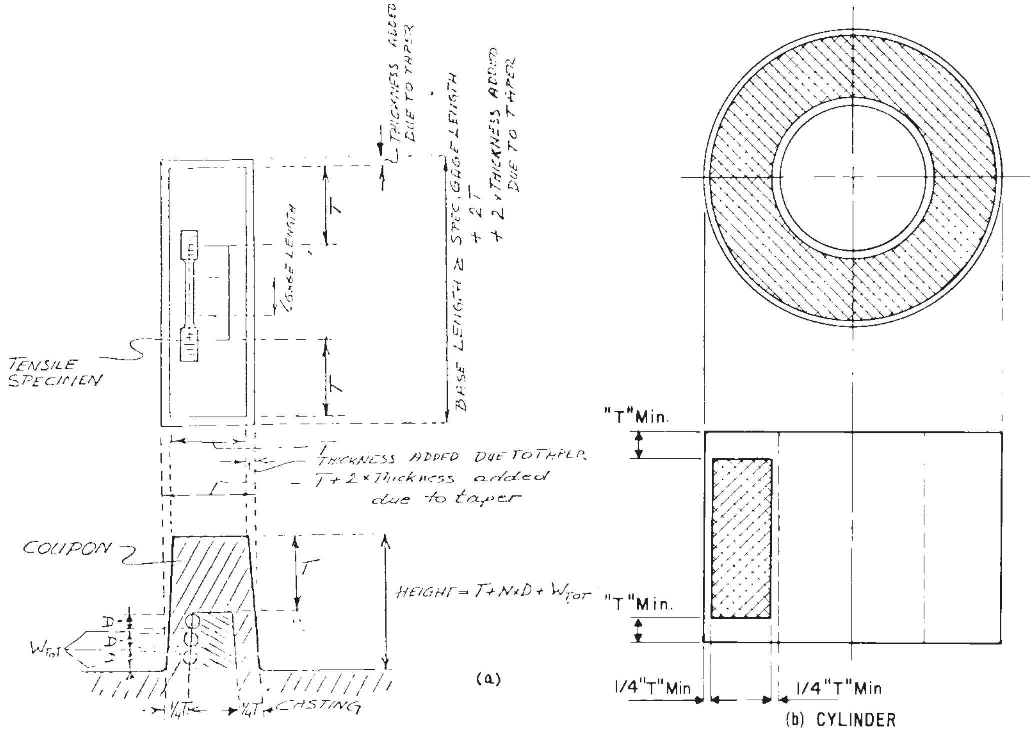
S15.3 One of the following shall apply:

S15.3.1 The longitudinal centerline of the test specimen shall be taken at least ¼ *T* from the *T* dimension surface and all of the gage length must be at least 1*T* from any other heat treated surface, exclusive of the surface opposite the *T* dimension surface. (See Fig. 4 (a).) For cylindrical castings, the longitudinal centerline of the specimens shall be taken at least ¼ *T* from the outside or inside and all of the gage length must be at least *T* from the as-heat-treated end. (See Fig. 4 (b).) For ferritic and martensitic castings, partial severing of test blocks prior to final heat treatment is permitted.

S15.3.2 Where separately cast test coupons are used, the dimension shall not be less than 3*T* by 3*T* by *T* and each specimen shall meet the requirements of S15.3.1, except that when *T* exceeds 5 in. [125 mm], the dimension may be 15 by 15 by 5 in. [375 by 375 by 125 mm], by agreement between the manufacturer and the purchaser. The test coupon shall be of the same heat of steel and shall receive substantially the same casting practices as the production casting it represents. Centrifugal castings may be represented by statically cast coupons. (See Fig. 5.)

S15.3.3 When agreed upon by the manufacturer and the purchaser, castings that are cast or machined to essentially the finished configuration prior to heat-treatment shall have test specimens removed from a prolongation or other stock on the casting at a location below the nearest heat-treated surface indicated on the order. The specimen location shall be at a distance below the nearest heat-treated surface equivalent to at least the greatest distance that the indicated high-tensile-stress surface will be from the nearest heat-treated surface and a minimum of twice this distance from a second heat-treated surface, except that the test specimens shall be no nearer than ¾ in. [19 mm] to a heat-treated surface and 1½ in. [38 mm] from a second heat-treated surface. (See Fig. 6.)

S15.3.4 Where specimens are to be removed from the body of quenched and tempered castings, either the requirements of S15.3.1 shall be met or a steel thermal buffer pad or thermal insulation or other thermal barriers shall be used during heat-treatment. Steel thermal buffer pads shall be a minimum of *T* by *T* by 3*T* in length and shall be joined to the casting surface by a partial penetration weld completely sealing the buffered surface. Test specimens shall be removed from the casting in a location adjacent to the center third of the buffer pad. They shall be located at a minimum distance of ½ in. [13 mm] from the buffered surface and ¼ *T* from other heat-treated surfaces (see Fig. 7). When thermal insulation is used, it shall be applied adjacent to the casting surface where the test specimens are to be removed. The producer shall demonstrate that the cooling rate of the test specimen location is no faster than that of specimens taken by the method described in S15.3.1.



Minimum length of the base—Specimen gage length + 2*xT* + *2x the thickness due to the tapes.* \
Minimum width of the base—*T + 2x the thickness added due to the taper.* \
Minimum height — $T + NxD + W_{tot}$. \
The taper is to be selected by the producer for ease of drawing the pattern from the mold.

where:

N = number of specimens to be cut from one side of the coupon,
D = diameter of the specimens, and
W_{tot} = the total width of metal required to remove the coupon from the casting, and to machine specimens from the coupon.

NOTE—Longitudinal axis and gage length of test specimen must be within shaded zone.

FIG. 4 Specimen from Casting

S16. Weld Repair Charts

S16.1 Major weld repairs shall be documented by means of sketches or photographs, or both, showing the location and major dimensions of cavities prepared for welding. Documentation shall be submitted to the purchaser at the completion of the order.

S16.2 A weld repair shall be considered major when it is made to correct leakage on hydrostatic testing, or when the depth of the cavity prepared for welding exceeds 20 % of the actual wall thickness or 1 in. [25 mm], whichever is smaller, or when the extent of the cavity exceeds approximately 10 in.^{2} [65 cm^2].

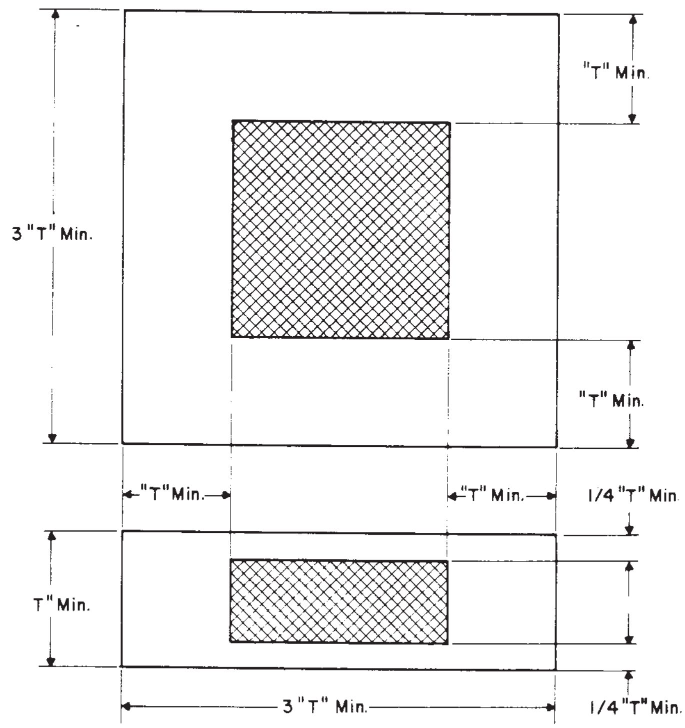
S17. Macroetch Test

S17.1 Apply Supplementary Requirement S13 for the spectrographic determination and reporting of the total residual aluminum content of all heats of ferritic and martensitic steels subjected to this macroetch test.

S17.2 When the heat analysis indicates a total residual aluminum content in excess of 0.08 %, the manufacturer shall etch a cross section of the casting with the heaviest section for which this supplementary requirement is invoked, or a coupon attached to that heaviest section or an area directly under a riser (see Note S17.1). Cross sections from a separately cast test block from the same heat and of a thickness representative of the heaviest section of castings purchased under this supplementary requirement may also be used for macroetch testing. The etching shall be performed on the selected section after its heat treatment, that is, after annealing, normalizing, or quenching and tempering following the initial cooling of the steel below the transformation range.

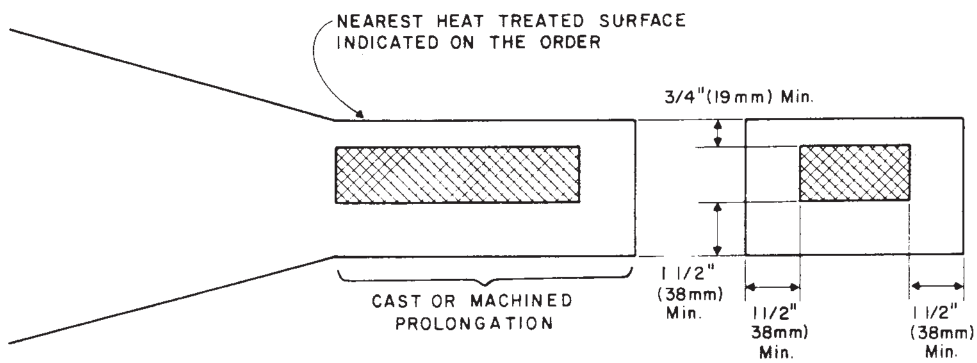
Note S17.1—High strength martensitic castings, in particular, may be damaged beyond use if the etch is applied directly to the casting.

S17.3 The preparation of the surface and the macroetching procedure with Solution No. 1 (1:1 HCI) of Table 5 in Test Method E 340 shall be followed. The resulting etched surface shall be compared and rated with the reference photographs in Fig. 8 depicting ten levels of severity of intergranular network structures indicative of the presence of aluminum nitride or other constituents prone toward precipitating at grain boundaries during solidification and subsequent cooling. Table S17.1 relates the severity levels shown in these photographs with specific delineation widths and percent of boundary outlining in the etched structures.



NOTE—Longitudinal axis and gage length of test specimen must be within cross-hatched zone.

FIG. 5 Separately Cast Block



NOTE—Longitudinal axis and gage length of test specimen must be within cross-hatched zone.

FIG. 6 Prolongation Test Specimen

S17.4 Castings represented by etched structures exhibiting a network rating in excess of Severity Level 4 shall be considered unacceptable until further evaluations are completed. The acceptability of individual castings may be determined by etching sections of each casting to ascertain the network severity level. Disposition of unacceptable castings shall be a matter of agreement between the manufacturer and purchaser. Those castings exhibiting etched severity levels greater than four may be evaluated further by any of the following agreed-upon methods:

S17.4.1 Fracture testing to determine the amount of "rock candy" structure.

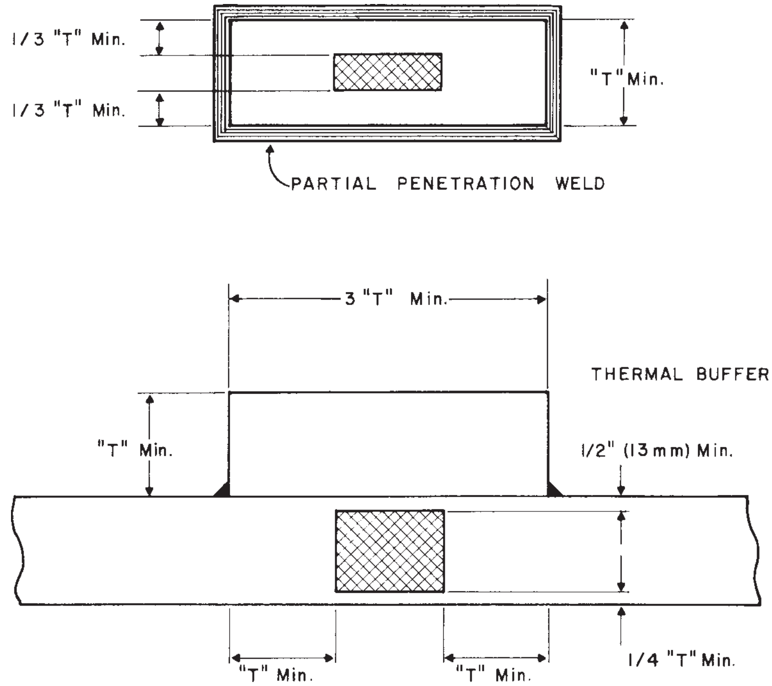
S17.4.2 Mechanical testing (for example, bend, tensile) to determine the ductility characteristics.

S17.4.3 Weld testing to determine crack susceptibility in the heat-affected zone of a circular groove welded with cellulose-coated electrodes.

S17.5 Alternatively, by agreement, it is permissible to subject castings from an unacceptable heat to a high temperature solution treatment prior to the normal production heat-treatment and subsequently macroetch test each casting.

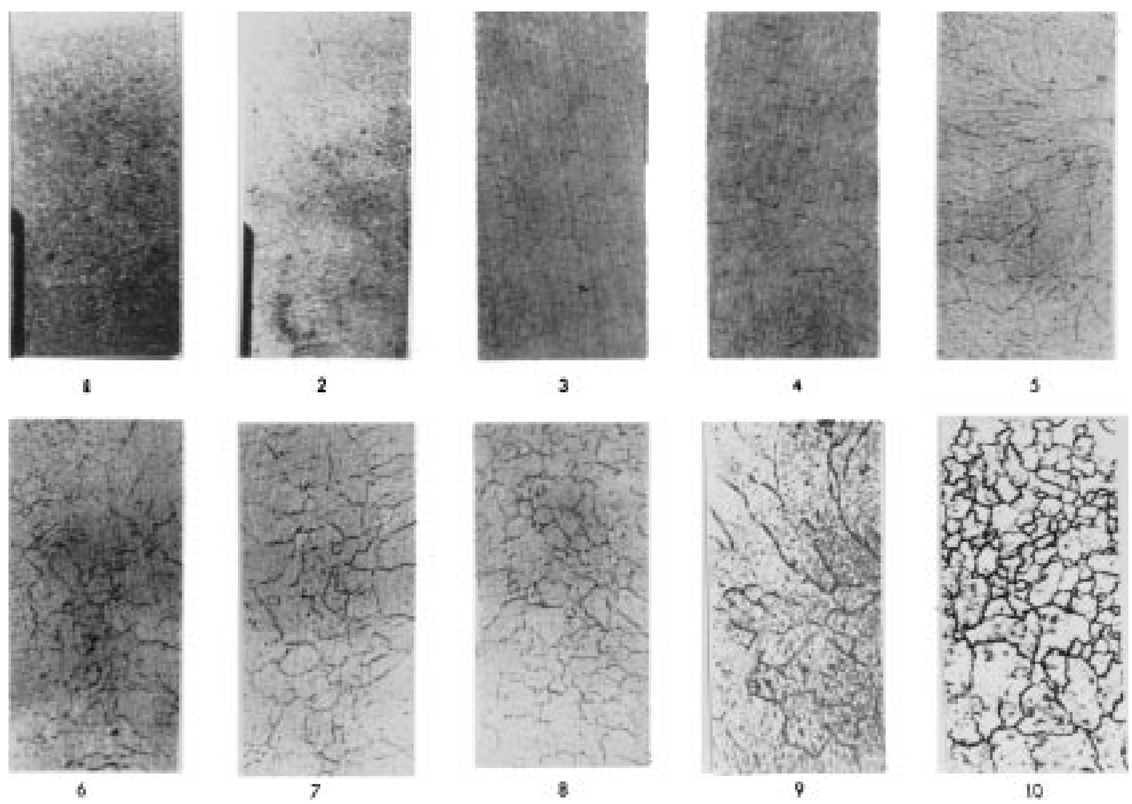
S17.6 Heavy section castings (see Note S17.2) whose configurations are amenable to the attachment of test coupons representative of the section thickness involved and from which standard 0.505 in. [12.827 mm] diameter tension specimens may be machined are exempt from this macroetch test if the results of the tension test on the coupon after heat-treatment of the casting meet the minimum requirements specified for the grade of steel involved.

NOTE S17.2—For purposes of this supplementary requirement, a heavy section casting is defined as one having a wall thickness of 1½ in. [37 mm] or greater, in combination with a casting weight of at least 1000 lb [455 kg].



NOTE—Longitudinal axis and gage length of test specimen must be within cross-hatched zone.

FIG. 7 Thermal Buffer Pad



NOTE—The ten levels of severity of intergranular network structures shown are indicative of the presence of aluminum nitride precipitation in the primary austenitic grain boundaries.

FIG. 8 Reference Photographs of Macroetched Cast Steel

S18. Hot Isostatic Pressing (HIPing)

S18.1 Castings shall be processed by Hot Isostatic Pressing (HIPing). The processing parameters for the HIPing process may be subject to an agreement between the manufacturer and purchaser.

S19. Cleaning of Stainless Steels

S19.1 Final cleaning of the casting surfaces shall be performed in accordance with one of the cleaning methods in Practice A 380 or Specification A 967 as agreed upon between the purchaser and the supplier. Acceptance testing shall be subject to agreement between the purchaser and supplier.

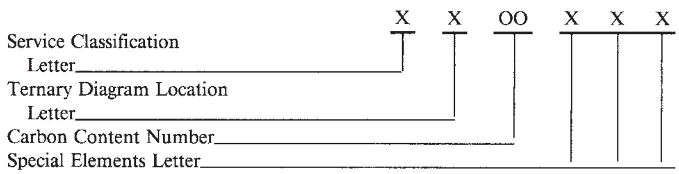
APPENDIXES

(Nonmandatory Information)

X1. ALLOY DESIGNATIONS FOR CAST STAINLESS STEELS

X1.1 Cast stainless steels are usually specified on the basis of composition using the alloy designation system established by the Alloy Casting Institute (ACI). The ACI designations, for example, CF8M, have been adopted by ASTM and are preferred for cast alloys over the designations used by the American Iron and Steel Institute for similar wrought steels.

X1.2 This nomenclature system has served successfully to accommodate changes in old alloys and to designate new ones.



X1.2.1 *Service Classification Letter*

The first letter of the cast stainless steel designation system identifies the intended service application of the alloy. The letter C indicates corrosion-resistant service, and the letter H indi-cates the heat-resistant service at and above 1200°F [649°C].

X1.2.2 *Ternary Diagram Location Letter*

The second letter indicates the approximate location of the nickel and chromium contents of the alloy grade on the FeCrNi ternary diagram shown in Fig. X1.1.

X1.2.3 *Carbon Content Number*

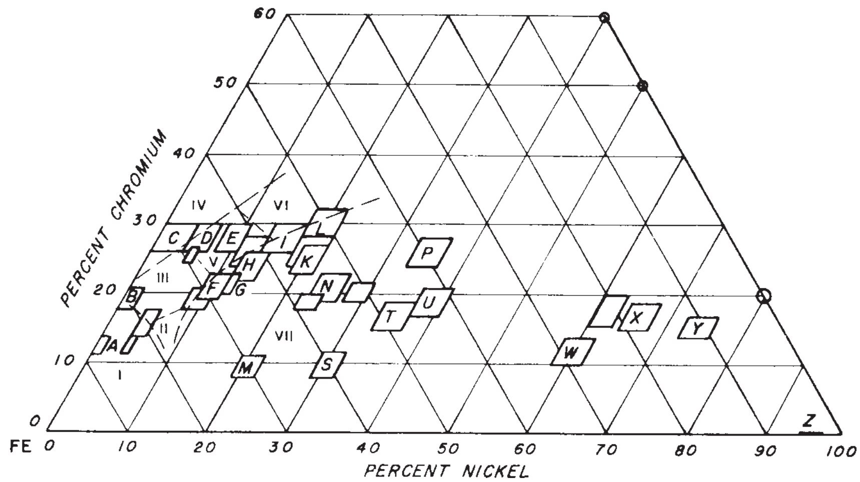
For C service classifications, this single or dual digit numeral represents the maximum carbon content in units of 0.01 %. For H service classifications, this number represents the midpoint of the range of carbon content in terms of 0.01 % with a ±0.05 % limit.

X1.2.4 *Special Elements Letter*

Additional letters following the numeral represent special chemical elements in the alloy grade, such as M for molybdenum, C for columbium, Cu for copper, W for tungsten. There are two exceptions; the letter A indicates Controlled Ferrite, and the letter F indicates Free Machining.

X1.3 In Fig. X1.1, unlettered Ni-Cr ranges are associated with the nearest lettered location. They may be the result of differences between corrosion and heat-resistant types, or because of the influence of additional elements, for example, the precipitation hardening grade CB-7Cu-1 and CB-7Cu-2.

LOCATION OF ACI ALLOY TYPES



NOTE 1—The approximate areas of microstructures to be expected at room temperature are indicated as follows:
I—Martensite
II—Martensite and untransformed austenite
III—Ferrite plus martensite and untransformed austenite
IV—Ferrite
V—Ferrite plus austenite
VI—Ferrite plus austenite plus sigma
VII—Austenite
NOTE 2—Carbides also may be present depending on carbon content and thermal history.

FIG. X1.1 Letters Assigned to Chromium and Nickel Ranges in ACI Designation System

X2. WROUGHT ALLOYS SIMILAR TO CASTING ALLOYS IN SPECIFICATIONS A 494, A 743, A 744, A 747 AND A 890

X2.1 Table X2.1 is provided for the user of the above listed specifications as an aid in selecting cast alloys which are similar in chemical composition to wrought alloys. It is not intended to imply that the cast alloy would have the same mechanical, physical or corrosion properties as the indicated wrought alloy.

TABLE X2.1 Similar Alloys

Nominal Composition	ASTM Casting Specification	Casting Grade Designation	UNS Number	Similar Wrought Alloy	UNS Number
~~11Cr-7Ni~~	~~A 743~~	~~CA-6N~~	~~J91650~~	~~. . .~~	~~. . .~~
11Cr-7Ni	A 743	CA6N	J91650	. . .	. . .
~~13Cr-4Ni~~	~~A 743~~	~~CA-6NM~~	~~J91540~~	~~F-6NM^A~~	~~S41500~~
13Cr-4Ni	A 743	CA6NM	J91540	F-6NM^A	S41500
~~13Cr~~	~~A 743~~	~~CA-15~~	~~J91150~~	~~410^B~~	~~S41000~~
13Cr	A 743	CA15	J91150	410^B	S41000
~~13Cr~~	~~A 743~~	~~CA-40~~	~~J91151~~	~~. . .~~	~~. . .~~
13Cr	A 743	CA40	J91151	. . .	. . .
12Cr-Mo-V-W	A 743	CA28MWV	J91422	422^B	S42200
13Cr-Mo	A 743	CA15M	J91153	420^B	S42000
~~13Cr-S~~	~~A 743~~	~~CA-40F~~	~~J91154~~	~~420F^B~~	~~S42020~~
13Cr-S	A 743	CA40F	J91154	420F^B	S42020
~~19Cr-1Ni~~	~~A 743~~	~~CB-30~~	~~J91803~~	~~442^B~~	~~S44200~~
19Cr-1Ni	A 743	CB30	J91803	442^B	S44200
16Cr-4Ni-4Cu	A 747	CB7Cu-1	J92180	17-4^C	S17400
15Cr-5Ni-3Cu	A 747	CB7Cu-2	J92110	15-5^C	S15500
~~27Cr~~	~~A 743~~	~~CC-50~~	~~J92615~~	~~446^B~~	~~S44600~~
27Cr	A 743	CC50	J92615	446^B	S44600
~~25Cr-5Ni-3Cu-2Mo~~	~~A 743, A 744, A 890~~	~~1A & CD-4MCu~~	~~J93370~~	~~255^C~~	~~S32550~~
25Cr-5Ni-3Cu-2Mo	A 890	1A & CD4MCu	J93370	255^C	S32550
25Cr-5Ni-3Cu-2Mo-N	A 890	1B & CD4MCuN	J93372	255^C	S32550
25Cr-6Ni-2Cu-3Mo-N	A 890	1C & CD3MCuN	J93373	255^C	S32550
~~24Cr-10Ni-3Mo-N~~	~~A 890~~	~~2A & CE-8MN~~	~~J93345~~	~~. . .~~	~~. . .~~

Nominal Composition	ASTM Casting Specification	Casting Grade Designation	UNS Number	Similar Wrought Alloy	UNS Number
24Cr-10Ni-3Mo-N	A 890	2A & CE8MN	J93345	. . .	. . .
25Cr-5Ni-2Mo-N	A 890	3A & CD6MN	J93371	. . .	. . .
22Cr-5Ni-3Mo-N	A 890	4A & CD3MN	J92205	2205[C]	S39205
25Cr-7Ni-4Mo-N	A 890	5A & CE3MN	J93404	. . .	. . .
25Cr-7Ni-Mo-N	A 890	6A & CD3MCuWN	J93380	Zeron 100	S32760
~~28Cr-9Ni~~	~~A 743~~	~~CE-30~~	~~J93423~~	~~. . .~~	~~. . .~~
28Cr-9Ni	A 743	CE30	J93423	. . .	. . .
~~18Cr-8Ni~~	~~A 743, A 744~~	~~CF-3~~	~~J92500~~	~~304L[B]~~	~~S30403~~
18Cr-8Ni	A 743, A 744	CF3	J92500	304L[B]	S30403
~~16Cr-12Ni-2Mo~~	~~A 743, A 744~~	~~CF-3M~~	~~J92800~~	~~316L[B]~~	~~S31603~~
16Cr-12Ni-2Mo	A 743, A 744	CF3M	J92800	316L[B]	S31603
~~16Cr-12Ni-2Mo-N~~	~~A 743~~	~~CF-3MN~~	~~J92804~~	~~316LN[B]~~	~~S31653~~
16Cr-12Ni-2Mo-N	A 743	CF3MN	J92804	316LN[B]	S31653
~~18Cr-8Ni~~	~~A 743, A 744~~	~~CF-8~~	~~J92600~~	~~304[B]~~	~~S30400~~
18Cr-8Ni	A 743, A 744	CF8	J92600	304[B]	S30400
~~18Cr-10Ni-Cb~~	~~A 743, A 744~~	~~CF-8C~~	~~J92710~~	~~347[B]~~	~~S34700~~
18Cr-10Ni-Cb	A 743, A 744	CF8C	J92710	347[B]	S34700
~~16Cr-12Ni-2Mo~~	~~A 743, A 744~~	~~CF-8M~~	~~J92900~~	~~316[B]~~	~~S31600~~
16Cr-12Ni-2Mo	A 743, A 744	CF8M	J92900	316[B]	S31600
~~18Cr-8Ni-4Si-N~~	~~A 743~~	~~CF-10SMnN~~	~~J92972~~	~~Nitronic 60[D]~~	~~S21800~~
18Cr-8Ni-4Si-N	A 743	CF10SMnN	J92972	Nitronic 60[D]	S21800
~~18Cr-8Ni-S~~	~~A 743~~	~~CF-16F~~	~~J92701~~	~~303Se[B]~~	~~S30300~~
18Cr-8Ni-S	A 743	CF16F	J92701	303Se[B]	S30300
~~18Cr-8Ni~~	~~A 743~~	~~CF-20~~	~~J92602~~	~~302[B]~~	~~S30200~~
18Cr-8Ni	A 743	CF20	J92602	302[B]	S30200
~~22Cr-13Ni-5Mn~~	~~A 743~~	~~CG-6MMN~~	~~J93790~~	~~Nitronic 50[D]~~	~~S20910~~
22Cr-13Ni-5Mn	A 743	CG6MMN	J93790	Nitronic 50[D]	S20910
~~18Cr-13Ni-3Mo~~	~~A 743, A 744~~	~~CG-8M~~	~~J93000~~	~~317[B]~~	~~S31700~~
18Cr-13Ni-3Mo	A 743, A 744	CG8M	J93000	317[B]	S31700
~~21Cr-11Ni~~	~~A 743~~	~~CG-12~~	~~J93001~~	~~308[B]~~	~~S30800~~
21Cr-11Ni	A 743	CG12	J93001	308[B]	S30800
~~23Cr-12Ni~~	~~A 743~~	~~CH-20~~	~~J93402~~	~~309[B]~~	~~S30900~~
23Cr-12Ni	A 743	CH20	J93402	309[B]	S30900
~~20Cr-18Ni-6Mo-Cu-N~~	~~A 743, A 744~~	~~CK-3MCuN~~	~~J93254~~	~~254 SMO[E]~~	~~S31254~~
20Cr-18Ni-6Mo-Cu-N	A 743, A 744	CK3MCuN	J93254	254 SMO[E]	S31254
~~25Cr-20Ni~~	~~A 743~~	~~CK-20~~	~~J94202~~	~~310[B]~~	~~S31000~~
25Cr-20Ni	A 743	CK20	J94202	310[B]	S31000
~~24Ni-21Cr-6Mo-N~~	~~A 743, A 744~~	~~CN-3MN~~	~~. . .~~	~~AL-6XN[F]~~	~~N08367~~
24Ni-21Cr-6Mo-N	A 743, A 744	CN3MN	. . .	AL-6XN[F]	N08367
~~29Ni-20Cr-3Cu-2Mo~~	~~A 743, A 744~~	~~CN-7M~~	~~N08007~~	~~Alloy 20[C]~~	~~N08020~~
29Ni-20Cr-3Cu-2Mo	A 743, A 744	CN7M	N08007	Alloy 20[C]	N08020
~~24Ni-19Cr-3Mo-2Cu~~	~~A 743, A 744~~	~~CN-7MS~~	~~J94650~~	~~. . .~~	~~. . .~~
24Ni-19Cr-3Mo-2Cu	A 743, A 744	CN7MS	J94650	. . .	. . .
41Ni-22Cr-3mO-fE	A 494	CU5MCuC	N08826	825	N28820
~~61Ni-16Mo-16Cr~~	~~A 494~~	~~CW-2M~~	~~N26455~~	~~C4[C]~~	~~N06455~~
61Ni-16Mo-16Cr	A 494	CW2M	N26455	C4[C]	N06455
~~59Ni-18Mo-18Cr~~	~~A 494~~	~~CW-6M~~	~~N30107~~	~~. . .~~	~~. . .~~
59Ni-18Mo-18Cr	A 494	CW6M	N30107	. . .	. . .
~~60Ni-22Cr-9Mo-3.5Cb~~	~~A 494~~	~~CW-6MC~~	~~N26625~~	~~625[C]~~	~~N06625~~
60Ni-22Cr-9Mo-3.5Cb	A 494	CW6MC	N26625	625[C]	N06625
~~55Ni-17Mo-16Cr-4W~~	~~A 494~~	~~CW-12MW~~	~~N30002~~	~~C[C]~~	~~N10002~~
55Ni-17Mo-16Cr-4W	A 494	CW12MW	N30002	C[C]	N10002
~~57Ni-13Mo-21Cr~~	~~A 494~~	~~CX-2MW~~	~~N26022~~	~~C22[C]~~	~~N06022~~
57Ni-13Mo-21Cr	A 494	CX2MW	N26022	C22[C]	N06022
~~74Ni-12Cr-4Bi-4Sn~~	~~A 494~~	~~CY-5SnBiM~~	~~N26055~~	~~. . .~~	~~. . .~~
74Ni-12Cr-4Bi-4Sn	A 494	CY5SnBiM	N26055	. . .	. . .
~~72Ni-15Cr-8Fe~~	~~A 494~~	~~CY-40~~	~~N06040~~	~~600[C]~~	~~N06600~~
72Ni-15Cr-8Fe	A 494	CY40	N06040	600[C]	N06600
~~95Ni~~	~~A 494~~	~~CZ-100~~	~~N02100~~	~~200[C]~~	~~N02200~~
95Ni	A 494	CZ100	N02100	200[C]	N02200
~~63Ni-29Cu-4Si~~	~~A 494~~	~~M-25S~~	~~N24025~~	~~. . .~~	~~. . .~~
63Ni-29Cu-4Si	A 494	M25S	N24025	. . .	. . .
~~63Ni-29Cu-2Cb~~	~~A 494~~	~~M-30C~~	~~N24130~~	~~. . .~~	~~. . .~~
63Ni-29Cu-2Cb	A 494	M30C	N24130	. . .	. . .
~~63Ni-29Cu-Si~~	~~A 494~~	~~M-30H~~	~~N24030~~	~~. . .~~	~~. . .~~
63Ni-29Cu-Si	A 494	M30H	N24030	. . .	. . .
67Ni-30Cu	A 494	M-35-1	N24135	400[C]	N04400
67Ni-30Cu	A 494	M-35-2	N04020	400[C]	N04400
~~65Ni-28Mo-2Fe~~	~~A 494~~	~~N-7M~~	~~N30007~~	~~B2[C]~~	~~N10665~~
65Ni-28Mo-2Fe	A 494	N7M	N30007	B2[C]	N10665
~~62Ni-28Mo-5Fe~~	~~A 494~~	~~N-12MV~~	~~N30012~~	~~B[C]~~	~~N10001~~ ~~25Cr-7Ni-Mo-N~~ [illegible]
62Ni-28Mo-5Fe	A 494	N12MV	N30012	B[C]	N10001 ~~25Cr-7Ni-Mo-N~~ [illegible]
~~41Ni-22Cr-3Mo-Fe~~	~~A 494~~	~~CU5MCuC~~	~~. . .~~	~~825~~	~~N28820~~

[A] ASTM designation.

[B] Common description, formerly used by AISI.
[C] Common name used by two or more producers; not a trademark.
[D] Proprietary trademark: Armco, Inc.
[E] Proprietary trademark: Avesta Sheffield AB.
[F] Proprietary trademark: Allegheny Ludlum Corporation.

X3. ADDITION OF NEW GRADES TO PRODUCT SPECIFICATIONS COVERED BY A 781/A 781M

X3.1 Information required for the inclusion of new material grades in product specifications covered by A 781/A 781M:

1. At least one user should support the request.
2. A set of data from 10 production heats, this data should include:

X3.1.1 Chemical Composition.

X3.1.2 Mechanical properties as applicable to the product specification being cited. These may include but are not limited to the following:

X3.1.2.1 Ultimate tensile strength,

X3.1.2.2 Yield strength,

X3.1.2.3 Reduction in area,

X3.1.2.4 Elongation, and

X3.1.2.5 Impact properties (Charpy V).

X3.2 The test coupon size from which the test pieces are removed should be stated for each test.

X3.2.1 Heat treatment requirements.

X3.2.2 Weld procedure (welding should be carried out using commercially available consumables).

SUMMARY OF CHANGES

Committee A01 has identified the location of selected changes to this standard since the last issue (A 781/A 781M – 0~~3a~~4) that may impact the use of this standard. (Approved ~~March~~ May 1, 2004.)

(1) Deleted hyphens from ACI Grade designations.
(2) Added A 890 1B and 1C.
(3) Repositioned A 890 6A in Table X2.1 and added or corrected UNS numbers.
(4) Revised Footnote D and added Footnotes G and H to Table X2.1.

Committee A01 has identified the location of selected changes to this standard since the last issue (A 781/A 781M – 03a) that may impact the use of this standard. (Approved March 1, 2004.)

(1) Removed Supplementary Requirement S20.

Committee A01 has identified the location of selected changes to this standard since the last issue (A 781/A 781M – 03) that may impact the use of this standard. (Approved June 10, 2003.)

*(1)*Added 4.2 to include requirements for performing temperature uniformity surveys of heat treament sources.
(2) Revised Section 6, 6.1, and S15 to include other mechanical tests in addition to tensile tests.
*(3)*Added 8.3.

Designation: A 799/A799M – 04

Standard Practice for Steel Castings, Stainless, Instrument Calibration, for Estimating Ferrite Content[1]

This standard is issued under the fixed designation A 799/A799M; 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 practice covers the procedure for calibration of instruments to be used for estimating the ferrite content of the microstructure of cast stainless steels by magnetic response or measurement of permeability. This procedure covers both primary and secondary instruments.

1.1.1 A primary instrument is one that has been calibrated using National Institute of Standards and Technology-Standard Reference Material (NIST-SRM) thickness coating standards. It is a laboratory tool to be used with test specimens. Some primary instruments may be used to directly measure the ferrite content of castings.

1.1.2 A secondary instrument is one that has been calibrated by the use of secondary standards that have been measured by a calibrated primary instrument. Secondary instruments are to be used to directly measure the ferrite content of castings.

1.2 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 must be used independently of the other. Combining values from the two systems may result in nonconformance with the specification.

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:* [2]

A 941 Terminology Relating to Steel, Stainless Steel, Related Alloys, and Ferroalloys

B 499 Test Method for Measurement of Coating Thicknesses by the Magnetic Method: Nonmagnetic Coatings on Magnetic Basis Metals

E 562 Practice for Determining Volume Fraction by Systematic Manual Point Count

2.2 *NIST Standard:*

NIST-SRM Coating Thickness Standards

NOTE 1—The specific coating thickness standards previously referenced in this practice are no longer available. Similar ones are now available from NIST.

3. Terminology

3.1 *Definitions:* The definitions in Terminology A 941 are applicable to this standard.

3.2 *Definitions of Terms Specific to This Standard:*

3.2.1 *ferrite*, *n*—the body-centered cubic microconstituent in stainless steel.

3.2.2 *ferrite percentage*, *n*—a value designating the ferrite content of stainless steels.

3.2.2.1 *Discussion*—The Steel Founders' Society of America (SFSA) has assigned ferrite percentages to the series of NIST coating thickness standards[3]. This assignment was based on the magnetic attraction for a standard magnet by the coating standards when compared with the magnetic attraction of the same magnet by a series of cast stainless steels whose ferrite content had been determined by an accurate metallographic point count. A similar assignment based on magnetic permeability was also established. Algebraic equations have now been derived from a plot of the thickness of these standards and the assigned ferrite percentages. By the use of these equations, any primary instrument will have its calibration traceable to the SFSA's instruments or any other calibrated instrument and thus afford comparable reproducible ferrite percentages. It also allows traceability to NIST.

3.2.3 *secondary standards*, *n*—a piece of cast stainless steel whose ferrite percentage has been determined by a calibrated primary instrument.

[1] This practice is under the jurisdiction of ASTM Committee A01 on Steel, Stainless Steel, and Related Alloys and is the direct responsibility of Subcommittee A01.18 on Castings.

Current edition approved March 1, 2004. Published April 2004. Originally approved in 1982. Last previous edition approved in 1992 as A 799/A 799M – 92 (2002).

[2] 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.

[3] Aubrey, L.S., Weiser, P.F., Pollard, W.J., and Schoefer, E.A., "Ferrite Measurement and Control in Cast Duplex Stainless Steels," *Stainless Steel Castings, ASTM STP 756*, ASTM, 1982, p 126.

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

3.2.3.1 *Discussion*—Secondary statements are used to calibrate secondary instruments (see Calibration of Secondary Instruments).

4. Significance and Use

4.1 The amount of ferrite present in an austenitic stainless steel has been shown to influence the strength, toughness and corrosion resistance of this type of cast alloy. The amount of ferrite present tends to correlate well with the magnetic permeability of the steel. The methods described in this standard cover calibration practice for estimating ferrite by the magnetic permeability of the steel. The practice is inexpensive to use over large areas of the cast part and is non-destructive.

4.2 This practice has been used for research, alloy development, quality control, and manufacturing control.

4.2.1 Many instruments are available having different designs, and different principles of operation. When the probe is placed on the material being investigated, a closed magnetic circuit is formed allowing measurement of the magnetic permeability. When calibrated with standards having known ferrite content, this permeability indicates the ferrite content of the material being analyzed. The estimated ferrite content is read from a calibrated dial or from a digital-readout dial. Follow the manufacturer's instructions for proper calibration of the instrument.

4.3 Since this practice measures magnetic attraction and not ferrite directly, it is subject to all of the variables that affect magnetic permeability, such as the shape, size, orientation, and composition of the ferrite phase. These in turn are affected by thermal history. Ferrite measurements by magnetic methods have also been found to be affected by the surface finish of the material being analyzed.

4.4 Magnetic methods should not be used for arbitration of conflicts on ferrite content except when agreed upon between manufacturer and purchaser.

5. Apparatus

5.1 One primary instrument that uses magnetic attraction consists of a spring-loaded balance arm from which a rod-shaped magnet is suspended.[4] The opposite end of the balance arm from the magnet has counterweights that balance most but not all of the weight of the magnet.

5.1.1 When this instrument is used, the spring load is relaxed sufficiently to allow the magnet to make contact with the material being tested.

5.1.2 The spring is then wound until the force of the coiled spring overcomes the magnetic attraction of the magnet for the material being tested, causing the magnet to break contact and the lever arm to rise.

5.1.3 The amount of force that the coiled spring has developed is determined from a marked dial securely attached to the shaft that is used to coil or uncoil the spring.

5.1.3.1 A weighted number 2 is used with this instrument, U5-0664W.

[4] Magne Gage, produced by Magne Gage Sales and Service Co., Inc., 629 Packer Street, Avoca, PA 18641; http://www.magne-gage.com.

5.2 When using a Feritscope,[5] follow the manufacturer's instructions for calibration. When traceability is required, confirm the calibration using the appropriate NIST standards.

5.2.1 Newer versions of this instrument have a single-point probe while older versions have a two-point probe as the sensing device. When this probe is placed on the material being investigated, a closed magnetic circuit is formed and energized by a low-frequency magnetic field. The voltage induced in the probe coil by this field is a measure of the permeability. When calibrated with standards having known ferrite content, this permeability indicates the ferrite content of the material being analyzed. The estimated ferrite content is read from a calibrated dial or from a digital-readout dial.

5.3 One secondary instrument consists of a balance arm that has a rod-shaped magnet attached to one end.[6] The opposite end is counterweighted to balance the magnet.

5.3.1 This arm with its magnet and counterweight is enclosed in a transparent box. The top face of this container has a threaded hole directly over the magnet. Into this hole are screwed-marked inserts that have metal plates on their bottom face. These plates have different strengths of attraction for the magnet.

5.3.2 In use, the bottom end of the magnet is touched to the material being investigated. The other end of the magnet is in contact with the metal plate on the bottom of the insert. The container is then raised. If the material being measured has a greater attraction for the magnet than does the plate on the bottom of the insert, the magnet will be pulled away from the insert. If not, the magnet will pull away from the material being measured. The insert buttons are changed until the ones that are just weaker and also stronger than the material being investigated are found.

5.3.3 The results of a measurement with this instrument are reported as less than A and greater than B.

5.4 NIST-SRM Coating Thickness Standards. These are mild steel plates that are covered by an electroplated copper layer which in turn is covered by a flash coat of chromium. The thickness of the copper coat varies from standard to standard and is certified by NIST. The strength of the magnetic attraction of each standard varies with the thickness of the coating. These are primary standards for calibration.

5.5 Other instruments such as the Elcometer[7] may be used.

6. Calibration

6.1 Calibrate primary instruments that use magnetic attraction as criterion as follows:

6.1.1 When calibrating magnetic instruments, make sure there is no magnetic material within the area that could affect the calibration. This includes beneath the surface on which the instrument rests.

6.1.2 *Magnet*—Use weighted standard No. 2 magnet for measurement of ferrite content of cast stainless steel.

[5] Feritscope, produced by Fischer Technology, Inc., 750 Marshall Road, Windsor, CT 06095; http://www.fischer-technology.com.

[6] Severn Gage, Severn Engineering Co., Old Stage Business Park, 555 Stage Road, Unit A, Auburn, AL 36830; http://www.severnengineering.com.

[7] Elcometer, Elcometer Instruments Ltd., Edge Lane, Manchester, UK M43 6BU; http://www.elcometer.com.

6.1.3 *Zoeroing*—Before calibration, zero each primary instrument.

6.1.3.1 When zeroing the instrument, use the "T"-shaped handle to lower the spring-loaded balance arm until the plastic-protection cylinder around the magnet is in contact with a nonmagnetic object. The base plate of the unit is satisfactory.

6.1.3.2 Turn the large-knurled knob on the central shaft counter-clockwise to a dead stop.

6.1.3.3 Rotate the large-knurled knob clockwise until the magnet lifts off the nonmagnetic object and the pivot arm from which the magnet is suspended is parallel to the base plate. Loosen the set screw holding the black dial in position.

6.1.3.4 Set the "0" position on the black dial at the index position and tighten the set screw.

6.1.4 *Determining Black Dial Values for the NIST-SRM Thickness Standards*—Use the NIST-SRM coating thickness standards.

6.1.4.1 Insert, one at a time in random order, the various NIST-SRM coating thickness standards under the plastic protection cylinder. Lower the instrument each time until the cylinder contacts the standard.

6.1.4.2 If the magnet is attracted to the plate when the plastic protection cylinder is placed in contact with the standard, rotate the large-knurled knob clockwise slowly until the magnet breaks contact with the standard. Record the black-dial reading.

6.1.4.3 If the magnet is not attracted to the plate when the plastic cylinder comes in contact with the standard, push the magnet into contact by using the push rod located over the magnet. If the magnet does not adhere to the standard, turn the large-knurled knob counterclockwise a few divisions at a time until the magnet does adhere when it comes in contact with the standard. When the magnet remains in contact with the standard, rotate the large knurled knob clockwise slowly until the magnet breaks contact with the standard. Record the black dial reading.

6.1.4.4 Repeat 6.1.4.3 several times, more than three, with each standard moving the standard under the plastic protection cylinder after each reading. Take the reading in the central area of the standard. Average the readings.

6.1.4.5 Tabulate the black dial readings and the thickness of the coatings on the standards.

6.1.5 *Preparation of Ferrite Percentage Curve*—Calculate the assigned ferrite percentage value for each NIST-SRM coating thickness used in 6.1.4.3 by using Eq. 1, where F is the assigned ferrite content and T is the coating thickness, and the coefficients from Table 1. Round the calculated value to the nearest 0.1 % ferrite.

$$F = B_0 + \frac{B_1}{T} + \frac{B_2}{T_2} + \frac{B_3}{T_3} + \frac{B_4}{T_4} \qquad (1)$$

6.1.5.1 Plot on an arithmetic scale the ferrite percentage for each standard and the black dial reading obtained for that standard. This is the calibration curve for the instrument. It is used to designate the ferrite percentage of any sample measured with the instrument.

6.2 *Calibrate primary instruments that use magnetic permeability as criterion as follows*:

NOTE 2—This calibration procedure applies only to the older (pre-1980), analog instruments with the two-point probe. Analog instruments may have iether an analog meter or a digital meter. Newer (post-1980) instruments with digital readouts or single-point probes must be calibrated using the procedure given under Calibration of Secondary Instruments.

6.2.1 If the instrument has more than one measuring range set the instrument to the desired range.

6.2.2 Connect the measuring probe to the instrument.

6.2.3 *Zeroing*—Bring the needle opposite "0" *on the dial* by means of the "zero" knob. Be sure the probe is at least 1 ft [305 mm] away from any magnetic material when this adjustment is made.

6.2.4 *Calibration of "End of Range":*

6.2.4.1 Apply the sensing probe to an NIST-SRM with 2.00-mil [51.0 µm] coating thickness. Using the "end point" control knob, bring the meter needle opposite "29" on the meter. If a digital readout meter is being used, bring the maximum digital reading to "29."

6.2.4.2 If an NIST-SRM with coating thickness other than 2.00-mil [51.0-µm] is used, determine the meter setting to be used from Table 2. It is recommended that coating thickness of 3.25 mil [82.5 µm] or less be used.

6.2.4.3 When measuring ranges are changed, the "zero" setting must be adjusted to "0."

6.2.5 *Determining the Meter Readings for the NIST-SRM Thickness Standards*:

6.2.5.1 Apply the probe to the various NIST-SRM standards several times, more than three. Rotate the probe 90° between reading. Record the readings and average them.

6.2.5.2 Tabulate the average meter readings and the thickness of the measured standards.

6.2.6 *Preparation of Ferrite Percentage Curve*:

6.2.6.1 Calculate the assigned ferrite percentage for each NIST-SRM measured in 6.2.5.1 by using Eq. 1, where F is the assigned ferritic content and T is the coating thickness, and the coefficients from Table 1. Round the calculated value to the nearest 0.1 % ferrite.

6.2.6.2 Plot on an arithmetic scale the ferrite percentage for each standard and the meter or digital readings obtained for that standard. This is the calibration curve for the instrument.

TABLE 1 Coefficients for Calculating Assigned Ferrite Values

Instrument	Units	B_0	B_1	B_2	B_3	B_4
Magne-Gage	Mils	–0.6727	164.8	–334.3	516.2	–352.6
	mm	–0.6727	6 486	–518 100	31 500 000	–847 100 000
Feritscope (Note 2)	Mils	–2.042	296.5	–1656	5 440	–6 945
	mm	–2.042	11 670	–2 566 000	332 000 000	–16 680 000 000

TABLE 2 "End Point" Settings to be used with Coating Thickness Other than 2.00 mils [51.0 μm]

Coating Thickness, mils [μm]	"End Point"
1.66 [42.2]	30
2.04 [51.8]	28.5
2.1 [53.3]	28
2.2 [55.9]	27.7
2.3 [58.4]	27.5
2.4 [61.0]	27
2.5 [63.5]	26.5
2.6 [66.0]	26.3
2.7 [68.6]	26
2.8 [71.1]	25.7
2.9 [73.7]	25.5
3.0 [76.2]	25.2
3.1 [78.8]	25
3.22 [81.8]	24.5

7. Checking Calibration

7.1 Whenever any instrument is to be used after a period of nonuse, the zero point and the black dial or meter readings of one or more coating thickness standards must be determined to see if the instrument is in calibration.

8. Calibration of Secondary Instruments

8.1 *Correlating Ferrite Percentage of Secondary Standards with Primary Instruments*:

8.1.1 Determine the proper readings (black dial or meter) with a calibrated instrument for each secondary standard[8].

8.1.1.1 Measure each secondary standard with a primary instrument and note the black dial or meter reading. Tabulate the results.

8.1.1.2 Determine the reading from the secondary instrument for each secondary standard. Make several readings on each standard.

8.1.1.3 Plot the black dial or meter readings and the readings from the secondary instrument. This curve can be used to obtain the ferrite percentage of the material measured with the secondary instrument from the primary calibration curve.

8.2 *Secondary Instruments that have Set Point Readings*:

8.2.1 Measure each secondary standard with various inserts in the secondary instrument set.

8.2.1.1 Note the lowest ferrite percentage of the secondary standard set that will pull the measuring magnet of the instrument away from the insert.

8.2.1.2 Note the highest ferrite percentage of the secondary standard set that will not pull the measuring magnet of the instrument from the insert.

8.2.1.3 For each insert, tabulate the values obtained in 8.2.1.1 and 8.2.1.2. Each insert will be designated as "greater than ________ ferrite percentage less than __________ ferrite percentage."

9. Checking of Calibration of Secondary Instruments

9.1 Before using a secondary instrument to measure the ferrite content of a casting, it should be checked with one or more of the secondary standards.

9.1.1 Periodically, the set of secondary standards shall be checked with the primary instrument by determining the proper readings. Compare these values with those obtained in 8.1.1.

10. Keywords

10.1 calibration; ferrite; stainless steel castings

[8] The secondary standards may be produced by a foundry that produces cast stainless steel or purchased from an organization such as NIST (Standard Reference Materials 8480 and 8481 are available from the NIST Standard Reference Materials Program at 100 Bureau Drive, Stop 2322, Gaithersburg, MD 20899–2322; http://ts.nist.gov/ts/htdocs/230/232/232.htm).

SUMMARY OF CHANGES

Subcommittee A01.18 has identified the location of selected changes to this standard since the last issue (A 799/A 799M – 92(2002)) that may impact the use of this standard.

(1) Eliminated references to specific NIST coating thickness standards in several places, including the deletion of Table 1.
(2) Revised the discussion of the definition of *ferrite percentage*.
(3) Revised 4.4.
(4) Added Notes 1 and 2.
(5) Removed Fig. 1, and replaced it with Eq. 1 and a new Table 1.
(6) Revised 6.1.5 and 6.2.6.1.

Designation: A 800/A 800M – 01

Standard Practice for Steel Casting, Austenitic Alloy, Estimating Ferrite Content Thereof[1]

This standard is issued under the fixed designation A 800/A 800M; 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 practice covers procedures and definitions for estimating ferrite content in certain grades of austenitic iron-chromium-nickel alloy castings that have compositions balanced to create the formation of ferrite as a second phase in amounts controlled to be within specified limits. Methods are described for estimating ferrite content by chemical, magnetic, and metallographic means.

1.2 The grades covered by this practice are: CF-3, CF-3A, CF-8, CF-8A, CF-3M, CF-3MA, CF-8M, CF-8C, CG-8M, and CH-10.

1.3 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 must be used independently of the other. Combining values from the two systems may result in nonconformance with the practice.

1.4 *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 determine the applicability of regulatory limitations prior to use.*

2. Referenced Documents

2.1 *ASTM Standards:*

A 351/A 351M Specification for Castings, Austenitic, Austenitic–Ferritic (Duplex), for Pressure–Containing Parts[2]

A 370 Test Methods and Definitions for Mechanical Testing of Steel Products[3]

A 799/A 799M Practice for Steel Castings, Stainless, Instrument Calibration, for Estimating Ferrite Content[2]

A 941 Terminology Relating to Steel, Stainless Steel, Related Alloys, and Ferroalloys[4]

E 38 Methods for Chemical Analysis of Nickel-Chromium and Nickel-Chromium-Iron Alloys[5]

E 353 Test Methods for Chemical Analysis of Stainless, Heat-Resisting, Maraging, and Other Similar Chromium-Nickel-Iron Alloys[6]

E 562 Practice for Determining Volume Fraction by Systematic Manual Point Count[7]

2.2 *Constitution Diagrams:*

Schoefer Diagram for Estimating Ferrite Content of Stainless Steel Castings (1980 revision)[8]

Schaeffler Diagram for Estimating Ferrite Content of Stainless Steel Weld Metal[9]

DeLong Diagram for Estimating Ferrite Content of Stainless Steel Weld Metal[10]

2.3 *American Welding Society Specification:*

AWS A 4.2, Procedures for Calibrating Magnetic Instruments to Measure the Delta Ferrite Content of Austenitic Stainless Steel Weld Metal[11]

3. Terminology

3.1 *Definitions:*

3.1.1 *ferrite*—the ferromagnetic, body-centered, cubic-microstructural constituent of variable chemical composition in iron-chromium-nickel alloys. This may be formed upon solidification from the molten metal (delta ferrite) or by transformation from austenite or sigma phase on cooling in the solid state (alpha ferrite).

3.1.2 *ferrite content*—the proportion of total volume of an iron-chromium-nickel alloy present as the ferrite phase.

3.1.3 *ferrite number*—the ferrite content expressed as an arbitrary number based on the magnetic response of the alloy in a weld deposit.

3.1.4 *ferrite percentage*—the ferrite content expressed as a volume percent.

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[1] This practice is under the jurisdiction of ASTM Committee A01 on Steel, Stainless Steel, and Related Alloys and is the direct responsibility of Subcommittee A01.18 on Castings.

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[2] *Annual Book of ASTM Standards*, Vol 01.02.

[3] *Annual Book of ASTM Standards*, Vol 01.03.

[4] *Annual Book of ASTM Standards*, Vol 01.01.

[5] Discontinued; see *1988 Annual Book of ASTM Standards*, Vol 03.05.

[6] *Annual Book of ASTM Standards*, Vol 03.05.

[7] *Annual Book of ASTM Standards*, Vol 03.01.

[8] Appendix of this practice.

[9] *Metal Progress Data Book*, American Society for Metals, Mid June 1977, p. 161.

[10] *Welding Journal*, American Welding Society, Vol 38, No. 7, July 1973, p. 293–s.

[11] Available from the American Welding Society, P. O. Box 351040, 550 N. W. LeJeune Rd., Miami, FL 33135.

3.1.5 *heat treatment*—the definitions in Terminology A 941 are applicable to this practice.

4. Significance and Use

4.1 The tensile and impact properties, the weldability, and the corrosion resistance of iron-chromium-nickel alloy castings may be influenced beneficially or detrimentally by the ratio of the amount of ferrite to the amount of austenite in the microstructure. The ferrite content may be limited by purchase order requirements or by the design construction codes governing the equipment in which the castings will be used. The quantity of ferrite in the structure is fundamentally a function of the chemical composition of the alloy and its thermal history. Because of segregation, the chemical composition, and, therefore, the ferrite content, may differ from point to point on a casting. Determination of the ferrite content by *any* of the procedures described in the following practice is subject to varying degrees of imprecision which must be recognized in setting realistic limits on the range of ferrite content specified. Sources of error include the following:

4.1.1 *In Determinations from Chemical Composition*—Deviations from the actual quantity of each element present in an alloy because of chemical analysis variance, although possibly minor in each case, can result in substantial difference in the ratio of total ferrite-promoting to total austenite-promoting elements. Therefore, the precision of the ferrite content estimated from chemical composition depends on the accuracy of the chemical analysis procedure.

4.1.2 *In Determinations from Magnetic Response*—Phases other than ferrite and austenite may be formed at certain temperatures and persist at room temperature. These may so alter the magnetic response of the alloy that the indicated ferrite content is quite different from that of the same chemical composition that has undergone different thermal treatment. Also, because the magnets or probes of the various measuring instruments are small, different degrees of surface roughness or surface curvature will vary the magnetic linkage with the material being measured.

4.1.3 *In Determinations from Metallographic Examination*—Metallographic point count estimates of ferrite percentage may vary with the etching technique used for identification of the ferrite phase and with the number of grid points chosen for the examination, as explained in Test Method E 562.

4.2 The estimation of ferrite percent by chemical composition offers the most useful and most common method of ferrite control during melting of the metal.

4.3 For most accurate estimate of ferrite percent, a quantitative metallographic method should be used.

5. Ordering Information

5.1 Orders for material to this practice should include the following as required:

5.1.1 Applicable ASTM product specification or other document covering product requirements,

5.1.2 Alloy grade,

5.1.3 Required ferrite content range, in volume percent, of the castings after final heat treatment. Also, if desired by the purchaser, required ferrite content range, in ferrite number, for weld deposits (Note 1) as deposited, and

5.1.4 Supplementary requirements, if any, desired.

NOTE 1—There may be a substantial decrease in the ferrite content of weld deposits after solution heat treatment in comparison with the as-deposited value.

6. General Caution

6.1 In specifying ferrite content as required in 5.1.3, the purchaser should not set limits that conflict with applicable material specification requirements: for example, a maximum limit of 10 % ferrite for Grade CF-3A in Specification A 351/A 351M for which the minimum tensile strength requirement is 77 ksi [530 MPa].

6.2 When Supplementary Requirement S1 is specified, the purchaser should set ferrite content limits that are compatible with the measuring instrument to be used.

7. Estimation of Ferrite Content

7.1 Estimation in the base metal of the casting by chemical composition in accordance with the Schoefer diagram (see Appendix X1):

7.1.1 A chemical analysis of the heat from which the castings are poured shall include the following elements whether or not required by the chemical requirements of the product specification: carbon, manganese, silicon, chromium, nickel, molybdenum, columbium, and nitrogen.

7.1.1.1 Upon written agreement between the purchaser and the producer, an estimated nitrogen content may be reported instead of an amount determined by analysis of the specific heat if actual chemical analyses have been made for nitrogen in a sufficient number of heats of the same alloy type, produced by the same melting practice, to establish the average nitrogen content to be expected.

7.1.2 The ferrite content of the casting shall be estimated from the central line of the diagram at the composition ratio of "chromium equivalent" (Cr_e) to "nickel equivalent" (Ni_e) determined from the following formula:

$$\begin{aligned}&(Cr(\%) + 1.5Si(\%) + 1.4Mo(\%) + Cb(\%) - 4.99)/(Ni(\%)\\&\quad +30C(\%) + 0.5Mn(\%) + 26(N - 0.02\%) + 2.77)\\&\quad = (Cr_e)/(Ni_e)\end{aligned}$$

7.1.3 When a product analysis is made by the purchaser, it shall include the elements listed in 7.1.1. If a comparison is made of ferrite content estimated from a product analysis performed by the purchaser, with that estimated from the heat analysis (see 7.1.1), the reproducibility data in the precision statements of Test Methods E 353 shall be used as a guide.

7.1.3.1 Methods E 38 or Test Methods E 353, as applicable, shall be used as referee chemical analysis methods.

7.2 Estimation in weld deposits by chemical composition in accordance with the Schaeffler or DeLong diagrams:

7.2.1 The ferrite content shall be estimated (*a*) from the deposit chemical analysis included on the electrode manufacturer's certified material test report, or (*b*) from chemical analysis of a weld deposit pad made by the casting manufacturer.

7.3 Estimation of ferrite content in heat, product, or weld metal may be made by the magnetic response or metallographic methods by imposition of Supplementary Requirements S1 or S2, respectively.

8. Acceptance Standards

8.1 Conformance with the required ferrite content range specified in 5.1.3 as indicated by the estimation procedure of 7.1 and 7.2 shall be the basis for acceptance of material supplied under this practice unless other methods of estimation are ordered as supplementary requirements, in which case the supplementary requirement shall be the basis of acceptance.

8.2 If lack of conformance with the ferrite content range specified in 5.1.3 is indicated by a product analysis made by the purchaser (7.1.3) and by a referee analysis as provided in 7.1.3.1, rejection of material shall be subject to the tests of 7.3 as established by written agreement between the manufacturer and the purchaser.

9. Certification

9.1 The manufacturer's certification shall be furnished to the purchaser stating that the material was sampled and tested in accordance with the specification (including year date) and was found to meet the requirements.

9.2 The test report shall contain the results of the actual chemical analyses required by 7.1.1 and 7.2.1 and the indicated ferrite content range. The estimates of ferrite content from magnetic measurements (S1) or from point counts (S2), or both, if ordered by the purchaser, also shall be reported.

9.3 The test report shall be signed by an authorized agent of the manufacturer.

9.4 The test report shall be furnished within five working days of shipment of the castings.

10. Keywords

10.1 austenite; austenitic stainless steel; ferrite; Schoefer Diagram; steel castings

SUPPLEMENTARY REQUIREMENTS

The following supplementary requirements are for use when desired by the purchaser. They shall not apply unless specified in the order, in which event the specified methods of ferrite content estimation shall be employed by the manufacturer before shipment of the castings.

S1. Estimation of Ferrite Content by Measurement of Magnetic Response

S1.1 The ferrite content of the heat from which the castings are poured shall be estimated from measurements made by primary or secondary instruments calibrated in accordance with the requirements of Practice A 799/A 799M. All measurements shall be made on material after the solution heat treatment required by the applicable product specification, or, if any subsequent solution heat treatment is employed, then after the final solution heat treatment.

S1.1.1 *Location of measurements—base metal:*

S1.1.1.1 Measurements shall be made on the unstrained ends of tension test specimens from the same heat as the castings represented. Measurements may be made either before or after performance of the tension test. If a tension test is not required by the applicable product specification, measurements may be made on a specimen cut from a keel block of a design in Fig. 3 of Test Methods and Definitions A 370.

S1.1.1.2 When further specified, measurements shall be made on the base metal of the castings, or a specified sample of castings (*not* on weld repairs or other weld deposits), in locations designated on the design drawing or as otherwise agreed in writing between the purchaser and the manufacturer.

S1.2 The ferrite content of weld deposits shall be estimated from measurements made by primary or secondary instruments calibrated in accordance with the requirements of Specification AWS A4.2. All measurements shall be made on weld deposits as deposited.

S1.2.1 *Location of measurements—weld deposits:*

S1.2.1.1 Measurements shall be made on a weld pad deposited in accordance with the electrode specification.

S1.2.1.2 When further specified, measurements shall be made on repair or fabrication welds on castings in locations as agreed in writing between the purchaser and manufacturer.

S1.3 *Number of Measurements*—Six measurements shall be made at random in each designated location. For instruments having probes making two contacts with the surface being measured, a "measurement" shall consist of a pair of readings taken with the probe oriented on perpendicular axes.

S1.4 *Surface Condition:*

S1.4.1 The instrument magnet or probe and the surface to be measured shall be dry and cleaned prior to testing to remove any scale, grease, lint, or dirt that could affect the accuracy of measurement.

S1.4.2 Measurements shall be made more than 0.25 in. [6.350 mm] from the edge of a surface. When measurements are made on a curved surface the radius of curvature must be greater than 0.375 in. [9.525 mm].

S1.5 *Acceptance Criteria:*

S1.5.1 The average of the ferrite contents estimated from measurements in each designated location shall be within the limits stated in the order, and not more than two individual measurements shall indicate ferrite contents less than or in excess of these limits.

S1.5.1.1 If ferrite contents are estimated with an instrument that indicates for each measurement a value between an upper and a lower limit, more than one-half of all measurements shall be within the limits stated in the order.

S1.5.2 Should the requirements of S1.5.1 not be met, a referee estimation of ferrite content may be made by the metallographic method of Supplementary Requirement S2 that shall take precedence over the magnetic method.

S2. Estimation of Ferrite Content by Metallographic Examination

S2.1 The locations of specimens to be examined shall be specified on the drawing radiographic shooting sketch, or otherwise in writing by the purchaser.

S2.2 Specimens shall be prepared so that metallographic examination may be made on three orthogonal planes.

S2.3 The volume fraction of ferrite shall be estimated from the specimens by the point count practice recommended in Test Method E 562.

APPENDIX

(Nonmandatory Information)

X1. NOTES TO SCHOEFER DIAGRAM

X1.1 Fig. X1.1 is applicable to alloys containing elements in the following ranges:

	Weight, %
Carbon	0.20 max
Manganese	2.00 max
Silicon	2.00 max
Chromium	17.0 to 28.0
Nickel	4.0 to 13.0
Molybdenum	4.00 max
Columbium	1.00 max
Nitrogen	0.20 max

X1.2 The Cr_e/Ni_e Composition Ratio necessary to produce alloy castings within a specified ferrite content range may be read from the diagram at the intersection of the central line with the desired ferrite percentage, or may be obtained from Table X1.1. *Example:* For a ferrite content of 12 % the composition ratio should be 1.234.

X1.3 The estimated average ferrite content of castings may be read from the diagram at the intersection of the central line with the composition ratio calculated from the chemical composition of the heat from which they were poured. Because of errors in chemical analyses, the calculated ratio may differ

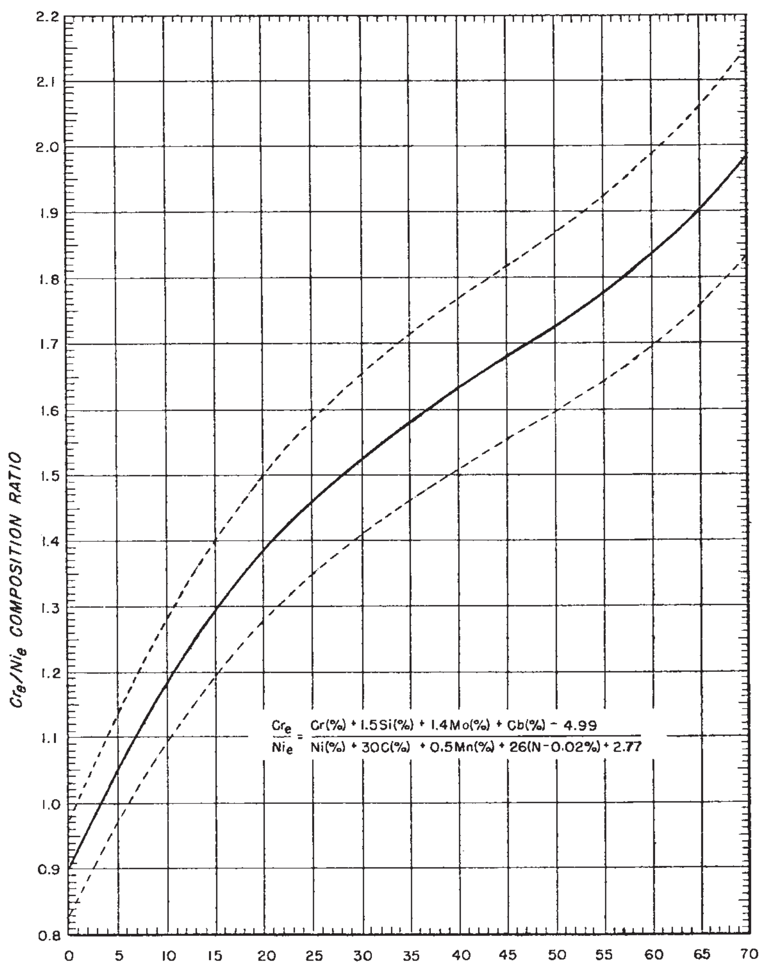

FIG. X1.1 Schoefer Diagram for Estimating the Average Ferrite Content in Austenitic Iron-Chromium-Nickel Alloy Castings

TABLE X1.1 Composition Ratio Required for a Desired Ferrite Content

Volume Percent Ferrite	0	1	2	3	4	5	6	7	8	9
0	0.900	0.933	0.966	0.997	1.027	1.056	1.084	1.111	1.138	1.163
10	1.187	1.211	1.234	1.256	1.277	1.297	1.317	1.336	1.354	1.371
20	1.388	1.405	1.420	1.436	1.450	1.464	1.478	1.491	1.504	1.516
30	1.528	1.540	1.551	1.562	1.573	1.584	1.594	1.604	1.614	1.623
40	1.633	1.643	1.652	1.661	1.671	1.680	1.689	1.699	1.708	1.718
50	1.728	1.737	1.747	1.758	1.768	1.779	1.790	1.801	1.813	1.825
60	1.837	1.850	1.863	1.877	1.891	1.906	1.921	1.937	1.953	1.970
70	1.988									

from the actual composition ratio and, as a result, the ferrite content may be higher or lower than indicated by the central line. Accordingly, if additional estimates of ferrite content are made by magnetic or metallographic methods, they can be expected to differ from the diagram value. The possible extent of this difference is shown by the broken lines. *Example:* If the composition ratio is 1.234, the indicated ferrite content is 12 % with a probable maximum range from 8 to 17 %. Similar information is available in Table X1.2.

X1.4 The ferrite content ranges are related to the upper and lower bounds of the composition ratio that are determined from the ratios $1.04Cr_e/0.96Ni_e$ and $0.96Cr_e/1.04Ni_e$. These correspond approximately to $\pm 1\ \sigma$ deviations in all the ferrite promoting elements and $\pm 1\ \sigma$ deviations in all the austenite promoting elements (based on standard deviations of individual elements as derived in a round-robin test project of the Steel Founders' Society of America).

X1.5 Values of composition ratio (*CR*) for a given ferrite content (*F*), or vice versa, may be determined mathematically from the equation of the central line:

$$CR = 0.9 + 3.38883 \times 10^{-2}F - 5.58175 \times 10^{-4}F^{2} + 4.22861 \times 10^{-6}F^{3}$$

TABLE X1.2 Volume Percent Ferrite Indicated by Composition Ratio

	Composition Ratio[A]	0.00	0.01	0.02	0.03	0.04	0.05	0.06	0.07	0.08	0.09
U		0.0	0.0	0.0	0.0	0.5	0.5	1.0	1.5	1.5	2.0
	0.80	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
L		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
U		2.5	2.5	3.0	3.5	3.5	4.0	4.5	5.0	5.0	5.5
	0.90	0.0	0.5	0.5	1.0	1.0	1.5	2.0	2.0	2.5	3.0
L		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.5
U		6.0	6.5	7.0	7.0	7.5	8.0	8.5	9.0	9.5	9.5
	1.00	3.0	3.5	4.0	4.0	4.5	5.0	5.0	5.5	6.0	6.0
L		0.5	1.0	1.5	1.5	2.0	2.0	2.5	2.5	3.0	3.0
U		10.0	10.5	11.0	11.5	12.0	12.5	13.0	13.5	14.0	14.5
	1.10	6.5	7.0	7.5	7.5	8.0	8.5	9.0	9.5	9.5	10.0
L		3.5	4.0	4.0	4.5	5.0	5.0	5.5	6.0	6.0	6.5
U		15.0	15.5	16.5	17.0	17.5	18.0	18.5	19.5	20.0	20.5
	1.20	10.5	11.0	11.5	12.0	12.5	12.5	13.0	13.5	14.0	14.5
L		7.0	7.0	7.5	8.0	8.5	8.5	9.0	9.5	10.0	10.0
U		21.0	22.0	22.5	23.5	24.0	25.0	25.5	26.5	27.5	28.0
	1.30	15.0	15.5	16.0	16.5	17.0	18.0	18.5	19.0	19.5	20.0
L		10.5	11.0	16.5	11.5	12.0	12.5	13.0	13.5	14.0	14.5
U		29.0	30.0	31.0	32.0	33.0	34.0	35.0	36.0	37.0	38.0
	1.40	20.5	21.5	22.0	22.5	23.5	24.0	24.5	25.5	26.0	27.0
L		15.0	15.0	15.5	16.0	16.5	17.0	17.5	18.0	18.5	19.0
U		39.0	40.5	41.5	42.5	43.5	45.0	46.0	47.0	48.5	49.5
	1.50	27.5	28.5	29.5	30.0	31.0	32.0	33.0	33.5	34.5	35.5
L		20.0	20.5	21.0	21.5	22.0	22.5	23.5	24.0	24.5	25.0
U		50.5	51.5	52.5	54.0	55.0	56.0	56.5	57.5	58.5	59.5
	1.60	36.5	37.5	38.5	39.5	40.5	42.0	43.0	44.0	45.0	46.0
L		26.0	26.5	27.5	28.0	29.0	29.5	30.5	31.0	32.0	33.0
U		60.5	61.0	62.0	63.0	63.5	64.5	65.0	66.0	66.0	67.0
	1.70	47.0	48.0	49.0	50.0	51.5	52.0	53.0	54.0	55.0	56.0
L		33.5	34.5	35.5	36.5	37.0	38.0	39.0	40.0	41.0	42.0

TABLE X1.2 *Continued*

Composition Ratio[A]	0.00	0.01	0.02	0.03	0.04	0.05	0.06	0.07	0.08	0.09
U	68.0	68.5	69.0	69.5	70.5	>70				
1.80 [e1]	57.0	58.0	58.5	59.5	60.0	61.0	62.0	62.5	63.0	64.0
L	43.0	44.0	45.0	46.0	47.0	48.0	49.0	50.0	51.0	51.5
U	>70									
1.90	64.5	65.5	66.0	66.5	67.0	68.0	68.5	69.0	69.5	70.0
L	52.5	53.5	54.5	55.0	56.0	57.0	57.5	58.5	59.0	60.0
U	>70									
2.00	>70									
L	61.0	61.5	62.0	63.0	63.5	64.0	64.5	65.5	66.0	66.5
U	>70									
2.10	>70									
L	67.0	67.5	68.0	69.0	69.5	70.0	>70			

[A] For a given composition ratio the ferrite content estimate will be found at the intersection of the appropriate line and column. The figures immediately above and below on the lines *U* and *L* indicate the probable upper and lower bounds of the ferrite range that may be expected.

[e1] Corrected editorially.

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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.

Designation: A 802/A 802M – 95 (Reapproved 2001)

Standard Practice for Steel Castings, Surface Acceptance Standards, Visual Examination[1]

This standard is issued under the fixed designation A 802/A 802M; 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 practice covers the acceptance criteria for the surface inspection of steel castings by visual examination. Four levels of acceptance standards are provided.

1.2 Acceptance levels utilize Steel Castings Research and Trade Association (SCRATA)[2] graded reference comparators for the visual determination of surface texture, surface roughness, and surface discontinuities described as follows:

Acceptance levels

A—Surface Texture
B—Nonmetallic Inclusions
C—Gas Porosity
D—Solidification Discontinuities
E—Sand Expansion Discontinuities
F—Metal Inserts
G—Thermally Cut Surfaces
H—Mechanically Prepared Surfaces
J—Welded Surfaces

1.3 Descriptions of terms related to casting discontinuities are in Section 2.

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. Terminology

2.1 *Definitions of Terms Specific to This Standard:*

2.1.1 *expansion discontinuities:*

2.1.1.1 *veins, n*—raised, narrow, linear ridges that form upon cracking of the sand mold or core due to expansion of sand and the resulting mold or core stresses during filling of the mold with liquid steel.

2.1.1.2 *rat tails, n*—long, narrow, linear depressions or small steps occurring on a casting surface. Rat tails form as a result of sand expansion and minor buckling of the mold surface during filling of the mold with liquid metal.

2.1.1.3 *scab, n*—a raised, rough area on a casting that usually consists of a crust of metal covering a layer of sand. Sometimes, a scab consists of a raised, rough area of essentially solid metal on the surface of a casting.

2.1.2 *external chills:*

2.1.2.1 *external chills, n*—usually metal blocks, or graphite and carbon blocks, that are incorporated into the mold to locally increase the rate of heat removal during solidification. Brackets have the same purpose but represent an integral part of the casting. Brackets are produced by providing suitable cavities in the mold or core. External chills may produce flat spots and edges (raised areas or depressions) on the casting surface. Brackets merely change the casting appearance due to their presence. Brackets may be removed or allowed to remain on the casting.

2.1.2.2 *parting line and core print fins, n*—thin projections of excess metal at the parting plane between mold halves or core and mold. Causes are improper closing of the mold, insufficient weighting or clamping of the mold for pouring, or uneven pattern surfaces at the matching locations. Core print fins are usually caused by improper dimensions of core prints of the pattern or core box, by rough placement of cores in a soft mold, or by inadequately secured cores.

2.1.3 *fusion discontinuities:*

2.1.3.1 *wrinkles, n*—elongated, smooth depressions of the casting surface, frequently appearing in closely spaced groups. Wrinkles result from irregularities of the liquid metal flow in the mold cavity, frequently associated with low temperature, and are distinguished from the more severe phenomenon of laps, folds, or cold shuts where the casting surface is actually folded over.

2.1.3.2 *laps, folds, and cold shuts, n*—interchangeable terms to describe the appearance of the casting surface that is actually folded over. They develop due to low temperature, unfavorable flow conditions caused by oxide films, or combinations thereof.

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[1] This practice is under the jurisdiction of ASTM Committee A01 on Steel, Stainless Steel, and Related Alloysand is the direct responsibility of Subcommittee A01.18 on Castings.

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[2] Available from The Castings Development Centre, 7 East Bank Road, Sheffield, UK S2 3PT.

2.1.3.3 *misrun, n*—an incompletely formed casting, due to only partial filling of the mold cavity when the liquid metal solidifies prematurely. The resulting casting appearance is characterized by rounded edges, for a mild degree of misrun. Irregular, malformed edges of more severe misruns, and not fully formed castings, are characteristic. Frequently, misruns are associated with such discontinuities as wrinkles or laps and folds, or both.

2.1.4 *gas porosity, n*—a concave discontinuity in castings due to the evolution of gas, either from the solidifying metal or the surrounding mold.

2.1.5 *inserts:*

2.1.5.1 *chaplets, n*—metallic (steel) devices used to maintain the spacing between the core and the mold. Low liquid metal temperature and unfavorable flow conditions in the mold may produce insufficient fusion and cause irregular contact areas on the casting surface.

2.1.5.2 *internal chills, n*—metallic (steel) devices used to locally increase the rate of heat removal during solidification. Incomplete fusion due to low liquid steel temperatures and prevailing flow conditions may produce irregularities of the surface similar to those that may be associated with chaplets.

2.1.6 *linear discontinuities, n*—elongated discontinuities are considered linear if their length equals or exceeds three times the width.

2.1.6.1 *cracks, n—cold and hot*, less jagged, sometimes straight ruptures that occur after solidification of the casting, due to excessive strain. Sometimes cracks are referred to as cold, hot, or heat treat-cracks to indicate the condition of the castings, or the operation during which the cracks occur.

2.1.6.2 *hot tears, n*—jagged ruptures in castings that occur during the final stages of solidification, while there is still some liquid in the interdendritic spaces, or shortly after solidification is complete.

2.1.7 *metal removal marks, n*—flame cutting and air carbon-arc cutting produce parallel grooves in the cut-off area. Finer marks are produced with the abrasive cut-off wheel and grinding.

2.1.8 *nonmetallic inclusions, n*—casting surface inclusions such as ceroxides, slag, and sand are partially or completely removed during the cleaning process of pressure blasting. Surface discontinuities left by these inclusions are referred to by the inclusion type that caused their formation:

2.1.8.1 Ceroxides cause depressions on the surface of the casting by displacement of molten metal. Ceroxides consist of a mixture of low-melting oxides and partially fused sand. The crater-like appearance of the casting surface depression is typical.

2.1.8.2 Depressions on the casting surface caused by slag are similar to those caused by ceroxides. They differ by a more rounded appearance of the depression and do not exhibit the crater-like appearance of ceroxides.

2.1.8.3 Depressions caused by sand are similar to those of ceroxides and slag. Their appearance may, at times, more closely reflect the granular nature of the sand.

2.1.9 *shrinkage under risers and gates, and revealed by machining, n*—a shrinkage void is a discontinuity in castings due to the lack of available liquid feed metal during solidification contraction. Riser removal and machining may reveal shrinkage that extends from the interior of the casting to the near surface area.

2.1.10 *surface texture, n*—cast surfaces have a multidirectional lay, without the uniform sequence of ridges and valleys of machined surfaces.

2.1.11 *welding:*

2.1.11.1 *weld undercuts, n*—narrow elongated depressions that border the weld contour and result from improper welding conditions or inadequate control of welding operations.

2.1.11.2 *weld spatter, n*—weld metal droplets that solidified against and adhere to the component being welded.

3. Ordering Information

3.1 The inquiry and order should specify the following information:

3.1.1 *Acceptance Level*—More than one acceptance level may be specified for different surfaces of the same casting (see Section 4),

3.1.2 If any types of discontinuities are unacceptable,

3.1.3 Extent of casting surfaces to be examined, and

3.1.4 Number of castings to be examined.

4. Acceptance Standards

4.1 Levels of acceptance for visual inspection are listed in Table 1.

4.2 Surface discontinuities not covered in Practice A 802/A 802M shall be a matter of agreement between the purchaser and the manufacturer.

5. Keywords

5.1 steel castings; surface acceptance standards; visual

TABLE 1 Visual Inspection Acceptance Criteria

Surface Feature	Level I	Level II	Level III	Level IV
Surface texture	A1	A2	A3	A4
Nonmetallic inclusions	B1	B2	B4	B5
Gas porosity	C2	C1	C3	C4
Fusion discontinuities	. . .[A]	D1	D2	D5
Expansion discontinuities	. . .[A]	. . .[A]	E3	E5
Inserts	. . .[A]	. . .[A]	F1	F3
Metal removal marks:				
Thermal	G1	G2	G3	G5
Mechanical	H1	H3	H4	H5
Welds	J1	J2	J3	J5

[A] No reference comparator plate is available for this surface feature and level.

Standard Specification for Statically Cast Permanent Mold Gray Iron Castings[1]

This standard is issued under the fixed designation A 823; 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 gray iron castings that are statically cast in permanent molds.

1.2 No precise quantitative relationship can be stated between the properties of the iron in various locations of the same casting or between the properties of a casting and those of a test specimen cast from the same iron (see Appendix X1).

1.3 The values stated in inch-pound units are to be regarded as the standard.

2. Referenced Documents

2.1 *ASTM Standards:* [2]

A 247 Test Method for Evaluating the Microstructure of Graphite in Iron Castings

A 644 Terminology Relating to Iron Castings

E 8 Test Methods for Tension Testing of Metallic Materials

E 10 Test Method for Brinell Hardness of Metallic Materials

2.2 *Federal Standard:*

Fed. Std. No. 123 Marking for Shipment[3]

2.3 *Military Standard:*

MIL-STD-129 Marking for Shipment and Storage[3]

3. Terminology

3.1 Definitions for many terms common to iron castings are found in Terminology A 644. A classification of graphite structure is found in Test Method A 247.

4. Classification

4.1 Castings ordered and produced under this specification are classified into a number of grades based on the properties of separately cast test bars. The test bar shall be selected on the basis of the controlling section size of the casting (see 9.1 and 9.2 and Table 1).

TABLE 1 Permanent Mold Gray Iron Specifications

Grade	Tensile Strength, min, ksi (MPa)[A]	BHN
	Uncored—Annealed	
A-SA	30 000 (207)	163–207
A-SB	25 000 (172)	163–207
A-SC	20 000 (138)	163–207
A-SS	18 000 (124)	143–207
	Cored—Annealed	
A-CA	30 000 (207)	143–207
A-CB	25 000 (172)	143–207
A-CC	20 000 (138)	143–207
	Uncored—Normalized	
N-SA	30 000 (207)	170–229
N-SB	25 000 (172)	170–229
N-SC	20 000 (138)	170–229
N-SS	18 000 (124)	149–229
	Cored—Normalized	
N-CA	30 000 (207)	170–229
N-CB	25 000 (172)	149–229
N-CC	20 000 (138)	149–229

[A] Refer to Fig. X1.1 for the relationship between tensile strength and section size.

4.2 Castings may be produced in the as cast state provided the requirements of this standard in Table 1 are met. However, annealing or normalizing heat treatments are usual and customary and are a basis for classification.

4.3 The grades are designated A for annealed or N for normalized. This is followed by an S or a C to designate a solid or a cored casting, followed by an A, B, C, or S to designate the test bar to be poured with the castings. Examples of proper designations are as follows:

Permanent Mold Castings, ASTM Specification A 823, Grade N-SB

Permanent Mold Castings, ASTM Specification A 823, Grade A-CC

5. Ordering Information

5.1 Orders for material to this specification shall include the following information:

5.1.1 ASTM designation number and year of issue.

5.1.2 Grade of iron required (see Section 4 and Table 1).

5.1.3 The size of the separately cast test bar (letter classification A, B, C, or S) which best represents the thickness of the controlling section of the casting (see 4.1 and Table 2).

5.1.4 Location for Brinell Hardness determination (see 10.1.1).

[1] This specification is under the jurisdiction of ASTM Committee A04 on Iron Castings and is the direct responsibility of Subcommittee A04.01 on Gray Iron Castings.

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[2] 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.

[3] Available from Standardization Documents Order Desk, Bldg. 4 Section D, 700 Robbins Ave., Philadelphia, PA 19111-5094, Attn: NPODS.

TABLE 2 Diameters and Lengths of Cast Test Bars

Test Bar	As-Cast Diameter, in. (mm)[A]			Length, in. (mm)	
	Nominal (Mid-Length)	Minimum (Bottom)	Maximum (Top)	Minimum (Specified)	Maximum (Recommended)
A	0.88 (22.4)	0.85 (21.6)	0.96 (24.4)	5.0 (125)	6.0 (150)
B	1.20 (30.5)	1.14 (29.0)	1.32 (33.5)	6.0 (150)	9.0 (230)
C	2.00 (50.8)	1.90 (48.3)	2.10 (53.3)	7.0 (175)	10.0 (255)
S[B]	. . .	. . .	. . .	. . .	. . .

[A] The diameter is the controlling section for the appropriate permanent mold specification (see Section 9).
[B] All dimensions of test bar S shall be agreed upon by the manufacturer and the purchaser.

5.1.5 Lot size (see Section 16).
5.1.6 Special requirements (see Section 17).
5.1.7 Special preparation for delivery (see Section 22).
5.1.8 Saving tested specimens or unbroken test bars (see 19.1.1).

6. Chemical Composition

6.1 The chemical composition shall be such as to produce the mechanical properties required by this specification. As a reference, typical compositions covering all grades are shown in Table X1.1 in Appendix X1.

6.2 By agreement between the manufacturer and purchaser, chemical composition requirements may be specified.

7. Heat Treatment

7.1 Although castings may be provided in the as cast condition, when necessary, heat treatment shall be such as to produce the mechanical properties required in this standard.

8. Tensile Requirements

8.1 Test bars representing castings conforming to this specification shall meet the requirements for tensile strength described in Table 1.

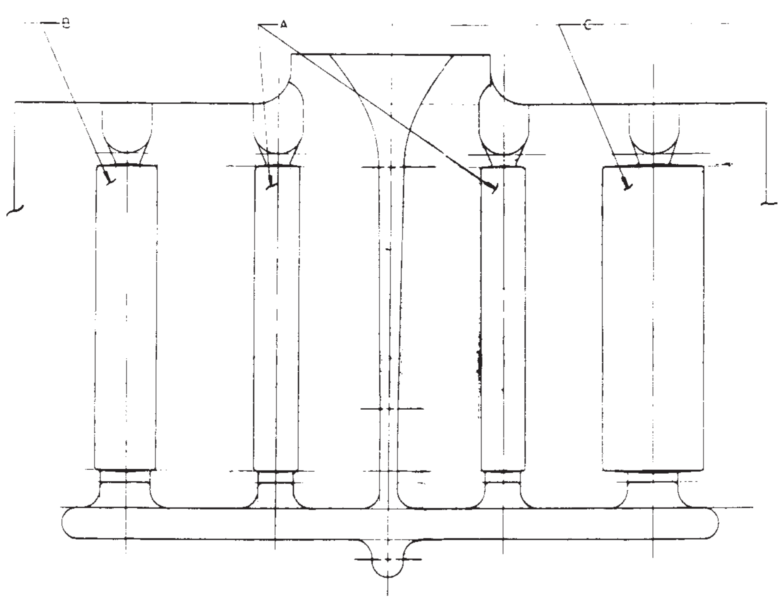
9. Cast Test Bars

9.1 Test bars shall be separate castings poured from the same iron as the castings they represent and shall have dimensions as shown in Table 2. Allowance may be made for reasonable pattern draft within the tolerances shown in Table 2. Test bars A, B, and C are all standard test bars in the form of simple cylinders. Test bar S is special and is intended for use where the controlling section of the casting is over 2 in.

9.2 The test bar selected shall be based on the controlling section size of the casting. This shall be determined by the dimensions of the largest cylinder that will fit into the controlling section of the casting with the additional requirement that the height of the cylinder must be at least equal to its diameter.

9.3 The test bars shall be cast in a permanent mold. The mold shall be of similar material, design, and construction as that used to make the production castings. The test bar permanent mold shall be preheated with three consecutive pours, after which, starting with the fourth pour, the bars can be used for the tension test. A suitable design for a mold is shown in Fig. 1.

9.4 By specific agreement between the manufacturer and the purchaser, test bars removed from the castings may be substituted for separately cast test bars. The location from which the bars are taken shall be as agreed between the parties and indicated on the casting drawing or data base equivalent.



Required Features:
1. Material—Permanent molds.
2. Position—Bars vertical.
3. *L*—See Table 2.
4. *D*—See Table 2.

FIG. 1 Suitable Design and Dimensions for Mold for Separately Cast Cylindrical Test Bars for Gray Iron

9.5 Where test specimens are to represent heat treated castings, they shall accompany the castings in the same heat treat lot(s), or by agreement, be subjected to the same thermal cycle that the castings undergo.

10. Hardness Requirements

10.1 Brinell hardness readings taken on the castings shall conform to the requirements in Table 1.

10.1.1 The area or areas on the castings where the hardness is to be determined shall be established by agreement between manufacturer and purchaser and shall be shown on the casting drawing.

10.1.2 Brinell hardness shall be determined in accordance with Test Method E 10. Sufficient surface material shall be removed (generally 0.010 to 0.030 in.) to ensure that the measured hardness is representative of the basic iron structure.

10.1.3 Brinell hardness measurements shall be undertaken at room temperature, defined as 50–95 °F (10–35 °C).

11. Dimensional Requirements

11.1 The castings shall conform to the dimensions or drawings furnished by the purchaser, or, if there are no drawings, to the dimensions predicted by the pattern equipment supplied by the purchaser.

12. Workmanship and Finish

12.1 The surface of the casting shall be inspected visually, particularly in critical areas, for such surface defects as cracks, hot tears, adhering sand and scale, cold shuts, and gas holes.

12.2 No repairing by plugging or welding of any kind shall be permitted unless written permission is granted by the purchaser.

13. Number of Tests and Retests

13.1 The manufacturer shall cast and prepare at least three test bars for each lot of castings intended to conform to this specification. The manufacturer shall conduct the specified tests unless the manufacturer and purchaser agree that the tests shall be made by another qualified laboratory. Only one bar need be tested if the results conform to the property requirements of this specification. If any test specimen shows defective or improper machining, or obvious lack of continuity of metal, it may be discarded and replaced by another specimen from another test bar from the same lot.

13.2 If after testing, a test specimen shows evidence of a defect, the results of the test may be invalidated and another made on a specimen from the same lot.

13.3 If the results of a valid test fail to conform to the requirements of this specification, two retests shall be made. If either retest fails to meet the specification requirements, the castings represented by these test specimens shall be rejected. A valid test is one wherein the specimen has been properly prepared and appears to be sound and on which the approved test procedure has been followed.

13.4 If sufficient separately cast test pieces are not available, the manufacturer shall have the option of removing a test specimen from a location of representative casting, as agreed upon between the manufacturer and purchaser.

13.5 If the first test results indicate that a heat treatment or an additional heat treatment is needed to meet the test requirements, the entire lot of castings and the representative test specimens shall be heat treated or reheat treated together. Testing shall proceed in accordance with 13.1,13.2,13.3, and 13.4 .

14. Tension Test Specimens

14.1 For test bar A, the tension test specimen A, as shown in Fig. 2, shall be machined concentric with the axis of the test bar.

14.2 For test bar B, the tension test specimen B, as shown in Fig. 2, shall be machined concentric with the axis of the test bar.

14.3 For test bar C, tension test specimen C, as shown in Fig. 2, shall be machined concentric with the axis of the test bar. Unless the size of the tensile test specimen to be machined from test bar C is specified in writing by the purchaser, the decision whether to use tension test specimen B or C shall be made by the manufacturer of the castings.

14.4 For test bar S, the nature and dimensions of the tension test specimen shall be determined by agreement between the manufacturer and the purchaser. Test bar S is to be used whenever the controlling section exceeds 2 in.

15. Tension Test

15.1 Tension testing shall be determined in accordance with Test Methods E 8.

15.2 The tension test specimens shall fit the holders of the testing machine in such a way that the load shall be axial.

15.3 The elapsed time from the beginning of loading in the tension test to the instant of fracture shall be not less than 15 s for test specimen A and not less than 20 s for test specimens B or C.

16. Description of a Lot

16.1 The manufacturer may define a lot as any of the following:

16.1.1 A lot size may be established by agreement between the manufacturer and the purchaser.

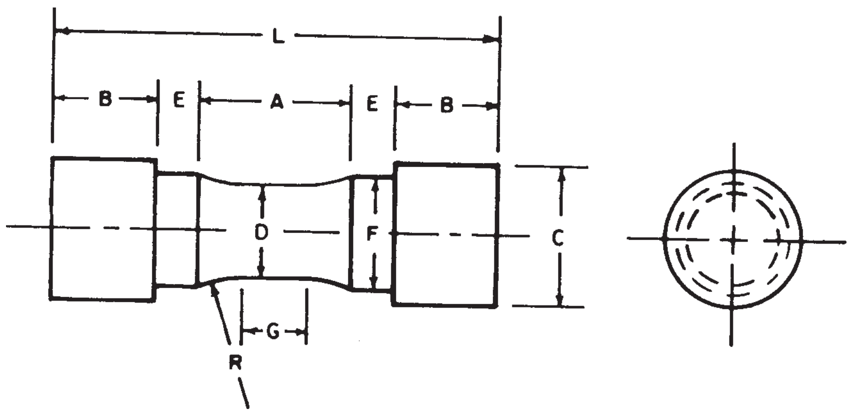
16.1.2 Absent such an agreement as described in 16.1.1, a lot shall be a group of castings weighing less than 2000 lb (910 kg) each when the total weight of the group does not exceed 8000 lb (3600 kg) and when poured continuously within 4 h from the same melt and from consecutive charges of essentially the same percentages and types of materials.

17. Special Requirements

17.1 When agreed upon in writing by the manufacturer and the purchaser, it may be necessary for the castings to meet special requirements as to hardness, chemical composition, microstructure, pressure tightness, radiographic soundness, dimensions, surface finish, etc.

18. Identification Marking

18.1 When the size of the casting permits, each casting shall bear the identifying mark of the manufacturer and the part or



Dimensions, in. (mm)	Tension Test Specimen A	Tension Test Specimen B	Tension Test Specimen C
G—Length of parallel, min	0.50 (13)	0.75 (19)	1.25 (32)
D—Diameter	0.500 ± 0.010 (12.7 ± 0.25)	0.750 ± 0.015 (19.1 x± 0.4)	1.25 ± 0.025 (32 ± 0.6)
R—Radius of fillet, min	1 (25)	1 (25)	2 (50)
A—Length of reduced section, min	1 1⁄4 (32)	1 21⁄32 (42)	2 17⁄32 (64)
L—Overall length, min	3 3⁄4 (95)	4 5⁄32 (106)	6 3⁄8 (160)
C—Diameter of end section, approx	7⁄8 (22.2)	11⁄4 (31.8)	1 7⁄8 (47)
E—Length of shoulder, min	1⁄4 (6)	1⁄4 (6)	5⁄16 (8)
F—Diameter of shoulder	5⁄8 ± 1⁄64 (16 ± 0.5)	15⁄16 ± 1⁄64 (25 ± 0.5)	1 7⁄16 ± 1⁄64 (36 ± 0.5)
B—Length of end section	[A]	[A]	[A]

[A] Optional to fit holders on testing machine. If threaded, root diameter shall not be less than dimension *F*.

FIG. 2 Tension Test Specimens

pattern number at a location shown on the covering drawing or, if not shown on the drawing, at a location at the discretion of the producer.

19. Responsibility for Inspection

19.1 Unless otherwise specified in the contract or purchase order, the manufacturer shall be responsible for carrying out all the tests and inspections required by this specification, using his own or other reliable facilities, and he shall maintain complete records of all such tests and inspections. Such records shall be available for review by the purchaser.

19.1.1 When agreed upon between manufacturer and purchaser, tested specimens or unbroken test bars from the same lot shall be saved for a period for 3 months after the date of the test report.

19.2 The purchaser reserves the right to perform any of the inspections set forth in the specification where such inspections are deemed necessary to assure that supplies and services conform to the prescribed requirements.

20. Rejection and Resubmission

20.1 Any castings or lot of castings failing to comply with the requirements of this specification may, where possible, be reprocessed, retested, and reinspected. If the tests and inspections on the reprocessed casting(s) show compliance with this specification, the castings shall be acceptable; if they do not, they shall be rejected.

20.2 If the purchaser should find that a casting or lot of castings fails to comply with this specification subsequent to receipt at his facility, he shall so notify the manufacturer promptly and in no case later than 6 weeks after receipt of the shipment, stating clearly the basis for rejection.

21. Certification

21.1 When specified by the purchaser's order or contract, a manufacturer's certification or compliance statement that the casting or lot of castings was made, sampled, tested, and inspected in accordance with this specification, including a report of test results signed by an authorized agent of the manufacturer, shall be furnished at the time of shipment, and such certification or compliance statement shall be the basis for acceptance of the casting or lot of castings.

22. Preparation for Delivery

22.1 Unless otherwise stated in the contract or order, the cleaning, preservation, and packing of castings for shipment shall be in accordance with the manufacturer's commercial practice. Packaging and marking shall also be adequate to identify the contents and to ensure acceptance and safe delivery by the carrier for the mode of transportation employed.

22.2 *U.S. Government Procurement*—When specified in the contract or purchase order, marking for shipment shall be in accordance with the requirements of Fed. Std. No. 123 for civil agencies and MIL-STD-129 for military activities.

23. Keywords

23.1 chemical composition; gray iron; hardness; heat treatment; iron castings; statically cast permanent mold; tensile strength

APPENDIXES

(Nonmandatory Information)

X1. MECHANICAL PROPERTIES OF CASTINGS

X1.1 The mechanical properties of iron castings are influenced by the cooling rate during and after solidification, by chemical composition (particularly carbon equivalent)(see Table X1.1), by the design of the casting, by the design and nature of the mold, by the location and effectiveness of gates and risers, and by certain other factors.

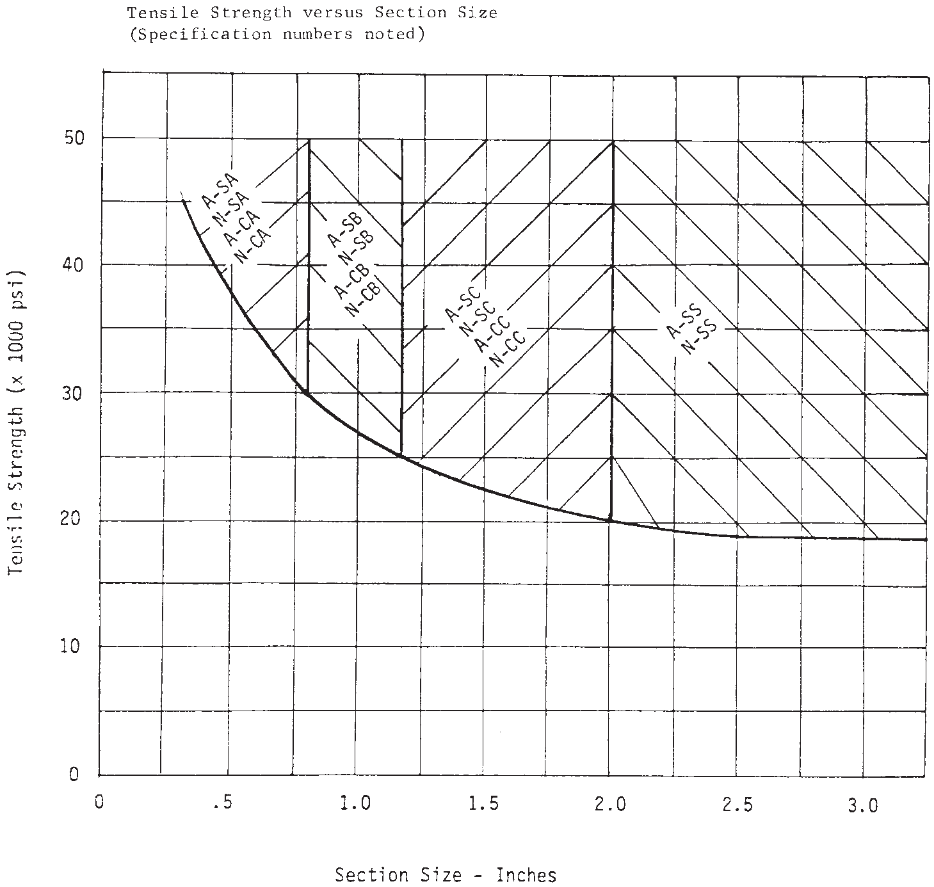
X1.2 The cooling rate in the mold and, hence, the properties developed in any particular section are influenced by the presence of cores, chills and chaplets, changes in section thickness, and the existence of bosses, projections, and intersections, such as junctions of ribs and bosses. Because of the complexity of the interactions of these factors, no precise quantitative relationship can be stated between the properties of the iron in various locations of the same casting or between the properties of a casting and those of a test specimen cast from the same iron. When such a relationship is important and must be known for a specific application, it may be determined by appropriate experimentation.

TABLE X1.1 Typical Chemical Compositions—All Grades

Carbon	3.30–3.70 %
Silicon	2.20–2.80 %
Manganese	0.40–1.00 %
Phosphorus	0.45 % max
Sulfur	0.15 % max

X1.3 When reliable information is unavailable on the relationship between properties in a casting and those in a separately cast test specimen and where experimentation would be unfeasible, the size of the test casting should be so selected as to approximate the thickness of the main or controlling section of the casting (see Fig. X1.1).

X1.4 If iron castings are welded, (see 12.2), the microstructure of the iron is usually altered, particularly in the vicinity of the weldment. Therefore, the properties of the casting may be adversely affected by welding. Where practical, appropriate post weld heat treatment may reduce this effect of the welding.



NOTE—The relationship of permanent mold gray iron tensile strength versus section size is shown above. Castings with controlling section up to 0.875 in. will have a minimum tensile strength of 30 000 psi (207 MPa). Castings with controlling section between 0.875 and 1.2 in. will have a minimum tensile strength of 25 000 psi (172 MPa). Castings with controlling section between 1.2 and 2.0 in. will have a minimum tensile strength of 20 000 psi (138 MPa).

FIG. X1.1 Tensile Strength versus Section Size of Permanent Mold Gray Iron

X2. MICROSTRUCTURE

X2.1 Information on microstructure is given in Table X2.1.

TABLE X2.1 Permanent Mold Gray Iron Graphite and Matrix Information

Grade	Graphite[A]	Matrix
	Uncored—Annealed	
A-SA, A-SB, A-SC	Predominantly type D, size 5-8, some type A, size 4-6	Essentially ferrite
A-SS	Type D, size 5-8 with type A, size 3-6 and some type C	
	Cored—Annealed	
A-CA, A-CB	Predominantly type D, size 5-8 and some type A, size 4-6	Essentially ferrite
A-CC	Type D, size 5-8, type A and B, size 3-6	
	Uncored—Normalized	
N-SA, N-SB	Predominantly type D, size 5-8, some type A, size 4-6	Ferrite plus 10–20 % pearlite
N-SC	Type D, size 5-8 and type A, size 3-6, some type C	Ferrite plus 10–25 % pearlite at surface, up to 50 % at center
N-SS	Type D, size 5-8, type A, size 3-6, some type C	Ferrite plus 10 % pearlite at surface, up to 60 % at center
	Cored—Normalized	
N-CA, N-CB	Predominantly type D, size 5-8, some type A, size 4-6.	Ferrite plus 10–20 % pearlite Ferrite plus 10–20 % pearlite near core
N-CC	Type D, size 5-8, type A and B, size 3-6	Ferrite plus 10 % pearlite at surface and 50 % pearlite at center

[A] Graphite type and size in accordance with Test Method A 247.

X3. HEAT TREATMENT

X3.1 Castings may be in the as-cast, annealed, or normalized conditions.

X3.2 When needed to achieve the requirements of this standard, the annealing or normalizing heat treatment cycles may be determined by the manufacturer.

Standard Specification for Common Requirements for Iron Castings for General Industrial Use[1]

This standard is issued under the fixed designation A 834; 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 a group of requirements that are mandatory requirements when used in conjunction with the following iron casting specifications issued by ASTM:

ASTM Specification[2]
A47
A48
A197
A220
A278
A319
A395
A436
A439
A 518
A 532
A536
A571
A 823
A 842
A 874
A 897

1.2 This specification also covers a group of supplementary requirements which may be applied to the above specifications as indicated herein. These are provided for use when additional testing or inspection is desired and apply only when specified individually by the purchaser in the order.

1.3 The requirements of the individual material specification, and this general specification shall prevail in the sequence named.

1.4 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 47 Specification for Ferritic Malleable Iron Castings[2]
A 48 Specification for Gray Iron Castings[2]
A 197 Specification for Cupola Malleable Iron[2]
A 220 Specification for Pearlitic Malleable Iron[2]
A 247 Test Method for Evaluating the Microstructure of Graphite in Iron Castings[2]
A 278 Specification for Gray Iron Castings for Pressure-Containing Parts for Temperatures Up to 650°F[2]
A 319 Specification for Gray Iron Castings for Elevated Temperatures for Non-Pressure Containing Parts[2]
A 395 Specification for Ferritic Ductile Iron Pressure-Retaining Castings for Use at Elevated Temperatures[2]
A 436 Specification for Austenitic Gray Iron Castings[2]
A 439 Specification for Austenitic Ductile Iron Castings[2]
A 518 Specification for Corrosion-Resistant High-Silicon Iron Castings[2]
A 532 Specification for Abrasion-Resistant Cast Irons[2]
A 536 Specification for Ductile Iron Castings[2]
A 571 Specification for Austenitic Ductile Iron Castings for Pressure-Containing Parts Suitable for Low-Temperature Service[2]
A 644 Terminology Relating to Iron Castings[2]
A 802/A802M Practice for Steel Castings, Surface Acceptance Standards, Visual Examination[2]
A 823 Specification for Statically Cast Permanent Mold Gray Iron Castings[2]
A 842 Specification for Compacted Graphite Iron Castings[2]
A 874 Specification for Ferritic Ductile Iron Castings Suitable for Low-Temperature Service[2]
A 897 Specification for Austempered Ductile Iron Castings[2]
A 919 Terminology Relating to Heat Treatment of Metals[3]
E 8 Test Methods for Tension Testing of Metallic Materials[4]
E 10 Test Method for Brinell Hardness of Metallic Materials[4]
E 29 Practice for Using Significant Digits in Test Data to Determine Conformance with Specifications[5]
E 30 Test Methods for Chemical Analysis of Steel, Cast Iron, Open-Hearth Iron, and Wrought Iron[6]
E 59 Practice for Sampling Steel and Iron for Determination of Chemical Composition[7]
E 94 Guide for Radiographic Testing[8]

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[1] This specification is under the jurisdiction of ASTM Committee A04 on Iron Castings and is the direct responsibility of Subcommittee A04.01 on Gray and White Iron Castings.

Current edition approved Oct. 10, 1995. Published December 1995. Originally published as A 834 – 84. Last previous edition A 834 – 94.

[2] *Annual Book of ASTM Standards*, Vol 01.02.

[3] Discontinued; see *1999 Annual Book of ASTM Standards*, Vol 01.01.

[4] *Annual Book of ASTM Standards*, Vol 03.01.

[5] *Annual Book of ASTM Standards*, Vol 14.02.

[6] Discontinued; see *1994 Annual Book of ASTM Standards*, Vol 03.05.

[7] Discontinued; see *1995 Annual Book of ASTM Standards*, Vol 03.05.

[8] *Annual Book of ASTM Standards*, Vol 03.03.

E 165 Test Method for Liquid Penetrant Examination[8]
E 351 Test Methods for Chemical Analysis of Cast Iron—All Types[9]
E 689 Reference Radiographs for Ductile Iron Castings[8]
E 709 Guide for Magnetic Particle Examination[8]
E 802 Reference Radiographs for Gray Iron Castings Up to 4½in. (114 mm) in Thickness[8]

2.2 *Military Standard:*
MIL-STD-129 Marking for Shipment and Storage[10]

2.3 *Federal Standard:*
Fed. Std. No. 123 Marking for Shipment (Civil Agencies)[10]

3. Terminology

3.1 *Definitions:*

3.1.1 Definitions for many terms common to iron castings and their heat treatment are found in Terminology A 919 and Terminology A 644. A classification of graphite structure is found in Test Method A 247.

4. Ordering Information

4.1 The purchase order for castings ordered under this specification shall stipulate the applicable material specification(s), grade of iron, and any options or additions to the basic requirements, including the supplementary requirements included in this specification.

5. Tensile Requirements

5.1 The individual product specifications vary as to whether tension tests are required. For this reason, and to determine specific test requirements, the individual product specification shall be reviewed. When required, tension tests shall be determined in accordance with Test Methods E 8.

6. Chemical Requirements

6.1 The individual product specifications vary as to whether chemical analysis is required. To determine specific requirements, the individual product specification should be reviewed.

6.2 Sampling shall be conducted in accordance with Test Method E 59. Spectrographic or other methods such as those in Test Methods E 30 and E 351 may be used for chemical analysis. In the event of a dispute regarding chemical composition, Test Methods E 351 and E 30 shall be used for referee purposes.

6.3 The chemical analysis for total carbon shall be made on chilled pencil-type specimens or from thin wafers approximately 1⁄32 in. (0.8 mm) thick cut from test coupons. Drillings are not reliable because of a probable loss of graphite.

6.4 Chemical analysis results shall be rounded, in accordance with Practice E 29, to the nearest unit in the last right-hand place of values in the table of chemical requirements.

6.5 A product analysis may be made by the purchaser from material representing each heat, lot, or casting. The analysis shall be made on representative material. Samples for carbon analysis shall be taken no closer than ¼ in. to a cast surface, and shall follow the practice in 5.3, except where the size or shape of the casting does not permit such sampling. The chemical composition thus determined shall meet the requirements specified in the applicable specification for the grade involved.

7. Workmanship, Finish, and Appearance

7.1 All castings shall be made in a workman-like manner and shall conform to the dimensions on drawings furnished by the purchaser before manufacture is started. If the pattern is supplied by the purchaser, the dimensions of the casting shall be as predicted by the pattern.

8. Sampling

8.1 A lot shall consist of one of the following:

8.1.1 All the metal from a single heating in a batch–type melting furnace.

8.1.2 All the metal poured from two or more batch–type melting furnaces into a single ladle or a single casting.

8.1.3 All the metal poured from a continuous melting furnace for a given period of time between changes in charge, processing conditions, or aim-for chemistry, or 4 h, whichever is the shorter period.

8.1.3.1 The purchaser may agree to extend the 4-h time period to 8 h if the manufacturer can demonstrate sufficient process control to warrant such an extension.

9. Inspection

9.1 All tests and inspections required by this specification shall be performed by the manufacturer or other reliable sources whose services have been contracted for by the manufacturer. Complete records of all tests and inspections shall be maintained by the manufacturer and shall be available for review by the purchaser.

9.2 The manufacturer shall afford the purchaser's inspector all reasonable facilities necessary to satisfy that the material is being produced and furnished in accordance with the applicable specification. Foundry inspection by the purchaser shall not interfere unnecessarily with the manufacturer's operations.

9.3 When agreed upon between manufacturer and purchaser, test specimens or unbroken test bars from the same lot shall be saved for a period of 3 months after date of the test report.

9.4 When unbroken test bars are reprocessed with castings for rehearing, test specimens from these bars shall be saved, as described in 9.3.

9.5 The purchaser reserves the right to perform any inspections set forth in the specification where such inspections are deemed necessary to assure that supplies and services conform to the prescribed requirements.

10. Repair

10.1 Any repair shall be made in accordance with the requirements of the individual specification using procedures qualified by the manufacturer for the type of repair involved.

11. Rejection and Rehearing

11.1 Castings which fail to conform to the requirements specified when inspected or tested by the purchaser or his agent

[9] *Annual Book of ASTM Standards*, Vol 03.05.

[10] Available from Standardization Documents Order Desk, Bldg. 4 Section D, 700 Robbins Ave., Philadelphia, PA 19111-5094, Attn: NPODS.

may be rejected. Rejection shall be reported to the manufacturer or supplier promptly and in writing. In case of dissatisfaction with the test results, the manufacturer or supplier may make claim for a rehearing.

12. Packaging and Package Marking

12.1 Unless otherwise specified in the contract or purchase order, cleaning, preservation, and packaging of castings shall be in accordance with the manufacturer's commercial practice. Packing and marking shall also be adequate to identify the contents and to ensure acceptance and safe delivery by the carrier for the mode of transportation employed.

12.2 *Government Procurement*—When specified in the contract or purchase order, marking for shipment shall be in accordance with the requirements of Fed. Std. No. 123 for civil agencies and MIL-STD-129 for military activities.

13. Quality Assurance

13.1 The surface of the casting shall be free of adhering sand, scale, cracks, and hot tears as determined by visual examination. Other surface discontinuities shall meet the visual acceptance standards specified in the order. Visual Practice A 802/A 802M or other visual standards may be used to define acceptable surface discontinuities and finish. Unacceptable visual surface discontinuities shall be removed and their removal verified by visual examination of the resultant cavities.

13.2 When additional inspection is desired, Supplementary Requirements S1, S2, or S3 may be specified.

14. Keywords

14.1 chemical composition; common requirements; general industry; inspection; iron castings; ordering information; packaging; quality assurance; repair; sampling; tensile requirements; terminology; workmanship

SUPPLEMENTARY REQUIREMENTS

Supplementary requirements shall be applied only when specified by the purchaser. Details of the supplementary requirements shall be agreed upon by the manufacturer and purchaser. The specified tests shall be performed by the manufacturer prior to shipment of the castings.

S1. Magnetic Particle Examination

S1.1 Castings shall be examined for surface discontinuities by magnetic particle examination. The examination shall be in accordance with Practice E 709. The extent of examination and the basis for acceptance shall be agreed upon between the manufacturer and purchaser.

S2. Radiographic Examination

S2.1 Castings shall be examined for internal defects by means of X-rays or gamma rays. The procedure shall be in accordance with Guide E 94, and types and degrees of discontinuities considered shall be judged by Reference Radiographs E 689 and E 802. The extent of examination and basis for acceptance shall be agreed upon between the manufacturer and purchaser.

S3. Liquid Penetrant Examination

S3.1 Castings shall be examined for surface discontinuities by means of liquid penetrant examination. The examination shall be in accordance with Practice E 165. Areas to be inspected, methods and types of liquid penetrants to be used, developing procedure, and basis for acceptance shall be agreed upon between the manufacturer and purchaser.

S4. Certification

S4.1 The manufacturer's certification shall be furnished to the purchaser stating that the material was manufactured, sampled, tested, and inspected in accordance with the material specification, including the year date, and was found to meet the requirements. Additionally, the certification shall include for each lot the results of all tests required by the material specification and any supplementary or additional requirements imposed by the purchase order.

S4.2 A signature is not required on the certification or test report. However, the document shall clearly identify the organization submitting the certification and the authorized agent of the manufacturer who certified the test results. Notwithstanding the absence of a signature, the organization submitting the certification is responsible for its content.

S4.3 The test report shall be furnished within 5 working days of shipment of the castings.

S5. Prior Approval of Major Repairs

S5.1 Major repairs as defined and agreed upon between the manufacturer and purchaser shall be subject to the prior approval of the purchaser.

S6. Marking

S6.1 The manufacturer's name or identification mark and the part identification number shall be cast or stamped on all castings. When further specified, lot numbers shall be marked on individual castings.

S6.2 When the castings are of such size that individual marking is impracticable, they shall be grouped by part identification or lot number and placed in a container. The container shall be marked with the required identification.

S7. Hardness Test

S7.1 Hardness measurements at specified locations on the castings shall be made in accordance with Test Method E 10 and reported.

Designation: A 835 – 84 (Reapproved 2000)

Standard Specification for Sizes of Ferroalloys and Alloy Additives[1]

This standard is issued under the fixed designation A 835; 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 nominal sizes and size tolerances of screened ferroalloy and alloy additive products. This specification provides a range of sizes as referenced in all ASTM specifications for ferroalloys and alloy additives.

1.2 The sizes and tolerances allow for varying degrees of friability upon receipt of material since some attrition may be expected in transit, storage, and handling.

1.3 Specifications of sieve sizes used to define tolerances are listed in Specification E 11. Representative procedures for evaluation of each lot are described in Methods A 610. Refer to Appendix X1 for applicable sieve designations (see Table X1.1).

2. Referenced Documents

2.1 *ASTM Standards:*

A 610 Methods of Sampling and Testing Ferroalloys for Determination of Size[2]

E 11 Specification for Wire-Cloth Sieves for Testing Purposes[3]

3. Dimensional Requirements

3.1 Screened products shall conform to the sizes given in Table 1.

3.1.1 The sizes listed in Table 1 are typical as shipped from the manufacturer's plant. Ferroalloys exhibit varying degrees of friability; therefore, some attrition may be expected in transit, storage, and handling. A quantitative test is not available for rating relative friability of ferroalloys. A code system has been developed, therefore, for this purpose, and a number rating each product type is given.

NOTE 1—For further description of friability ratings for ferroalloys, refer to Appendix X2

TABLE 1 Requirements for Screened Products[A]

Nominal Size, in.	Standard Ordered Size, in.[B]	Maximum Allowable Oversize		Maximum Allowable Undersize		Friability Rating Code No.[C]
		Size	Percent	Size	Percent	
Lump to Crushed Sizes:						
6	8 by 4	to 10 in.	10 %	through 4 in.	10 %	1–6
5	8 by 2	to 10 in.	10 %	through 2 in.	10 %	1–6
4	6 by 2	to 8 in.	10 %	through 2 in.	10 %	1–6
3½	5 by 2	to 7 in.	10 %	through 2 in.	10 %	1–6
3 (A)	5 by 1	to 7 in.	10 %	through 1 in.	10 %	1–6
3 (B)	4 by 2	to 6 in.	10 %	through 2 in.	10 %	1–6
2½	4 by 1	to 6 in.	10 %	through 1 in.	10 %	1–6
2¼	4 by ½	to 5 in.	10 %	through ½ in.	10 %	1–6
2	3 by 1	to 4 in.	10 %	through 1 in.	10 %	1–6
1½	3 by ½	to 4 in.	10 %	through ½ in.	10 %	1–6
1¼	2 by ½	to 3 in.	10 %	through ½ in.	10 %	1–6
1⅛	2 by ¼	to 3 in.	10 %	through ¼ in.	10 %	1–6
Small Crushed Sizes by Down:						
2	4 by D	to 5 in.	10 %	through ½ in.	15 %	1–6
1½	3 by D	to 4 in.	10 %	through ⅛in.	15 %	1–6
1	2 by D	to 3 in.	10 %	through ⅛ in.	15 %	1–4
		to 3 in.	8 %	through No. 8	20 %	5,6
½	1 by D	to 1½ in.	10 %	through No. 16	15 %	1–4
		to 1½ in.	8 %	through No. 20	15 %	5,6
¼	½ by D	to ¾ in.	10 %	through No. 20	15 %	1–4
		to [n|]P	8 %	through No. 70	20 %	5,6
		in.				

[A] For screened products below ½ in. by down-crushed sizes, size tolerances should be agreed upon between manufacturer and purchaser.

[B] 1 in. = 25.4 mm.

[C] See Appendix X2 for description of rating code.

[1] This specification is under the jurisdiction of ASTM Committee A-1 on Steel, Stainless Steel, and Related Alloys and is the direct responsibility of Subcommittee A01.18 on Castings. Current edition approved Oct. 25, 1984. Published December 1984.

[2] *Annual Book of ASTM Standards*, Vol 01.02.

[3] *Annual Book of ASTM Standards*, Vol 14.02.

APPENDIXES

(Nonmandatory Information)

X1. APPLICABLE SIEVE DESIGNATIONS

TABLE X1.1 Sieve Designation

Standard	Alternative
250 mm	10 in.
200 mm	8 in.
175 mm	7 in.
150 mm	6 in.
125 mm	5 in.
100 mm	4 in.
75 mm	3 in.
50 mm	2 in.
25 mm	1 in.
19 mm	¾in.
12.5 mm	½in.
6.3 mm	¼in.
3.1 mm	⅛in.
2.36 mm	No. 8
1.18 mm	No. 16
850 µm[A]	No. 20
212 µm	No. 70

[A] 1000 µm = 1 mm.

X2. FRIABILITY RATINGS OF FERROALLOYS

X2.1 Descriptions of material of each friability rating are given in Table X2.1.

TABLE X2.1 Friability Ratings of Ferroalloys

Friability Code No.	Description
1	Very tough materials which are susceptible to little, if any, breakage during shipment or handling. (Example: low-carbon ferrochrome)
2	Some breakage of large pieces probable in shipping and handling. No appreciable fines produced from either lump or crushed sizes. (Example: chrome metal)
3	Appreciable reduction in size of large pieces possible in shipping and handling. No appreciable production of fines in handling of crushed sizes. (Example: ferrotitanium)
4	Appreciable reduction in size of large pieces upon repeated handling. Some fines produced upon repeated handling of crushed sizes. (Example: standard ferromanganese)
5	Appreciable reduction in size in repeated handling of large pieces. Appreciable fines may be produced in the handling of crushed sizes. (Example: 50 % ferrosilicon)
6	This category represents the most friable alloys. (Example: calcium silicon)

Designation: A 842 – 85 (Reapproved 2004)

An American National Standard

Standard Specification for Compacted Graphite Iron Castings[1]

This standard is issued under the fixed designation A 842; 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 castings made of compacted graphite iron, which is described as cast iron with the graphite in compacted (vermiform) shapes and essentially free of flake graphite.

1.2 The values stated in SI units are to be considered as the standard.

1.3 No precise quantitative relationship can be stated between the properties of iron in the various locations of the same casting and those of a test bar cast from the same iron (see Appendix X1).

2. Referenced Documents

2.1 *ASTM Standards:* [2]

A 247 Test Method for Evaluating the Microstructure of Graphite in Iron Castings

E 8M Test Methods for Tension Testing of Metallic Materials (Metric)

2.2 *Federal Standard:*[3]

Fed. Std. No. 123 Marking for Shipment (Civil Agencies)

2.3 *American National Standard:*[4]

MIL-STD-129 Marking for Shipment and Storage

3. Ordering Information

3.1 Orders for material to this specification shall include the following information:

3.1.1 ASTM designation and year of issue,

3.1.2 Grade of compacted graphite iron required as identified in Table 1,

3.1.3 Special properties if required, (see 4.1 and 10.1),

3.1.4 If samples other than those identified in Section 9 are required,

3.1.5 Certification if so designated by the purchaser, and

3.1.6 Special preparation for delivery if required.

TABLE 1 Tensile Requirements

	Grade[A] 250	Grade 300	Grade 350	Grade 400	Grade[B] 450
Tensile strength, min, MPa	250	300	350	400	450
Yield strength, min, MPa	175	210	245	280	315
Elongation in 50 mm, min, %	3.0	1.5	1.0	1.0	1.0

[A] The 250 grade is a ferritic grade. Heat treatment to attain required mechanical properties and microstructure shall be the option of the manufacturer.

[B] The 450 grade is a pearlitic grade usually produced without heat treatment with addition of certain alloys to promote pearlite as a major part of the matrix.

4. Chemical Composition

4.1 It is the intent of this specification to subordinate chemical composition to mechanical properties; however, any chemical requirement may be specified by agreement between the manufacturer and the purchaser.

5. Microstructure Requirements

5.1 Compacted graphite cast iron shall be examined metallographically for the acceptable graphite formation.

5.2 The metallographic examination shall be performed on a casting, a separately cast test coupon, as shown in Fig. 1 or on a test lug from a casting. The test coupon or casting lug shall represent the last metal from the treated batch. The casting lug dimension and location will be agreed on by manufacturer and purchaser.

5.3 When castings are produced to this specification by treating the iron in the mold for graphite form control, the manufacturer may use separately cast test coupons or cut test specimens from castings to qualify conformance of the microstructure requirements. When separately cast test coupons are used, the test coupons shall have a chemical composition representative of that in the castings, produced from that iron poured, and having a cooling rate equivalent to that obtained through use of test molds as shown in Figs. 1-4. The size of the cast coupon representing the castings shall be the option of the purchaser. In case no option is expressed, the manufacturer shall make the choice. When test specimens are to be taken from a casting, the location shall be agreed on by the purchaser and the manufacturer and documented on the casting drawing.

[1] This specification is under the jurisdiction of ASTM Committee A04 on Iron Castings and is the direct responsibility of Subcommittee A04.02 on Malleable and Ductile Iron Castings.

Current edition approved May 1, 2004. Published May 2004. Originally approved in 1985. Last previous edition approved in 1997 as A 842 - 85 (1997).

[2] 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.

[3] Available from Standardization Documents Order Desk, Bldg. 4 Section D, 700 Robbins Ave., Philadelphia, PA 19111-5094, Attn: NPODS.

[4] Available from American National Standards Institute (ANSI), 25 W. 43rd St., 4th Floor, New York, NY 10036.

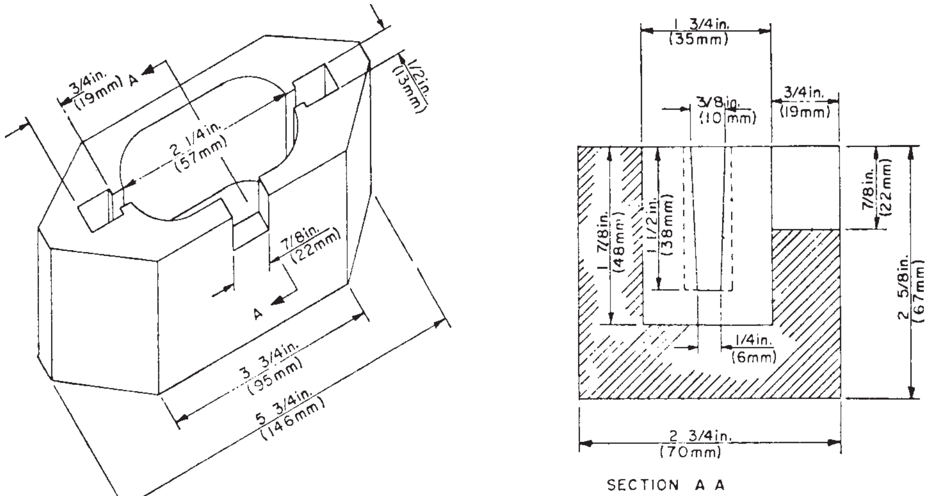


FIG. 1 Test Coupon for Microscopical Examination of Compacted Graphite Iron

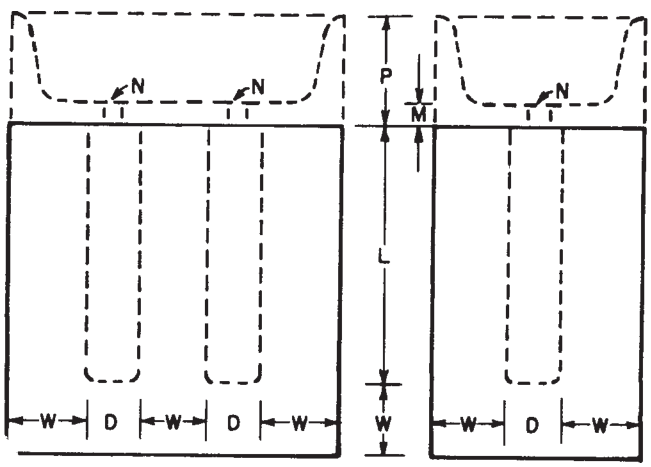


FIG. 2 Design and Dimensions for Mold for Separately Cast Cylindrical Test Bars

It is the manufacturer's required responsibility to maintain adequate controls and documentation to assure the customer that test specimen microstructures are representative of microstructure in the castings shipped.

5.4 The acceptable graphite formation in the microstructure of the test coupon or casting lug shall contain 80 % minimum Type IV graphite (see Plate 1, Graphite Form Types of Test Method A 247). The percentage graphite can be arrived at by using the manual particle count, semiautomatic, or automatic image analysis methods. Whichever method is used, the procedure should be agreed on between the manufacturer and the purchaser.

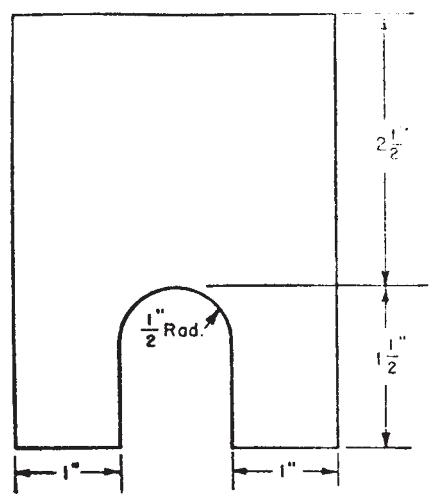
5.5 Unless otherwise specified, the matrix microstructure of castings covered by this specification shall be substantially free of primary cementite.

6. Tensile Requirements

6.1 The iron as represented by the test specimens shall conform to the requirements for tensile properties, as identified in Table 1.

6.2 The yield strength presented in Table 1 shall be determined at 0.2 % offset by the offset method as described in Test

NOTE—The length of the keel block shall be 6 in. (152 mm).



Metric Equivalents

in.	mm	in.	mm
½	12.7	1½	38.1
1	25.4	2½	63.5

FIG. 3 Keel Block

Methods E 8M. Other methods may be used by mutual agreement between manufacturer and purchaser.

7. Cast Test Bars

7.1 Test bars shall be separate castings poured from the same iron as the castings they represent. The 30-mm diameter cylindrical test bar shall be used as described in Table 2 and shown in Fig. 2.

7.2 Test coupons may also be cast to the size and shape of the keel block or modified keel block shown in Fig. 3 and Fig. 4, respectively.

7.3 Test bars and test coupons shall be cast in dried, baked, or chemically bonded molds consisting of an aggregate of silica sand with the appropriate binders. All molds shall have a

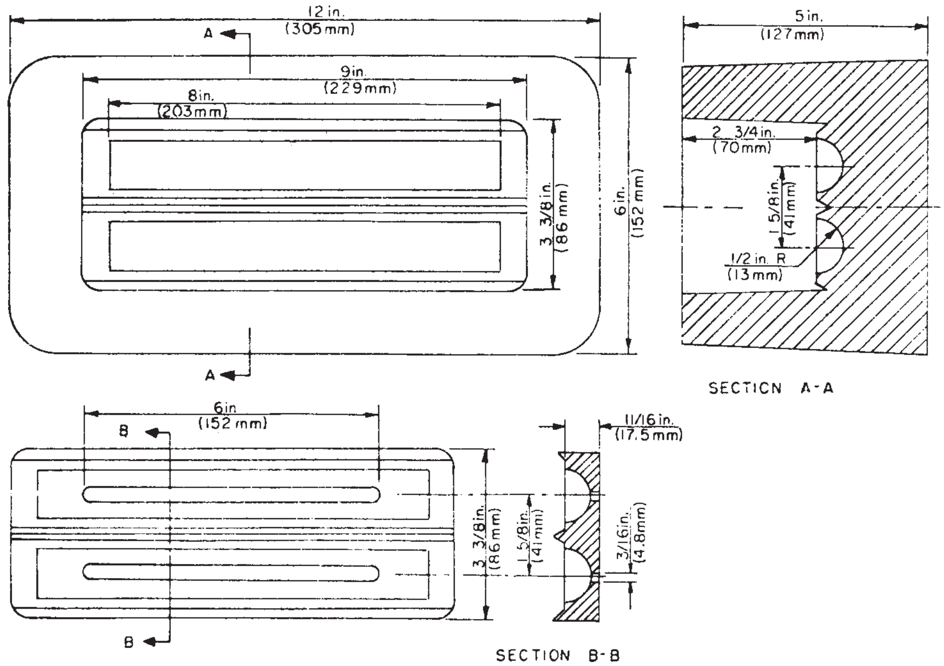


FIG. 4 Mold for Modified Keel Block

TABLE 2 Diameter and Length of Cast Test Bar

Test Bar	Nominal	As Cast Diameter, mm		Length, mm	
		Minimum	Maximum	Minimum	Maximum
B	30	29	31	150	230

thickness of sand adjacent to the test piece equal to or greater than the thickness of the piece.

7.4 The test bars or test coupons shall be poured from the same ladle or heat of iron as the castings they represent.

7.5 Test bars and test coupons shall be subjected to the same thermal treatment as the castings they represent.

8. Tension Test Specimen

8.1 The standard round tension test specimen with 50-mm gage length described in Test Methods E 8M shall be used.

9. Workmanship, Finish, and Appearance

9.1 The surface of the casting shall be inspected visually for surface discontinuities such as cracks, hot tears, adhering sand or scale, cold shuts, and gas holes. Surface discontinuities shall meet visual acceptance standards mutually agreed on between the purchaser and the supplier.

9.2 No repairing by plugging or welding of any kind shall be permitted unless written permission is granted by the purchaser.

10. Number of Tests and Retests

10.1 The manufacturer shall cast a minimum of three test bars for each lot of castings intended to conform to this specification. The manufacturer shall make the specified tests. If any test specimen shows defective or improper machining, or obvious lack of continuity of metal, it may be discarded and replaced by another specimen from another test bar from the same lot. Only one bar need be tested if its results conform to the property requirements of this specification.

10.2 If after testing, a test specimen shows evidence of a defect, the results of the test may be invalidated and another made on a specimen from the same lot.

10.3 If the results of a valid test fail to conform to the requirements of this specification, two retests shall be made. If either retest fails to meet the specification requirements, the castings represented by these test specimens shall be rejected. A valid test is one wherein the specimen has been properly prepared and appears to be sound and on which the approved test procedure has been followed.

10.4 If sufficient separately cast test pieces are not available, the manufacturer shall have the option of removing a test specimen from a location of a representative casting as agreed upon between the manufacturer and purchaser.

10.5 If the first test results indicate that a thermal treatment is needed to meet the test requirements, the entire lot of castings and the representative test specimens shall be thermally treated together. Testing shall proceed in accordance with 10.1-10.4.

11. Inspection

11.1 Unless otherwise specified in the contract or purchase order, the manufacturer shall be responsible for carrying out all the tests and inspections required by this specification, using his own or other reliable facilities, and he shall maintain complete records of all such tests and inspections. Such records shall be available for review by the purchaser.

11.2 The purchaser reserves the right to perform any of the inspections set forth in the specification where such inspections are deemed necessary to assure that supplies and services conform to the prescribed requirements.

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. Product Marking

13.1 When the size of the casting permits, each casting shall bear the cast date, the identifying mark of the manufacturer, and the part or pattern number at a location shown on the covering drawing and, if not shown on the drawing, the location should be at the discretion of the producer.

14. Packaging and Package Marking

14.1 Unless otherwise stated in the contract or order, the cleaning, preservation, and packing of castings for shipment shall be in accordance with the manufacturer's commercial practice. Packaging and marking shall also be adequate to identify the contents and to ensure acceptance and safe delivery by the carrier for the mode of transportation employed.

14.2 *U.S. Government Procurement*—When specified in the contract or purchase order, marking for shipment shall be in accordance with the requirements of Federal Standard No. 123 for civil agencies and MIL-STD-129 for military activities.

SUPPLEMENTARY REQUIREMENTS

S1. When specified in the contract or purchase order, castings shall meet special requirements as to hardness, chemical composition, microstructure, pressure tightness, radiographic soundness, magnetic particle inspection dimensions, and surface finish.

APPENDIX

(Nonmandatory Information)

X1. MECHANICAL PROPERTIES OF CASTINGS

X1.1 The mechanical properties of iron castings are influenced by the cooling rate during and after solidification, by chemical composition (particularly carbon equivalent), by the design of the casting, by the design and nature of the mold, by graphite form, by the location and effectiveness of gates and risers, and by certain other factors. In compacted graphite cast iron, the proportions of nodular form and compacted form graphite may vary in varying sections due to the above factors.

X1.2 The cooling rate in the mold and, therefore, the properties developed in any particular section are influenced by the presence of cores, chills, and chaplets; changes in section thickness; and the existence of bosses, projections, and intersections, such as junctions of ribs and bosses. Because of the complexity of the interactions of these factors, no precise quantitative relationship can be stated between the properties of the iron in various locations of the same casting or between the properties of a casting and those of a test specimen cast from the same iron. When such a relationship is important and must be known for a specification application, it may be determined by appropriate experimentation.

X1.3 When reliable information is unavailable on the relationship between properties in a casting and those in a separately cast test specimen, and where experimentation would be infeasible, the size of the test casting should be so selected as to approximate the thickness of the main or controlling section of the casting.

X1.4 Table X1.1 is a typical hardness range for the grades of compacted graphite cast iron in this specification. The chemical composition of the base iron used to produce compacted graphite cast iron may result in the hardness range moving to either side of the given range.

TABLE X1.1 Compacted Graphite Cast Iron Hardness Range

Grade	Hardness	BID[A]
250	179 max	(4.50 min)
300	143–207	(5.0–4.2)
350	163–229	(4.7–4.0)
400	197–255	(4.3–3.8)
450	207–269	(4.2–3.7)

[A] Brinell impression diameter (BID) is the diameter in millimetres of the impression of a 10-mm ball at a 3000-kg load.

Designation: A 845 – 85 (Reapproved 2000)

Standard Specification for Titanium Scrap for Use in Deoxidation and Alloying of Steel[1]

This standard is issued under the fixed designation A 845; 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 titanium and titanium alloys in the form of processed scrap, designated as shown in Table 1, for use in the manufacture of steel.

1.2 The values stated in inch-pound units are to be regarded as the standard. The metric equivalents of inch-pound units may be approximate.

2. Referenced Documents

2.1 *ASTM Standards:*

E 120 Test Methods for Chemical Analysis of Titanium and Titanium Alloys[2]

3. Ordering Information

3.1 Orders for material under this specification shall include the following information:

3.1.1 Quantity,

3.1.2 Name or form of material,

3.1.3 Size desired,

3.1.4 Requirement for packaging, and

3.1.5 Reports requested with shipment.

4. Materials and Manufacture

4.1 The material may be in the form of titanium processing scrap; or cut up rolled sections with individual weight tolerance as agreed between buyer and seller.

4.2 The material may be delivered loose or pressed into pieces, as agreed between buyer and seller.

5. Chemical Composition

5.1 The material shall conform to the requirements as to chemical composition prescribed in Table 1.

6. Sampling

6.1 If the metal is shipped in carload lots of the same grade, not less than five samples of a minimum of 2 lbs each shall be taken at random from the carload for sampling. If the shipment is in less than carload lots, one sample shall be taken for each 6000 lb (2700 kg) or fraction thereof.

TABLE 1 Chemical Requirements

NOTE— Material of Grade 1 shall be chemically washed and dried or ultrasonically cleaned or processed, or both by a method agreed between buyer and seller.

Grade	Ti, %, min	Al, %, max	V, %, max	Ni + Cr + Mo + Fe, %, max	Sn, %, max	Pb + Bi, %, max	C, %, max
1 (Note 1)	87.0	6.5	4.5	2.0	1.00	0.01	0.15
2	85.0	. . .	. . .	. . .	3.00	0.02	0.50

7. Methods of Chemical Analysis

7.1 The chemical analysis for contaminants shall be made in accordance with Methods E 120 or by any other approved method agreed upon by the manufacturer and the purchaser. The analysis may be made by instrumental methods, provided that, in case of dispute, the results secured by Methods E 120, shall be the basis for acceptance.

8. Inspection

8.1 If the purchaser desires to make an inspection of the material at the manufacturer's works where the material is processed, it shall be so stated in the contract or purchaser order.

8.2 If the purchaser elects to make an inspection made at the manufacturer's plant, 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 so conducted as not to interfere unnecessarily with the operation of the works.

9. Rejection

9.1 Material that does not conform to the requirements of this specification may be rejected, and if rejected, shall be replaced by the manufacturer. The full weight of the rejected material shall be returned to the manufacturer.

10. Packaging and Package Marking

10.1 The material shall be packaged in such a manner as to prevent damage in ordinary handling and transportation. The type of packing and gross weight of individual containers shall be left to the discretion of the manufacturer unless otherwise agreed upon. Packaging methods and containers shall be so selected as to permit maximum utility of mechanical equipment in unloading and subsequent handling. Each package or

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[1] This specification is under the jurisdiction of ASTM Committee A-1 on Steel, Stainless Steel, and Related Alloys and is the direct responsibility of Subcommittee A01.18 on Castings.

Current edition approved July 26, 1985. Published September 1985.

[2] *Annual Book of ASTM Standards*, Vol 03.05.

container shall contain only one size or grade of material when packed for shipment unless otherwise agreed upon.

10.2 Each package or container shall be marked with the specification number or grade, net weight, and the name of the manufacturer.

10.3 Packages or containers shall be such as to ensure acceptance by common or other carriers for safe transportation at the lowest rate to the point of delivery.

10.4 The weight tolerance of individual packages shall be ± 3 %.

Standard Specification for Aluminum Scrap for Use in Deoxidation and Alloying of Steel[1]

This standard is issued under the fixed designation A 846; 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 aluminum and aluminum alloys in the form of processed scrap designated as shown in Table 1, for use in the manufacture of steel.

1.2 The values stated in inch-pound units are to be regarded as the standard. The metric equivalents of inch-pound units may be approximate.

2. Referenced Documents

2.1 *ASTM Standards:*

E 34 Test Methods for Chemical Analysis of Aluminum and Aluminum-Base Alloys[2]

3. Ordering Information

3.1 Orders for material under this specification shall include the following information:

3.1.1 Quantity,

3.1.2 Name or form of material,

3.1.3 Size desired,

3.1.4 Requirement for packaging, and

3.1.5 Reports requested with shipment.

3.2 The basis of payment shall be per pound of alloy.

4. Materials and Manufacture

4.1 The material may be in the form of cut up wire, cans, or other aluminum scrap of suitable purity; or cut up rolled sections, with individual weight tolerance as agreed between the buyer and seller.

4.2 The material may be delivered loose or pressed into pieces, as agreed between buyer and seller. If pressed, the bulk density of individual pieces shall be not less than 0.082 lb/in.^{3}(85 % of density of pure wrought aluminum). The density of pressed pieces shall be determined as follows:

4.2.1 Each sample piece shall be weighed on a scale capable of accuracy of 1 g weight.

4.2.2 The piece shall be completely sprayed with a lacquer and allowed to dry.

TABLE 1 Chemical and Physical Requirements The usual source of Grade 1*W* is chopped electrical wire (*W*); of Grade 1*C* chopped food cans (*C*).

Grade (Note 1)	Al, %, min	Mg, %, max	Si, %, max	Zn, %, max	Bulk Density, lb/ft^3, min (see 4.2)
1*W*	99.0	. . .	. . .	. . .	90
1*C*	96.0	2.0	1.0	. . .	90
1	95.0	1.5	3.0	1.5	90
2	90.0	2.5	5.0	3.0	. . .

4.2.3 A container of diameter at least twice the size of the tested piece and equipped with an overflow spout shall be filled with water until the overflow ceases; a measuring cylinder capable of ICC accuracy shall be placed under the spout.

4.2.4 The sample piece shall be suspended on a thin wire and gently lowered into the water.

4.2.5 The volume of the overflow, *V*, shall be read off.

4.2.6 The weight of the sample piece divided by the volume of the overflowed water, g/cc, multiplied by 0.036, is the density of the sample piece, that is $D = W \times 0.036/V$ in lb in.^{3}.

5. Chemical Composition

5.1 The material shall conform to the requirements as to chemical composition and physical properties prescribed in Table 1.

6. Sampling

6.1 If the metal is shipped in carload lots of the same grade, not less than five samples of a minimum of 2 lb each shall be taken at random from the carload for sampling. If the shipment is in less than carload lots, one sample shall be taken for each 6000 lb (2700 kg) or fraction thereof. When it is deemed necessary, a sample may be taken from each melt of 500 lb (230 kg) or more of the alloy.

6.2 If the manufacturer has made an analysis of the material during the course of manufacture, he shall not be required to sample and analyze the finished product.

6.3 If a saw, drill, or cutter is used for taking the sample, it shall be thoroughly cleaned. No lubricant shall be used in the operation, and the sawings or metal chips shall be carefully treated with a magnet to remove any particles of iron introduced in taking the sample.

[1] This specification is under the jurisdiction of ASTM Committee A-1 on Steel, Stainless Steel, and Related Alloys and is the direct responsibility of Subcommittee A01.18 on Castings.

Current edition approved July 26, 1985. Published September 1985.

[2] *Annual Book of ASTM Standards*, Vol 03.05.

7. Methods of Chemical Analysis

7.1 The chemical analysis shall be made in accordance with Test Methods E 34, or by any other approved method agreed upon by the manufacturer and the purchaser. The analysis may be made by instrumental methods, provided that, in case of dispute, the results secured by Test Methods E 34 shall be the basis for acceptance.

8. Inspection

8.1 If the purchaser desires to make an inspection of the material at the manufacturer's works where the material isprocessed, it shall be so stated in the contract or purchase order.

8.2 If the purchaser elects to make an inspection made at the manufacturer's plant, 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 so conducted as not to interfere unnecessarily with the operation of the works.

9. Rejection

9.1 Material that does not conform to the requirements of this specification may be rejected, and if rejected, shall be replaced by the manufacturer. The full weight of the rejected material shall be returned to the manufacturer.

10. Packaging and Package Marking

10.1 The material shall be packaged in such a manner as to prevent damage in ordinary handling and transportation. The type of packing and gross weight of individual containers shall be left to the discretion of the manufacturer unless otherwise agreed upon. Packaging methods and containers shall be so selected as to permit maximum utility of mechanical equipment in unloading and subsequent handling. Each package or container shall contain only one size or grade of material when packed for shipment unless otherwise agreed upon.

10.2 Each package or container shall be marked with the specification number or grade, net weight, and the name of the manufacturer.

10.3 Packages or containers shall be such as to ensure acceptance by common or other carriers for safe transportation at the lowest rate to the point of delivery.

10.4 The weight tolerance of individual packages shall be ± 3 % or ± 1 lb, whichever greater.

Designation: A 861 – 04

Standard Specification for High-Silicon Iron Pipe and Fittings[1]

This standard is issued under the fixed designation A 861; 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 high-silicon iron pipe and pipe fittings intended for corrosion-resistant service for both above- and below-grade construction.

1.2 Pipe and pipe fittings shall be the no-hub (MJ) or the hub and plain end design.

1.3 Pipe and pipe fittings shall be of the sizes specified in Table 1 and Table 2 and Figs. 1-71 or other sizes that shall be permitted to conform to the requirements given herein.

1.3.1 *Pipe*:

1.3.1.1 *No-hub (MJ) (Fig. 1)*:

Size (in.)	Length (ft)
1½	7
2	7
3	7
4	7

1.3.1.2 *Hub/Plain End (Fig. 35)*:

Size (in.)	Length (ft)
2	7
3	7
4	7
6	7
8	7
10	5
12	5
15	5

1.3.2 *Fitting (No-hub) (MJ)*:

	Figs.
Quarter Bends	2
Sixth Bends	3
Return Bends	4
Double-Branch Quarter Bend	5
Eighth Bends	6
Sixteenth Bends	7
Long-Sweep Quarter Bends	8
Sanitary Y Branches	9
Double-Branch Sanitary Y	10
Sanitary Combination Y and ⅛ Bend	11
Double-Branch Sanitary Combination Y and ⅛ Bend	12
Sanitary T Branches	13
Double Branch Sanitary T	14
Sanitary Running Traps	15
Sanitary P Traps	16
Swivel Trap P-Style Short	17
Swivel Trap P-Style Long	18
Swivel Trap S-Style Long	19
Centrifugal Drum Trap P Swivel Type	20
Centrifugal Drum Trap S Swivel Type	21
Combination Cleanout and Test Tees	22
Coupling	23
Pipe Plugs	24
Cleanout Plugs	25
No-hub (MJ) Adapter	26
Reducers—Increasers	27
Sink Outlet	28
Sink Overflows	29
Threaded Adapters	30
Trap Cleanout Details	31
No-hub (MJ) Adapter	32
(MJ) (No-hub) to Lead Adapter	33
Floor Drains	34

1.3.3 *Fitting (Hub/Plain End)*:

	Figs.
Hub Plain End Pipe	35
Straight Tees	36
Sanitary T Branches	37
Sanitary Y Branches	38
Double-Branch Sanitary Tee	39
Double-Branch Sanitary Y	40
Double-Branch Sanitary Combination Y and ⅛ Bend (T-Y)	41
Short-Sweep Quarter Bends	42
Long-Sweep Quarter Bends	43
Sanitary Combination Y and ⅛ Bend (T-Y)	44
Quarter Bends	45
Sixth Bends	46
Eighth Bends	47
Sixteenth Bends	48
Sanitary Increasers	49
Hub Strainers	50
Sanitary Reducers	51
Double Hubs	52
Pipe Plugs	53
Cleanout Plugs	54
Adapter—Plain end to Split Flange	55
Adapter—Hub to-Split Flange	56
Combination Cleanout and Test Tees	57
Insertable Joints	58
Backwater Valves	59
Sanitary P Traps	60
Sanitary S Traps	61
Sanitary Running Traps	62
Floor Drains	63, 64, 65
Floor Drains	66

[1] This specification is under the jurisdiction of ASTM Committee A04 on Iron Castings and is the direct responsibility of Subcommittee A04.12 on Pipes and Tubes.

Current edition approved May 1, 2004. Published May 2004. Originally approved in 1986. Last previous edition approved in 2002 as A 861 – 02.

2. Referenced Documents

2.1 *ASTM Standards:* [2]

A 518/A 518M Specification for Corrosion-Resistant High-Silicon Iron Castings

E 350 Test Methods for Chemical Analysis of Carbon Steel, Low-Alloy Steel, Silicon Electrical Steel, Ingot Iron, and Wrought Iron

E 351 Test Methods for Chemical Analysis of Cast Iron—All Types

2.2 *Other Standards:*

Uniform Classification Rules[3]

National Motor Freight Classification[3]

3. Terminology

3.1 *Definitions of Terms Specific to This Standard:*

3.1.1 *hubless*—a pipe or fitting without a hub, sometimes called no-hub, joined by a coupling.

3.1.2 *MJ*—an abbreviation for mechanical joint.

3.1.3 *no-hub*—a pipe or fitting without a hub, sometimes described as hubless joined by a coupling.

4. Ordering Information

4.1 Ordering for material under this specification shall include as a minimum the following information:

4.1.1 ASTM designation, grade (see Table 3) and year of issue.

4.1.2 Description of the casting by figure number (see Figs. 1 through 71) or by manufacturer's drawings or catalog number, or both.

4.1.3 Length, diameter, and type of pipe and size and shape of fittings.

4.1.4 Quantity.

4.1.5 Certification requirements.

4.1.6 Special packaging requirements (see Section 14).

4.1.7 Supplemental requirements desired, if any.

5. Materials and Manufacture

5.1 The castings shall be produced by any established commercial practice applicable to high-silicon iron.

5.2 The castings shall be true to pattern, reasonably smooth, and free from defects that would make the castings unfit for the use for which they are intended.

6. Chemical Composition

6.1 An analysis of each heat shall be made by the manufacturer from a test sample that is representative of the heat and that is taken during the heat. A heat shall consist of all castings poured from a furnace or crucible melt without recharging new metal into the furnace. The chemical composition thus determined shall conform to the requirements for the grade selected specified in Table 3.

6.2 A product analysis shall be permitted to be made by the purchaser from material representing the heat. The chemical composition thus determined shall meet the requirements specified in Table 3 or shall be subject to rejection by the purchaser.

6.3 Spectrometric or other instrumental methods and wet laboratory methods are acceptable for routine control determinations. Any method employed shall give essentially the same results as reference methods listed in Test Methods E 350. (For selected detailed methods of analysis, see Specification A 518, paragraph 6.4).

7. Heat Treatment

7.1 All centrifugally cast high-silicon iron pipe shall be supplied in the as-cast condition. All other pipe and fittings shall be supplied in the stress-relieved condition.

7.2 Stress relieving shall be performed as follows:

7.2.1 Hold the casting at 1650°F (870°C) minimum for 2 h plus an additional hour per inch of section thickness for castings over 2 in. in thickness.

7.2.2 Cool the castings to 400°F (205°C) maximum at a rate not to exceed 100°F (55°C)/15 min.

7.2.3 From 400°F (205°C) to ambient, the castings shall be permitted to be cooled in still, ambient air.

8. Joints

8.1 Acid-proof joints for hub/plain-end pipe shall require the use of an acid-proof rope packing.

8.2 No-hub pipe and fittings shall require a special acid resistant mechanical joint (MJ) coupling. One satisfactory coupling consists of an inner PTFE sleeve surrounded by neoprene. The two-bolt coupling is made of 300 series stainless steel.

8.3 High-silicon iron pipe can be cut with either manual or hydraulic snap cutters. Field cuts shall be permitted to be readily used with mechanical joint couplings to provide acceptable leak-proof joints.

9. Dimensions and Permissible Variations

9.1 *Pipe*:

9.1.1 Hub/plain-end pipe shall have a hub at one end and a plain end at the other and shall be cast in one piece (see Fig. 35).

9.1.2 Individual length of hub/plain-end pipe shall be either 7 or 5 ft nominal laying lengths as shown in Fig. 35.

9.1.3 Any deflections in the barrel of a single length of pipe shall not exceed 3⁄16 in.

9.1.4 No-hub pipe shall be cast in a single piece and conform to nominal dimensions shown in Fig. 1.

9.1.5 No dimension of hub/plain-end pipe shall exceed the tolerances specified in Table 1.

9.2 *Fittings*—All fittings shall conform to the nominal dimensions specified in applicable figures and be within the

[2] 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.

[3] Available from American Trucking Assoc., Traffic Dept., 2200 Mill Rd., Alexandria, VA 22314.

tolerances specified in Table 2 for fittings listed in Figs. 2 through 34 or in Table 1 for fittings listed in Figs. 36 through 39.

10. Inspection

10.1 *Inspection and Test by the Manufacturer*—Pipe and fittings shall be inspected by the manufacturer prior to shipment. Inspection by the manufacturer shall include all tests as specified herein. All tests and inspection with the exception of product analysis shall be made at the place of manufacture unless otherwise agreed upon.

10.2 *Inspection and Test by the Purchaser*—The manufacturer shall afford the purchaser's inspector all reasonable facilities necessary to satisfy that the material is being produced and furnished in accordance with this specification. Foundry inspection by the purchaser shall not interfere unnecessarily with the manufacturer's operations.

11. Rejection and Rehearing

11.1 Material that shows unacceptable discontinuities as determined by the acceptance standards specified in the order, subsequent to its acceptance at the manufacturer's works, shall be rejected and the manufacturer shall be notified within 30 days unless otherwise agreed upon.

12. Certification

12.1 Upon request of the purchaser, the manufacturer shall certify that his product conforms to the requirements of this specification. The results of tests shall be furnished to the purchaser upon request as mutually agreed upon.

13. Product Marking

13.1 Each length of pipe and fitting shall be identified by the manufacturer's name or identification mark. Marking shall be as not to impair the usefulness of the part.

13.2 Samples that represent rejected material shall be preserved for a minimum of 2 weeks from the date of transmission of the rejection report. In case of dissatisfaction with the results of the tests, the manufacturer shall be permitted to make claim for a rehearing within that time.

14. Packaging

14.1 Unless otherwise specified, the material shall be packaged in accordance with the supplier's standard practice and acceptable to the carrier at the lowest rates. Containers and packing shall comply with Uniform Classification Rules or National Motor Freight Classification Rules.

15. Keywords

15.1 corrosion resistant; fittings; high-silicon iron; hubless; hub/plain-end; no-hub; plain-end

SUPPLEMENTARY REQUIREMENTS

The following supplementary requirements are for use when desired by the purchaser. They shall not apply unless specified in the order, in which event the specified tests shall be made by the manufacturer before shipment of the castings.

S1. Transverse Bend Tests

S1.1 Transverse bend properties shall be determined from material representing each heat and shall meet the requirements shown in Table S1.1. Properties thus measured shall be considered representative of the quality of the high-silicon iron but may not represent properties in the actual castings.

S1.2 Transverse bend tests shall be conducted in accordance with the manufacturer's established test procedure for transverse bend test including the following:

S1.2.1 The specimens shall not be machined or ground and shall conform to the dimensions in Fig. 72.

S1.2.2 The specimens shall be cast in patterns in accordance with Fig. 73.

S1.2.3 The specimens shall be heat treated in accordance with Section 7.

S1.2.4 The actual breaking load shall be reported. The requirements of Table 2 allow for any deviation due to variations in test bar diameter. The deflection at fracture shall also be reported without correction.

S1.2.5 The rate of loading shall produce 0.025-in. (0.64-mm) deflection in 50 to 70 s. Continue loading at this rate until the specimen fractures.

TABLE S1.1 Transverse Bend Test Minimum Requirements[A]

Load at Center, min, lbf (N)	930 (4090)
Deflection at Center, min, in. (mm)	0.026 (0.66)

[A] Test bars are to be tested on supports 12 in. (305 mm) apart.

S2. Hydrostatic Testing

S2.1 Hydrostatic tests at 40 psi, minimum, shall be conducted on all castings specified in the order. Any leak revealed by this test shall be cause for rejection for the individual piece. A leak shall include any evidence of moisture on the outside diameter of the part established to have occurred due to through-wall leakage.

TABLE 1 Tolerances for High-Silicon Iron Hub/Plain-End Pipe

NOTE 1—1 in. = 25.4 mm.

Size, in.	Wall Thickness, in.	ID Tolerance, in.	OD Tolerance, in.
2	±1⁄32	±1⁄32	±1⁄32
3	±1⁄32	±1⁄32	±1⁄32
4	±1⁄32	±1⁄32	±1⁄32
6	±1⁄32	±1⁄32	±3⁄64
8	±1⁄32	±1⁄8	±1⁄8
10	±1⁄8	±1⁄8	±1⁄8
12	±1⁄8	±1⁄8	±1⁄8
15	±1⁄8	±1⁄8	±1⁄8

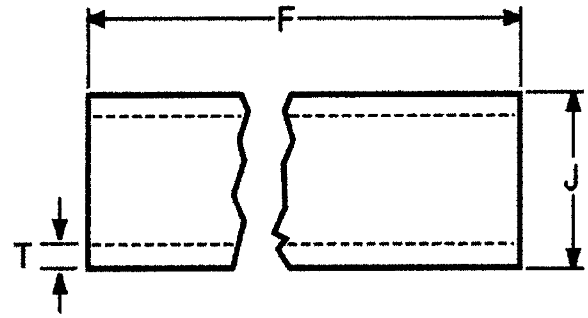
TABLE 2 Tolerances for High-Silicon Iron Fittings

NOTE 1—1 in. = 25.4 mm.

Size, in.	ID Tolerance, in.	OD Tolerance, in.	Stop Lug Depth Tolerance, in.
1½	±1⁄16	±1⁄16	±1⁄16
1½ × 1½	±1⁄16	±1⁄16	±1⁄16
2	±1⁄16	±1⁄16	±1⁄16
2 × 1½	±1⁄16	±1⁄16	±1⁄16
2 × 2	±1⁄16	±1⁄16	±1⁄16
3	±1⁄16	±1⁄16	±1⁄16
3 × 1½	±1⁄16	±1⁄16	±1⁄16
3 × 2	±1⁄16	±1⁄16	±1⁄16
3 × 3	±1⁄16	±1⁄16	±1⁄16
4	±1⁄16	±1⁄16	±1⁄16
4 × 1½	±1⁄16	±1⁄16	±1⁄16
4 × 2	±1⁄16	±1⁄16	±1⁄16
4 × 3	±1⁄16	±1⁄16	±1⁄16
4 × 4	±1⁄16	±1⁄16	±1⁄16

TABLE 3 Chemical Composition

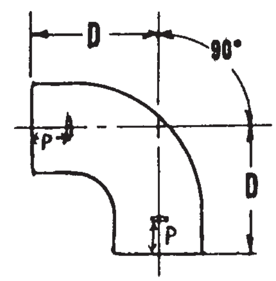
Element	Composition, Weight %	
	Grade 1	Grade 2
Carbon	0.65–1.10	0.75–1.15
Manganese	1.50 max	1.50 max
Silicon	14.20–14.75	14.20–14.75
Chromium	0.50 max	3.25-5.00
Molybdenum	0.50 max	0.40-0.60
Copper	0.50 max	0.50 max



Size, in.	J, in.	F, in.	t, in.
1½	2³⁄16 (2.19)	84	5⁄16
2	2¹¹⁄16 (2.69)	84	5⁄16
3	3⁴⁹⁄64 (3.77)	84	5⁄16
4	4⁴⁹⁄64 (4.77)	84	5⁄16

NOTE 1—1 in. = 25.4 mm.

FIG. 1 No-Hub Pipe (MJ)



Size, in.	D, in.	ID, in.	OD, in.	Stop Lug Depth (P), in.
1½	4¼	1½	2³⁄16 (2.19)	1¹⁄32
2	4½	2	2⅝ (2.62)	1¹⁄32
2 × 1½	4³⁄16 × 4½	2 × 1½	2⅝ × 2³⁄16	1¹⁄32
3	5	3	3¾ (3.75)	1¹⁄32
4	5½	4	4¾ (4.75)	1¹⁄32

NOTE 1—1 in. = 25.4 mm.

FIG. 2 Quarter Bends

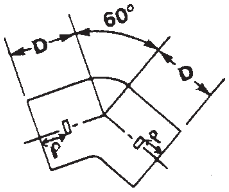
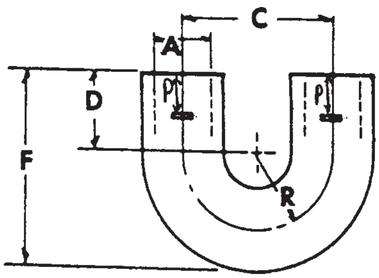


TABLE 3 *Continued*

Size, in.	D, in.	ID, in.	OD, in.	Stop Lug Depth (P), in.
1½	3	1½	2³⁄₁₆	1¹⁄₃₂
2	3¼	2	2⅝	1¹⁄₃₂
3	3½	3	3¾	1¹⁄₃₂
4	3¾	4	4¾	1¹⁄₃₂

NOTE 1—1 in. = 25.4 mm.

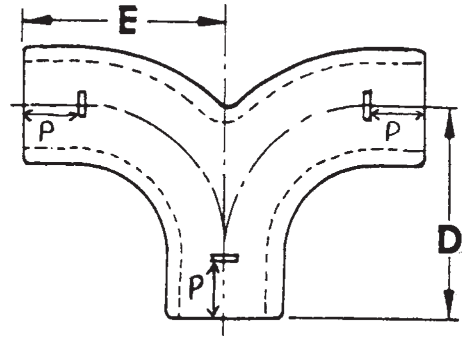
FIG. 3 Sixth Bends



Size, in.	C, in.	D, in.	F, in.	R, in.	ID, in.	OD, in.	Stop Lug Depth (P), in.
1½	4	2	5³⁄₃₂	2	1½	2³⁄₁₆	1¹⁄₃₂
2	4¾	2	5¹¹⁄₁₆	2⅜	2	2⅝	1¹⁄₃₂

NOTE 1—1 in. = 25.4 mm.

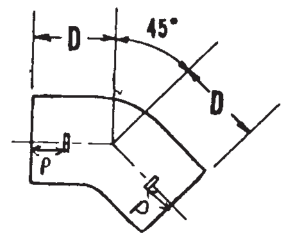
FIG. 4 Return Bends



Size, in.	D, in.	E, in.	ID, in.	OD, in.	Stop Lug Depth (P), in.
1½	3⅞	3¾	1½	2³⁄₁₆	1¹⁄₃₂

NOTE 1—1 in. = 25.4 mm.

FIG. 5 Double-Branch Quarter Bend



Size, in.	D, in.	ID, in.	OD, in.	Stop Lug Depth (P), in.
1½	2½	1½	2³⁄₁₆	1¹⁄₃₂
2	2¾	2	2⅝	1¹⁄₃₂
3	3	3	3¾	1¹⁄₃₂
4	3¼	4	4¾	1¹⁄₃₂

NOTE 1—1 in. = 25.4 mm.

FIG. 6 Eight Bends

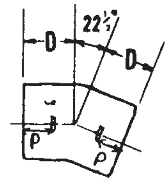
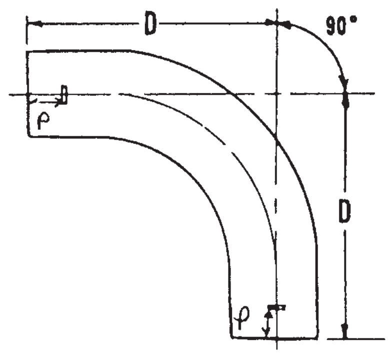


TABLE 3 *Continued*

Size, in.	D, in.	ID, in.	OD, in.	Stop Lug Depth (P), in.
1½	2	1½	2³⁄₁₆	1¹⁄₃₂
2	2⅛	2	2⅝	1¹⁄₃₂
3	2¼	3	3¾	1¹⁄₃₂
4	2⅜	4	4¾	1¹⁄₃₂

NOTE 1—1 in. = 25.4 mm.

FIG. 7 Sixteenth Bends



Size, in.	D, in.	ID, in.	OD, in.	Stop Lug Depth (P), in.
1½	9¼	1½	2³⁄₁₆	1¹⁄₃₂
2	9½	2	2⅝	1¹⁄₃₂
3	10	3	3¾	1¹⁄₃₂
4	10½	4	4¾	1¹⁄₃₂

FIG. 8 Long-Sweep Quarter Bends

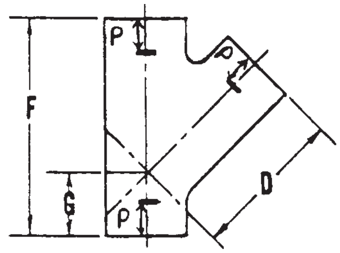
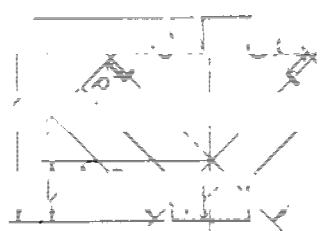


TABLE 3 *Continued*

Size, in.	D, in.	F, in.	G, in.	ID, in	OD, in.	Stop Lug Depth (P), in.
½ × 1½	4⅝	6½	1⅞	1½ × 1½	2 3/16 × 2 3/16	1 1/32
2 × 1½	4⅞	6½	1⅝	2 × 1½	2⅝ × 2 3/16	1 1/32
2 × 2	4⅝	6⅜	2	2 × 2	2⅝ × 2⅝	1 1/32
3 × 1½	5⅝	6½	1¼	3 × 1½	3¾ × 2 3/16	1 1/32
3 × 2	5⅞	7⅛	1½	3 × 2	3¾ × 2⅝	1 1/32
3 × 3	6⅜	8⅝	2¼	3 × 3	3¾ × 3¾	1 1/32
4 × 1½	6⅝	7½	1⅜	4 × 1½	4¾ × 2 3/16	1 1/32
4 × 2	6⅝	7½	1⅜	4 × 2	4¾ × 2⅝	1 1/32
4 × 3	7⅛	8¾	1¾	4 × 3	4¾ × 3¾	1 1/32
4 × 4	7⅝	10¼	2⅝	4 × 4	4¾ × 4¾	1 1/32

NOTE 1—1 in. = 25.4 mm.

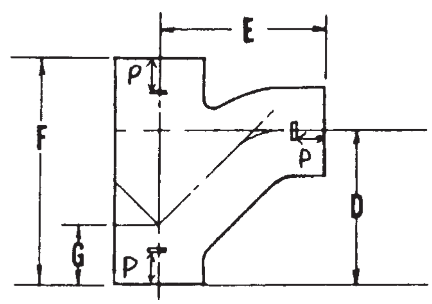
FIG. 9 Sanitary Y Branches



Size, in.	D, in.	F, in.	G, in.	ID, in.	OD, in.	Stop Lug Depth (P), in.
1½ × 1½	4⅝	6½	1⅞	1½ × 1½	2 3/16 × 2 3/16	1 1/32
2 × 1½	4⅞	6½	1⅝	2 × 1½	2⅝ × 2 3/16	1 1/32
2 × 2	4⅝	6⅜	2	2 × 2	2⅝ × 2⅝	1 1/32
3 × 1½	5⅝	6½	1¼	3 × 1½	3¾ × 2 3/16	1 1/32
3 × 2	5⅞	7⅛	1½	3 × 2	3¾ × 2⅝	1 1/32
3 × 3	6⅜	8⅝	2¼	3 × 3	3¾ × 3¾	1 1/32
4 × 2	6⅝	7½	1⅜	4 × 2	4¾ × 2⅝	1 1/32
4 × 3	7⅛	8¾	1¾	4 × 3	4¾ × 3¾	1 1/32
4 × 4	7⅝	10¼	2⅝	4 × 4	4¾ × 4¾	1 1/32

NOTE 1—1 in. = 25.4 mm.

FIG. 10 Double-Branch Sanitary Y



Size, in.	D, in.	E, in.	F, in.	G, in.	ID, in.	OD, in.	Stop Lug Depth (P), in.
1½ × 1½	4¾	5⅜	6½	1⅞	½ × 1½	2 3/16 × 2 3/16	1 1/32
2 × 1½	4¾	5¾	6½	1⅝	2 × 1½	2⅝ × 2 3/16	1 1/32
2 × 2	5	5⅞	6⅝	1⅞	2 × 2	2⅝ × 2⅝	1 1/32
3 × 1½	4	5¼	6½	1⅝	3 × 1½	3¾ × 2 3/16	1 1/32
3 × 2	5	6¼	7⅛	1½	3 × 2	3¾ × 2⅝	1 1/32
3 × 3	6¼	7	8½	2¼	3 × 3	3¾ × 3¾	1 1/32
4 × 1½	4 5/16	6⅛	6⅝	1⅜	4 × 1½	4¾ × 2 3/16	1 1/32
4 × 2	5	6⅜	7⅜	1⅜	4 × 2	4¾ × 2⅝	1 1/32
4 × 3	6	7¼	8¾	1¾	4× 3	4¾ × 3¾	1 1/32
4 × 4	7⅜	8	10¼	2⅝	4× 4	4¾ × 4¾	1 1/32

NOTE 1—1 in. = 25.4 mm.

FIG. 11 Sanitary Combination Y and ⅛ Bend

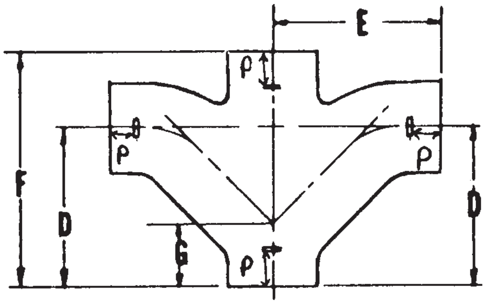
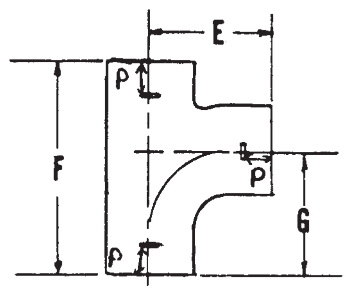


TABLE 3 *Continued*

Size, in.	D, in.	E, in.	F, in.	G, in.	ID, in.	OD, in.	Stop Lug Depth (P), in.
1½ × 1½	4¾	5⅜	6½	7⅞	1½ × 1½	2³⁄₁₆ × 2³⁄₁₆	1¹⁄₃₂
2 × 1½	4¾	5¾	6½	1⅝	2 × 1½	2⅝ × 2³⁄₁₆	1¹⁄₃₂
2 × 2	5	5⅞	6⅝	1⅝	2 × 2	2⅝ × 2⅝	1¹⁄₃₂
3 × 1½	4¼	5¼	6½	1⅝	3 × 1½	3¾ × 2³⁄₁₆	1¹⁄₃₂
3 × 2	5	6¼	7⅛	1½	3 × 2	3¾ × 2⅝	1¹⁄₃₂
3 × 3	6¼	7	8½	2¼	3 × 3	3¾ × 3¾	1¹⁄₃₂
4 × 2	5	6⅜	7⅜	1⅜	4 × 2	4¾ × 2⅝	1¹⁄₃₂
4 × 3	6	7¼	8¾	1¾	4 × 3	4¾ × 3¾	1¹⁄₃₂
4 × 4	7⅜	8	10¼	2⅝	4 × 4	4¾ × 4¾	1¹⁄₃₂

NOTE 1—1 in. = 25.4 mm.

FIG. 12 Double-Branch Sanitary Combination Y and ⅛ Bend



Size, in.	E, in.	F, in.	G, in.	ID, in.	OD, in.	Stop Lug Depth (P), in.
1½ × 1½	4¼	6¾	4¼	1½ × 1½	2³⁄₁₆ × 2³⁄₁₆	1¹⁄₃₂
2 × 1½	4½	6¾	4¼	2 × 1½	2⅝ × 2³⁄₁₆	1¹⁄₃₂
2 × 1½ × 1½	4½	6¾	4¼	2 × 1½ × 1½	2⅝ × 2³⁄₁₆ × 2³⁄₁₆	1¹⁄₃₂
2 × 2	4½	6⅞	4½	2 × 2	2 ⅝ × 2⅝	1¹⁄₃₂
3 × 1½	5	6¾	4¼	3 × 1½	3¾ × 2³⁄₁₆	1¹⁄₃₂
3 × 2	5	7¼	4½	3 × 2	3¾ × 2 ⅝	1¹⁄₃₂
3 × 3	5	8⅜	5	3× 3	3¾ × 3¾	1¹⁄₃₂
4 × 1½	5⁹⁄₁₆	6⅞	4⁷⁄₃₂	4× 1½	4¾ × 2³⁄₁₆	1¹⁄₃₂
4 × 2	5½	7¼	4½	4 × 2	4¾ × 2⅝	1¹⁄₃₂
4 × 3	5½	8¼	5	4 × 3	4¾ × 3¾	1¹⁄₃₂
4 × 4	5½	9⅜	5½	4 × 4	4¾ × 4¾	1¹⁄₃₂

NOTE 1—1 in. = 25.4 mm.

FIG. 13 Sanitary T Branches

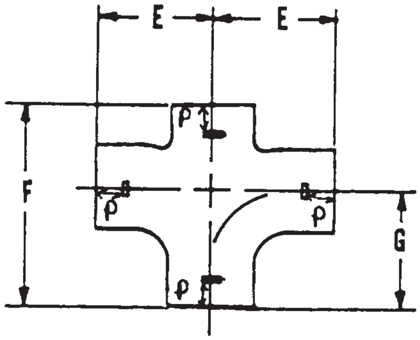
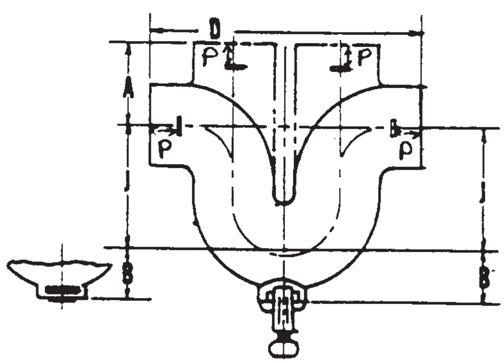


TABLE 3 *Continued*

Size, in.	E, in.	F, in.	G, in.	ID, in.	OD, in.	Stop Lug Depth (P), in.
1½ × 1½	4¼	6¾	4¼	1½ × 1½	2 3/16 × 2 3/16	1 1/32
2 × 1½	4½	6¾	4¼	2 × 1½	2⅝ × 2 3/16	1 1/32
2 × 2	4½	6⅞	4½	2 × 2	2⅝ × 2⅝	1 1/32
3 × 1½	5	6¾	4¼	3 ×1½	3¾ × 2 3/16	1 1/32
3 × 2	5	7¼	4½	3 × 2	3¾ × 2⅝	1 1/32
3 × 3	5	8⅜	5	3 × 3	3¾ × 3¾	1 1/32
4 × 2	5½	7¼	4½	4 × 2	4⅜ × 2⅝	1 1/32
4 × 3	5½	8¼	5	4 × 3	4¾ × 3¾	1 1/32
4 × 4	5½	9⅜	5½	4 × 4	4⅜ × 4⅜	1 1/32

NOTE 1—1 in. = 25.4 mm.

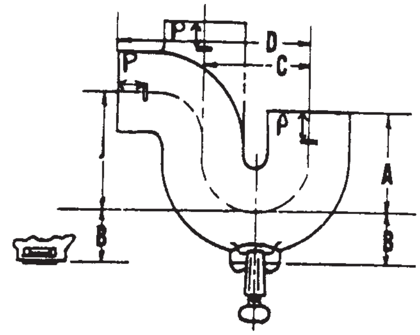
FIG. 14 Double-Branch Sanitary T



Size, in.	A, in.	B, in.	C, in.	D, in.	J, in.	R, in.	ID, in.	OD, in.	Stop Lug Depth (P), in.
1½	2¾	1⅝	5	10	4	1¾	1½	2 3/16	1 1/32
2	3½	1 15/16	5½	11	4	2	2	2⅝	1 1/32
3	4	2 5/16	6½	13	5½	2½	3	3¾	1 1/32
4	4½	3	7½	15	6½	3	4	4¾	1 1/32

NOTE 1—1 in. = 25.4 mm.

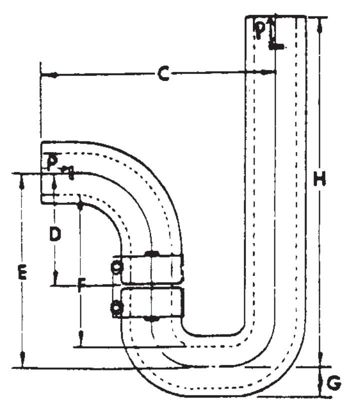
FIG. 15 Sanitary Running Traps



Size, in.	A, in.	B, in.	C, in.	D, in.	J, in.	R, in.	ID, in.	OD, in.	Stop Lug Depth (P), in.
1½	3¾	1⅝	3½	6¾	4	1¾	1½	2 3/16	1 1/32
2	4	1 15/16	4	7½	4	2	2	2⅝	1 1/32
3	4½	2 5/16	5	9	5½	2½	3	3¾	1 1/32
4	5	3	6	10½	6½	3	4	4¾	1 1/32

NOTE 1—1 in. = 25.4 mm.

FIG. 16 Sanitary P Traps



Size, in.	C, in.	D, in.	E, in.	F, in.	G, in.	H, in.	ID, in.	OD, in.	Stop Lug Depth (P), in.
1½	8¾	4	6 15/16	5 7/16	1 3/32	12½	1½	2 3/16	1 1/32
2	9¾	4½	7¾	5¾	1⅜	12	2	2⅝	1 1/32

NOTE 1—1 in. = 25.4 mm.

FIG. 17 Swivel Trap P-Style Short

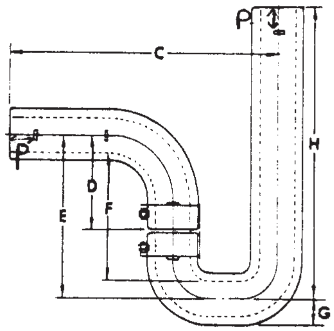


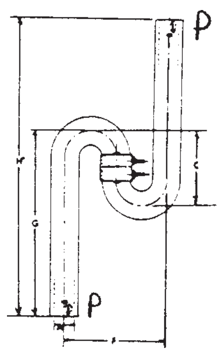
TABLE 3 *Continued*

Size, in.	C[A], in.	D, in.	E, in.	F, in.	G, in.	H[A], in.	ID, in.	OD, in.	Stop Lug Depth (P), in.
1½	12¾	4	6$^{15}/_{16}$	5$^{7}/_{16}$	1$^{3}/_{32}$	12½	1½	2$^{3}/_{16}$	1$^{1}/_{32}$

[A]For shorter C or H dimension, snap-cut to desired length.

NOTE 1—1 in. = 25.4 mm.

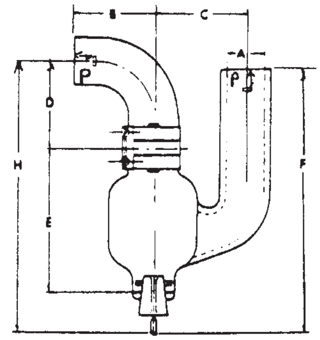
FIG. 18 Swivel Trap P-Style Long



Size, in.	C, in.	F, in.	G, in.	H, in.	ID, in.	OD, in.	Stop Lug Depth (P), in.
1½	6	8	14⅜	22¾	1½	2$^{3}/_{16}$	1$^{1}/_{32}$
2	6⅜	10½	12	17⅝	2	2⅝	1$^{1}/_{32}$

NOTE 1—1 in. = 25.4 mm.

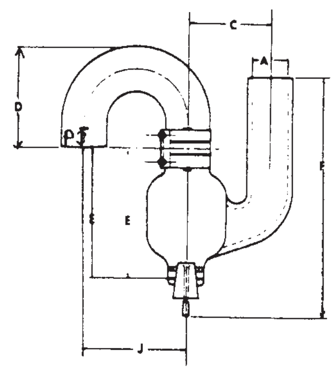
FIG. 19 Swivel Type-S Style Long



Size, in.	B, in.	C, in.	D, in.	E, in.	F, in.	H, in.	ID, in.	OD, in.	Stop Lug Depth (P), in.
1½	8	4	4	6¾	12¾	12$^{15}/_{16}$	1½	2$^{3}/_{16}$	1$^{1}/_{32}$
2	4½	4¾	4½	7$^{9}/_{16}$	14¼	14¼	2	2⅝	1$^{1}/_{32}$

NOTE—1 in. = 25.4 mm.

FIG. 20 Centrifugal Drum Trap P Swivel Type



Size, in.	C, in.	D, in.	E, in.	F, in.	J, in.	ID, in.	OD, in.	Stop Lug Depth (P), in.
1½	4	5$^{3}/_{32}$	6¾	12¾	4	1½	1⅛	1$^{1}/_{32}$
1½	4	15$^{15}/_{32}$	6¾	12¾	4	1½	1⅛	1$^{1}/_{32}$
2	4¾	5$^{11}/_{16}$	7$^{9}/_{16}$	14¼	4¾	2	2	1$^{1}/_{32}$

NOTE 1—1 in. = 25.4 mm.

FIG. 21 Centrifugal Drum Trap S Swivel Type

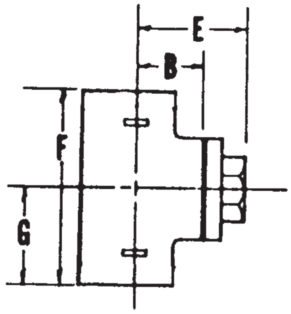
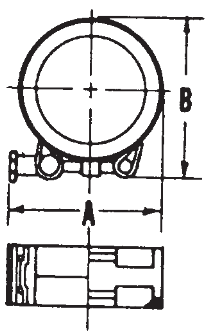


TABLE 3 *Continued*

Size, in.	B, in.	E, in.	F, in.	G, in.
2	2 7⁄16	3 3⁄4	6 7⁄8	3 7⁄16
3	3 3⁄8	4 11⁄16	8 3⁄8	4 3⁄16
4	3 7⁄8	5 7⁄16	9 3⁄8	4 11⁄16

NOTE 1—1 in. = 25.4 mm.

FIG. 22 Combination Cleanout and Test Tees



Size, in.	A, in.	B, in.
1 1⁄2	3 3⁄8	2 7⁄8
2	4	3 3⁄8
3	4 7⁄16	4 3⁄16
4	4 15⁄16	5 3⁄16

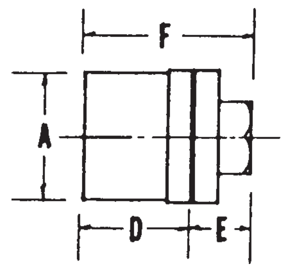
NOTE 1—1 in. = 25.4 mm.

FIG. 23 Coupling

Size, in.	F, in.
1⁄2	2
2	2 1⁄2
3	2 1⁄2
4	2 1⁄2

NOTE 1—1 in. = 25.4 mm.

FIG. 24 Pipe Plugs



Size, in.	A, in.	D, in.	E, in.	F, in.
1 1⁄2	2 3⁄16	2 1⁄4	1 5⁄16	3 9⁄16
2	2 21⁄32	2 1⁄4	1 5⁄16	3 9⁄16
3	3 3⁄4	2 1⁄2	1 3⁄8	3 7⁄8
4	4 3⁄4	2 3⁄4	1 7⁄16	4 3⁄16

NOTE 1—1 in. = 25.4 mm.

FIG. 25 Cleanout Plugs

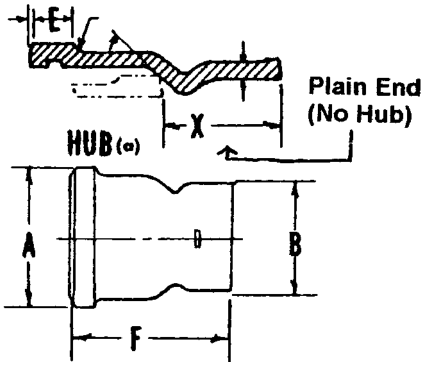
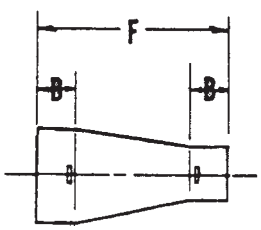


TABLE 3 *Continued*				
Size, in.	A, in.	B, in.	E, in.	F, in.
1½ × 1½	3²³⁄₃₂	2¼	9⁄16	4⅝
1½ × 2	3¹³⁄₁₆	2²¹⁄₃₂	9⁄16	4⅝
1½ × 3	3¹³⁄₁₆	3¹³⁄₁₆	9⁄16	4⅝
1½ × 4	3¹³⁄₁₆	4¹³⁄₁₆	9⁄16	4⅞
2 × 2	4⁵⁄₁₆	2²³⁄₃₂	⅝	5⅛
2 × 3	4⁵⁄₁₆	3¹³⁄₁₆	⅝	4¾
2 × 4	4⁵⁄₁₆	4¹³⁄₁₆	⅝	5
3 × 3	5⁵⁄₁₆	3¹³⁄₁₆	11⁄16	5⅜
4 × 4	6⁹⁄₃₂	4⅞	11⁄16	5⁹⁄₁₆

NOTE 1—1 in. = 25.4 mm.

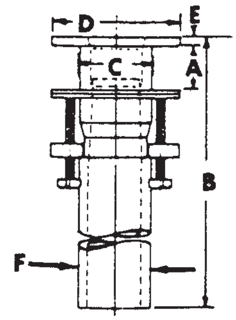
FIG. 26 Adapter/Hub to No-Hub



Size, in.	B, in.	F, in.
2 × 1½	1½	8
3 × 1½	1½	8
3 × 2	1½	8
4 × 1½	1½	8
4 × 2	1½	8
4 × 3	1½	8

NOTE 1—1 in. = 25.4 mm.

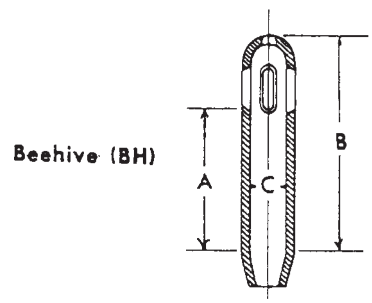
FIG. 27 Reducers-Increasers



Size, in.	A, in.	B, in.	C, in.	D, in.	E, in.	F, in.
1½	0 to 2	10¼	1⅞	3⁵⁄₁₆	¼	2³⁄₁₆

NOTE 1—1 in. = 25.4 mm.

FIG. 28 Sink Outlet

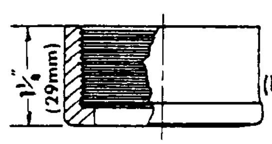


A, in.^{A}	B, in.^{A}	C, in.
4	6⅛	1
6	8⅛	1
8	10⅛	1

^{A}Dimension A and B will vary depending upon the sink strainer in which overflow is placed, depth of counterbore, and so forth, Dimension B is given only as a guide.

NOTE 1—1 in. = 25.4 mm.

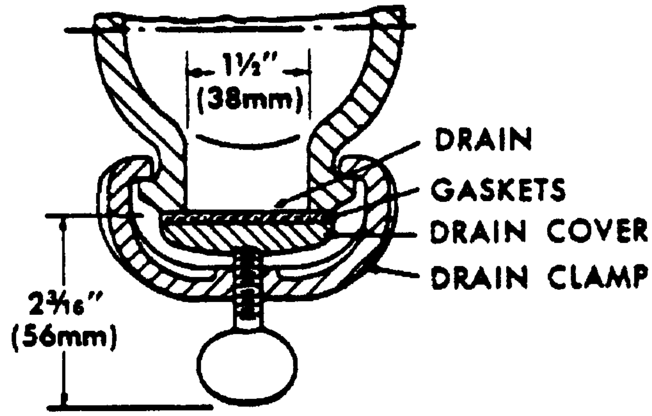
FIG. 29 Sink Overflows



Type	Size, in.
AD-7	1½ Outlet to 1½ MJ
AD-8	1½ Outlet to 2 MJ
AD-10	2 Outlet to 2 MJ

NOTE 1—1 in. = 25.4 mm.

FIG. 30 Threaded Adapters



NOTE 1—1 in. = 25.4 mm.

FIG. 31 Trap Cleanout Details

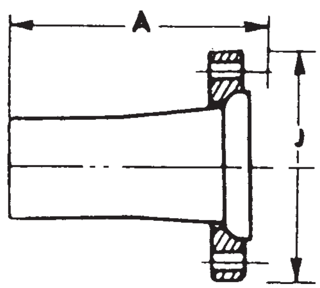


TABLE 3 *Continued*

Size, in.	A, in.	J, in.
2	5¾	6
3	7	7½
4	8	9

NOTE 1—Flange dimensions are 150 lb ANSI standard.
NOTE 2—1 in. = 25.4 mm.

FIG. 32 Adapter—No-Hub and Split Flange

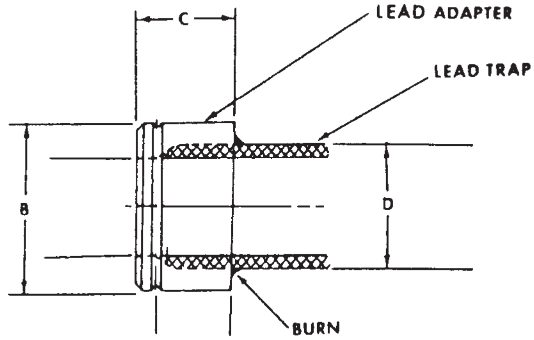
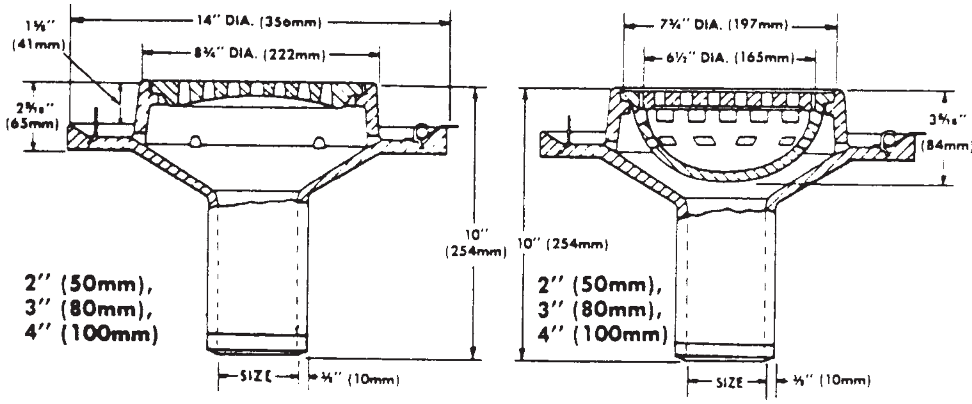


TABLE 3 *Continued*

Type	Size, in.	B, in.	C, in.	D, in.
AD-11	1½	2¼	1½	1 25⁄32
AD-12	2	2 23⁄32	1½	2 9⁄32

NOTE 1—1 in. = 25.4 mm.

FIG. 33 MJ to Lead Adapter



NOTE 1—1 in. = 25.4 mm.

FIG. 34 Floor Drains

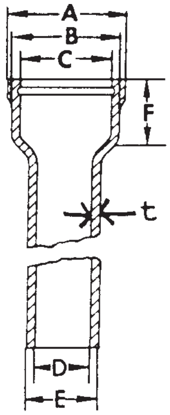


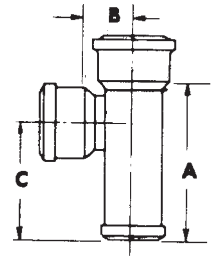
TABLE 3 *Continued*

Size, in.	A, in.	B, in.	C, in.	D, in.	E, in.	F, in.
2	4 9/16	4 3/16	3 5/16	2 1/32	2 11/16	2⅝
3	5 5/16	5 3/16	4 5/16	3⅛	3 25/32	2⅝
4	6⅜	6 3/16	5 5/16	4⅛	4 25/32	2⅝
6	8 17/32	8 11/32	7 5/16	5 15/16	6 11/16	3
8	11¼	10¾	9⅝	8¼	9	3
10	14¼	13¾	12¼	10	11¼	3⅞
12	16¾	16	14½	12	13¼	4
15	20¼	19¾	17¾	15	16¾	4⅛

Size, in.	t, in.	Weight, lb	Working Length, ft	Overall Length
2	5/16	0.31	7	7 ft 2⅝ in.
3	5/16	0.31	7	7 ft 2⅝ in.
4	5/16	0.31	7	7 ft 2⅝ in.
6	13/32	0.40	7	7 ft 3 in.
8	13/32	0.40	7	7 ft 3 in.
10	⅝	0.62	7	7 ft 3⅞ in.
12	⅝	0.62	5	5 ft 4 in.
15	⅞	0.75	5	5 ft 4⅛ in.

NOTE 1—1 in. = 25.4 mm.

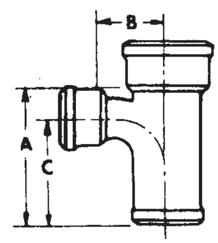
FIG. 35 Hub and Plain End Pipe



Size, in.	Weight, lb	A, in.	B, in.	C, in.
2 × 1½	11	8½	1⅞	6⅝
2 × 2	12	9	2	7
3 × 2	17	9	2½	6 13/16
3 × 3	19	10	2½	7½
4 × 2	20	9	3	7
4 × 3	22½	10	3	7¼
4 × 4	26	11	3	8

NOTE 1—1 in. = 25.4 mm.

FIG. 36 Straight Tees



Size, in.	Weight, lb	A, in.	B, in.	C, in.
2 × 1½	11	8½	3½	6¾
2 × 2	12	9	3½	7
3 × 1½	16	8½	4	6¾
3 × 2	18	9	4	7
3 × 3	20	10	4	7½
4 × 1½	18	8½	4½	6¾
4 × 2	19	9	4½	7
4 × 3	26	10	4½	7½
4 × 4	28	11	4½	8
6 × 2	31	9	5½	7
6 × 3	33	10	5½	7½
6 × 4	35	11	5½	8
6 × 6	50	13	5½	9
8 × 4	62	10⅝	6¼	8
8 × 6	65	14½	6⅝	10½
8 × 8	113	19	6⅝	13½
10 × 6	130	14¼	7⅝	10½
10 × 10	180	21	7¾	14½
12 × 8	187	19	8¾	13½

NOTE 1—1 in. = 25.4 mm.

FIG. 37 Sanitary T Branches

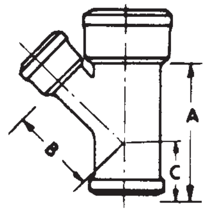
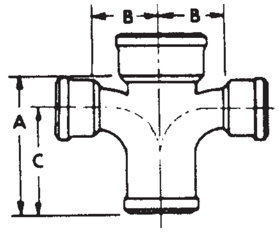


TABLE 3 *Continued*

Size, in.	Weight, lb	A, in.	B, in.	C, in.
2 × 1½	11	8⅝	4⅜	4⅜
2 × 2	12	9	4¼	4¾
3 × 1½	16	8⅝	5¹⁄₁₆	3⅞
3 × 2	17	9	5	4³⁄₁₆
3 × 3	21	10½	5½	5
4 × 1½	17	9⅛	5¹³⁄₁₆	3⅞
4 × 2	21	9	5¾	3¹¹⁄₁₆
4 × 3	26	10½	6¼	4½
4 × 4	30	12	6¾	5¼
6 × 2	28	9	7⅛	2¹¹⁄₁₆
6 × 3	35	10½	7⅝	3½
6 × 4	45	12¼	8¼	4¼
6 × 6	60	14¾	9⅛	5¾
8 × 2	60	16⅞	9	4½
8 × 3	63	12⅛	9	3¾
8 × 4	65	13½	10	4½
8 × 6	79	16½	11	6¹⁄₁₆
8 × 8	117	19½	12¼	7¼
10 × 4	160	13½	11½	3½
10 × 6	165	16⅝	13½	3⅞
10 × 8	170	19¾	14⅜	4⅜
10 × 10	180	22½	15	7⅝
12 × 4	173	18¼	15³⁄₁₆	4½
12 × 6	196	18¼	16½	4½
12 × 8	200	23⅜	15½	5
12 × 10	275	27	19½	6
12 × 12	288	25½	18⅜	7¼
15 × 15	455	32⅛	22¾	8⅛

NOTE 1—1 in. = 25.4 mm.

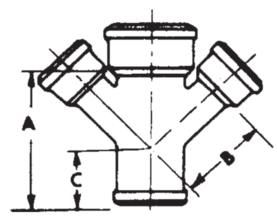
FIG. 38 Sanitary Y Branches



Size, in.	Weight, lb	A, in.	B & B, in.	C, in.
2 × 1½	14	8½	7	6¾
2 × 2	16	9	7	7
3 × 1½	15	8½	8	6¾
3 × 2	17	9	8	7
3 × 3	22	10	8	7½
4 × 1½	18	8½	9	6¾
4 × 2	21	9	9	7
4 × 3	24	10	9	7½
4 × 4	37	11	9	8
6 × 3	50	10	11	7½
6 × 4	46	11	11	8
6 × 6	58	13	11	9
8 × 6	80	14½	13¼	10½
8 × 8	113	19	6⅝	13½

NOTE—1 in. = 25.4 mm.

FIG. 39 Double-Branch Sanitary Tee



Size, in.	Weight, lb	A, in.	B, in.	C, in.
2 × 1½	14	8⅝	4⅜	4⅜
2 × 2	15	9	4¼	4¾
3 × 1½	19	8⅝	5¹⁄₁₆	3⅞
3 × 2	20	9	5	4³⁄₁₆
3 × 3	28	10½	5½	5
4 × 1½	21	9⅛	5¹³⁄₁₆	3⅞
4 × 2	23	9	5¾	3¹¹⁄₁₆
4 × 3	26	10½	6¼	4½
4 × 4	33	12	6¾	5¼
6 × 2	31	9	7⅛	2¹¹⁄₁₆
6 × 3	46	10½	7⅝	3½
6 × 4	52	12	8⅛	4¼
6 × 6	65	14¾	9⅛	5¾
8 × 4	71	13½	10	10½
8 × 6	86	16½	11	6¹⁄₁₆

NOTE 1—1 in. = 25.4 mm.

FIG. 40 Double-Branch Sanitary Y

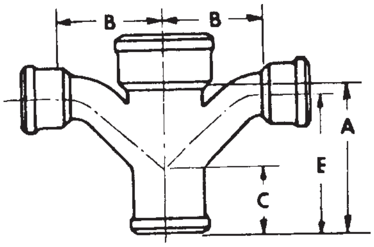
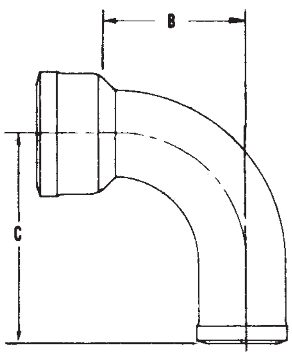


TABLE 3 *Continued*

Size, in.	Weight, lb	A, in.	B and B, in.	C, in.	E, in.
2 × 1½	15	8⅝	9¼	4⅜	7⅜
2 × 2	17	9	10½	4¾	8¼
3 × 1½	17	8⅝	10¼	3⅞	7⅜
3 × 2	22	9	11½	4³⁄₁₆	8³⁄₁₆
3 × 3	27	10½	13	5	9⁹⁄₁₆
4 × 1½	24	9⅛	11¾	3⅞	8⅛
4 × 2	24	9	12½	3¹¹⁄₁₆	8³⁄₁₆
4 × 3	28	10½	14	4½	9⁹⁄₁₆
4 × 4	40	12	15½	5¼	10¹³⁄₁₆
6 × 3	45	10½	16	3½	9⁹⁄₁₆
6 × 4	57	12	17½	4¼	10¹³⁄₁₆
6 × 6	83	15	20½	5¾	13⁷⁄₁₆

NOTE 1—1 in. = 25.4 mm.

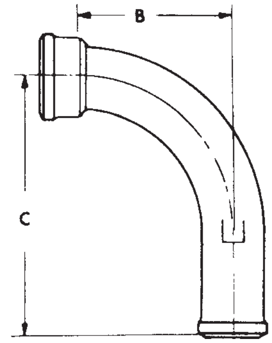
FIG. 41 Double-Branch Sanitary Combination Y and ⅛ Bend (T-Y)



Size, in.	Weight, lb	B, in.	C, in.
2	11	5¼	8
3	20	6	9
4	25	6½	10

NOTE 1—1 in. = 25.4 mm.

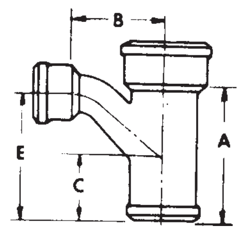
FIG. 42 Short-Sweep Quarter Bends



Size, in.	Weight, lb	B, in.	C, in.
2	14	8½	12
3	24	9	12½
4	29	9½	13
6	47	10½	14
8	98	11⅛	15

NOTE 1—1 in. = 25.4 mm.

FIG. 43 Long-Sweep Quarter Bends



Size, in.	Weight, lb	A, in.	B, in.	C, in.	E, in.
2 × 1½	11	8⅝	4⅝	4⅜	7⅜
2 × 2	13	9	5¼	4¾	8¼
3 × 1½	14	8⅝	5⅛	3⅞	7⅜
3 × 2	18	9	5¾	4³⁄₁₆	8³⁄₁₆
3 × 3	24	10½	6½	5	9⁹⁄₁₆
4 × 1½	17	9⅛	5⅞	3⅞	8⅛
4 × 2	21	9	6¼	3¹¹⁄₁₆	8³⁄₁₆
4 × 3	23	10½	7	4½	9⁹⁄₁₆
4 × 4	31	12	7¾	5¼	10³⁄₁₆
6 × 2	33	9	7¼	2¹¹⁄₁₆	8³⁄₁₆
6 × 3	37	10½	8	3½	9⁹⁄₁₆
6 × 4	47	12	8¾	4¼	10¹³⁄₁₆
6 × 6	63	15	10¼	5¾	13⁷⁄₁₆
10 × 6	185	16¾	12½	4⁷⁄₁₆	4⅜
10 × 8	192	21⅜	15⅛	6½	18½

NOTE 1—1 in. = 25.4 mm.

FIG. 44 Sanitary Combination Y and ⅛ Bend (T-Y)

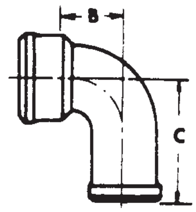
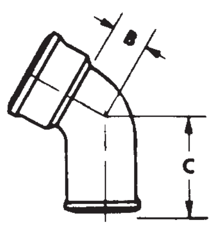


TABLE 3 *Continued*

Size, in.	Weight, lb	B, in.	C, in.
2	9	3½	7
3	16	4	7½
4	20	4½	8
6	36	5½	9
8	54	6⅛	10
10	116	8⅝	12
12	195	10⅜	14

NOTE 1—1 in. = 25.4 mm.

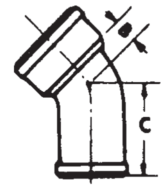
FIG. 45 Quarter Bends



Size, in.	Weight, lb	B, in.	C, in.
2	8	2¼	5¾
3	11	2½	6
4	15	2³⁄₁₆	6⁵⁄₁₆
6	27	3⅜	6⅞
8	71	4⅛	9

NOTE 1—1 in. = 25.4 mm.

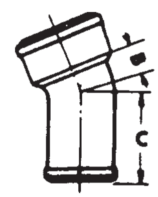
FIG. 46 Sixth Bends



Size, in.	Weight, lb	B, in.	C, in.
2	7	1¾	5¼
3	13	1¹⁵⁄₁₆	5⁷⁄₁₆
4	16	2³⁄₁₆	5¹¹⁄₁₆
6	25	2⁹⁄₁₆	6¹⁄₁₆
8	46	3¹¹⁄₁₆	8¹³⁄₁₆
10	95	4¼	9¼
12	132	5	9⅝

NOTE 1—1 in. = 25.4 mm.

FIG. 47 Eighth Bends



Size, in.	Weight, lb	B, in.	C, in.
2	6	1⅛	4⅝
3	8	1³⁄₁₆	4¹¹⁄₁₆
4	11	1⁵⁄₁₆	4¹³⁄₁₆
6	21	1½	5
8	44	2¹⁄₁₆	7⅛
10	80	2	6⅞

NOTE 1—1 in. = 25.4 mm.

FIG. 48 Sixteenth Bends

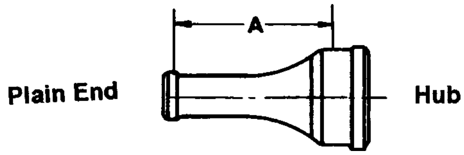
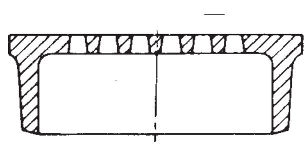


TABLE 3 *Continued*

Size, in.	Weight, lb	A, in.
2 × 3	9	9
2 × 4	13	9
2 × 6	17	9
3 × 4	17	9
3 × 6	16	9
4 × 6	17	9
4 × 8	33	11⅝
6 × 8	50	11⅞
8 × 10	85	16

NOTE 1—1 in. = 25.4 mm.

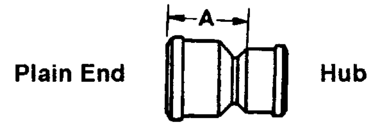
FIG. 49 Sanitary Increasers



Size, in.	Weight, lb
2	2½
3	3
4	5
6	10
8	18

NOTE 1—1 in. = 25.4 mm.

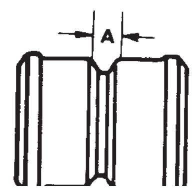
FIG. 50 Hub Strainers



Size, in.	Weight, lb	A, in.
3 × 1½	6	5
3 × 2	7	5
4 × 1½	7	5
4 × 2	9	5
4 × 3	11	5
6 × 2	12	5
6 × 3	13	5
6 × 4	14	5
8 × 4	22	6
8 × 6	25	6
10 × 6	39	6
10 × 8	51	6
12 × 6	55	6½
12 × 8	65	6
12 × 10	83	6
15 × 6	79	6
15 × 12	109	6

NOTE 1—1 in. = 25.4 mm.

FIG. 51 Sanitary Reducers



Size, in.	Weight, lb	A, in.
2	6½	1
3	9	1
4	12	1
6	18	1
8	40	2
10	82	2

NOTE 1—1 in. = 25.4 mm.

FIG. 52 Double Hubs

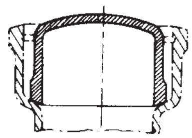
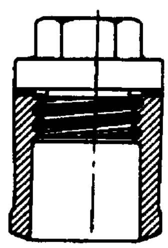


TABLE 3 *Continued*

Size, in.	Weight, lb
2	2
3	3
4	5
6	10
8	17
12	56

NOTE 1—1 in. = 25.4 mm.

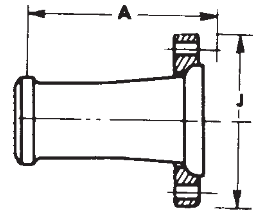
FIG. 53 Pipe Plugs



Size, in.	Weight, lb
2	3½
3	6½
4	11
6	14
8	26
10	39

NOTE 1—1 in. = 25.4 mm.

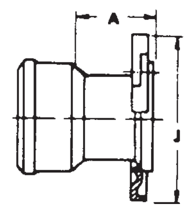
FIG. 54 Cleanout Plugs



Size, in.	Weight, lb	A, in.	J, in.
2	5	5¾	6
3	11	7	7½
4	12	8	9
6	22	9½	11
8	44	10¾	13½

NOTE 1—1 in. = 25.4 mm.

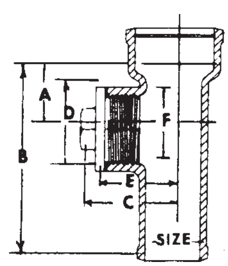
FIG. 55 Adapter—Plain-End and Split Flange



Size, in.	Weight, lb	A, in.	J, in.
2	5	2½	6
3	7	2½	7½
4	12	2¾	9
6	16	3	11
8	36	3½	13½

NOTE 1—1 in. = 25.4 mm.

FIG. 56 Adapter—Hub and Split Flange



Size, in.	Weight, lb	A, in.	B, in.	C, i n.	D, in.	E, in.	F, in.
2	12	2½	9	3¹³⁄₁₆	3⅝	3¹⁄₁₆	2⅞
3	22	2⅞	10	5	4⅝	4¼	3¹³⁄₁₆
4	29	3⁹⁄₁₆	11	5⁷⁄₁₆	5⅝	4½	4¹³⁄₁₆

NOTE 1—1 in. = 25.4 mm.

FIG. 57 Combination Cleanout and Test Tees

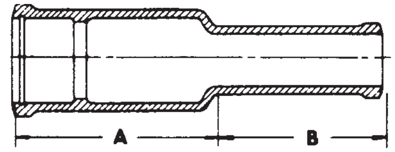
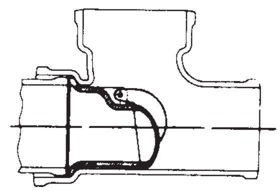


TABLE 3 *Continued*

Plate No.	Size, in.	Weight, lb	A, in.	B, in.
5045	2	11	7¾	6½
5070	3	17	8⅜	7⅜
5095	4	21	9⅛	7⅞
5144	6	37	9⅛	7⅞

NOTE 1—1 in. = 25.4 mm.

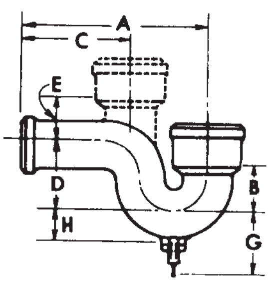
FIG. 58 Insertable Joints



Size, in.
3
4
6
8

NOTE 1—1 in. = 25.4 mm.

FIG. 59 Backwater Valves



Size, in.	Without Vent Weight, lb	Hub Vent Weight, lb	A, in.	B, in.	C, in.	D, in.	E, in.	G, in.	H, in.	Vent, in.
2	12	16	11	3	6¼	4½	2¼	3$^{13}/_{16}$	1⅝	2
3	25	32	12½	4¼	6¼	5½	3	4½	2$^{5}/_{16}$	3
4	37	45	14	5½	7	6½	3¼	5$^{3}/_{16}$	3	4
6	68	80	17	8½	8	8½	4	6½	3$^{15}/_{16}$	4

NOTE 1—Depth of seal on all traps shall be 2½ in.
NOTE 2—1 in. = 25.4 mm.

FIG. 60 Sanitary P Traps

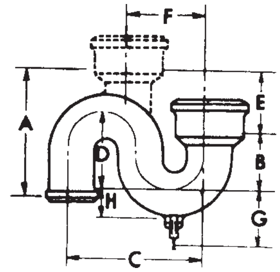
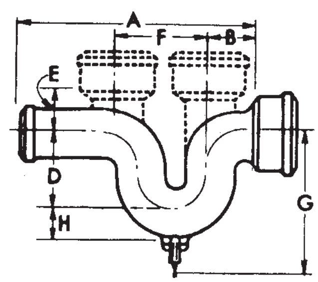


TABLE 3 *Continued*

Size, in.	Without Vent, Weight, lb	Hub Vent, Weight, lb	A, in.	B, in.	C, in.	D, in.	E, in.	F, in.	G, in.	H, in.	Vent, in.
2	16	18	$9\frac{1}{4}$	3	8	$4\frac{1}{2}$	$3\frac{3}{4}$	$4\frac{3}{4}$	$3\frac{13}{16}$	$1\frac{5}{8}$	2
3	24	29	$10\frac{1}{2}$	$4\frac{1}{4}$	10	$5\frac{1}{2}$	$4\frac{1}{4}$	$6\frac{1}{4}$	$4\frac{1}{2}$	$2\frac{5}{16}$	3
4	33	39	$11\frac{1}{4}$	$5\frac{1}{2}$	12	$6\frac{1}{2}$	$4\frac{1}{4}$	7	$5\frac{3}{16}$	3	4
6	82	89	14	$8\frac{1}{2}$	16	$8\frac{1}{2}$	5	9	$6\frac{1}{2}$	$3\frac{15}{16}$	4

NOTE 1—Depth of seal on all traps shall be $2\frac{1}{2}$ in.
NOTE 2—1 in. = 25.4 mm.

FIG. 61 Sanitary S Traps



Size, in.	Without Vent, Weight, lb	Single Hub Vent, Weight, lb	Double Hub Vent, Weight, lb	A, in.	B, in.	D, in.	E, in.	F, in.	G, in.	H, in.	Vent, in.
2	14	17	22	$13\frac{1}{2}$	$2\frac{1}{2}$	$4\frac{1}{2}$	$2\frac{1}{2}$	$5\frac{1}{4}$	$8\frac{5}{16}$	$1\frac{5}{8}$	2
3	29	36	42	$15\frac{1}{2}$	3	$5\frac{1}{2}$	$3\frac{1}{4}$	$6\frac{1}{4}$	10	$2\frac{5}{16}$	3
4	41	49	57	$17\frac{1}{2}$	$3\frac{1}{2}$	$6\frac{1}{2}$	$3\frac{1}{2}$	$7\frac{1}{4}$	$11\frac{11}{16}$	3	4
6	78	87	168	$21\frac{1}{2}$	$4\frac{1}{2}$	$8\frac{1}{2}$	$4\frac{1}{4}$	$8\frac{1}{4}$	15	$3\frac{15}{16}$	4
8	162	165	208	$26\frac{7}{8}$	$5\frac{1}{2}$	11	$3\frac{7}{8}$	12	$18\frac{7}{16}$	$5\frac{1}{4}$	6
10	330	334	346	$31\frac{7}{8}$	$7\frac{1}{8}$	13	$5\frac{1}{8}$	16	$22\frac{1}{4}$	$6\frac{11}{16}$	6

NOTE 1—Single hub vent is located on the inlet side. Depth of seal on 8 and 10-in. traps is 3 in. All others $2\frac{1}{2}$ in.
NOTE 2—1 in. = 25.4 mm.

FIG. 62 Sanitary Running Traps

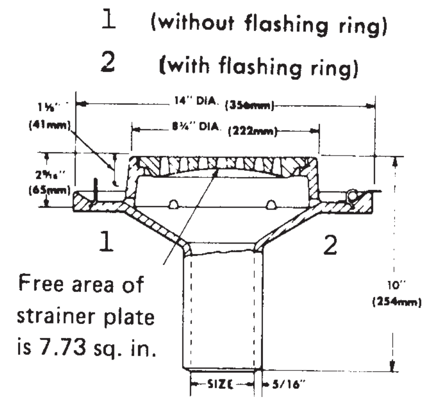


TABLE 3 *Continued*

Plate No.	Outlet Size, in.	Weight, lb
1	2, 3, 4 and 6	45
2	2, 3, 4 and 6	45
3	2, 3, 4 and 6	53
4	2, 3, 4 and 6	53
5	2, 3, 4 and 6	41
6	2, 3, 4 and 6	42
7	2, 3, 4 and 6	48
8	2, 3, 4 and 6	49

NOTE 1—1 in. = 25.4 mm.

FIG. 63 Outside Caulk

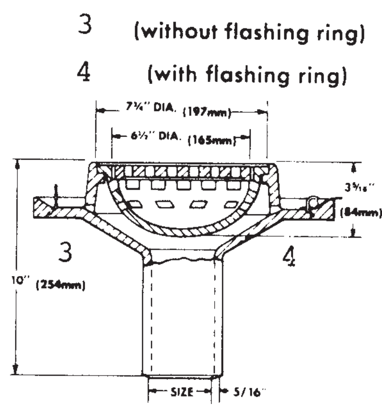


Plate No.	Size, in.	A, in.	B, in.	C, in.
5, 6, 7, 8	2	2⅞	3½	5⁄16
	3	3⅞	4½	5⁄16
	4	4⅞	5½	⅜
	6	7	7¾	⅜

NOTE 1—1 in. = 25.4 mm.

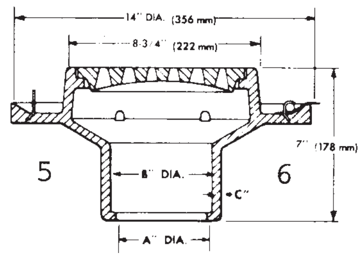
FIG. 64 Outside Caulk with Basin

5 (without flashing ring)

6 (with flashing ring)

7 * (with sediment basin and without flashing ring)

8 * (with sediment basin and with flashing ring)



NOTE 1—1 in. = 25.4 mm.

FIG. 65 Inside Caulk

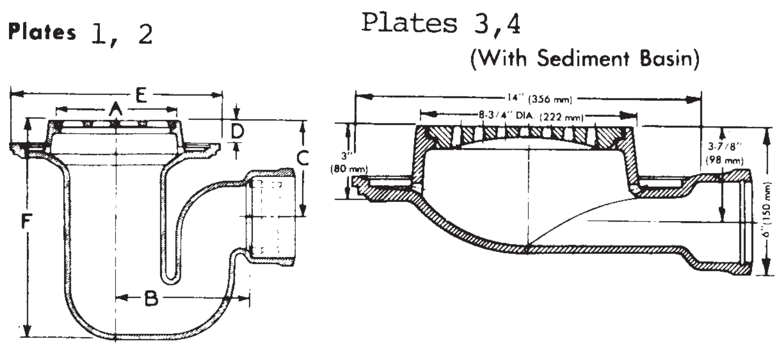


TABLE 3 *Continued*

Plate No.	Outlet Size, in.	Weight, lb
1	3	70
2	4	73
3	2	37
4	2	45

Plate No.	Size, in.	A, in.	B, in.	C, in.	D, in.	E, in.	F, in.
1	3	8	9	5⅞	1½	14	14½
2	4	8	9	6⅜	1½	14	14½

NOTE 1—1 in. = 25.4 mm.

FIG. 66 Floor Drains

With Flashing Ring

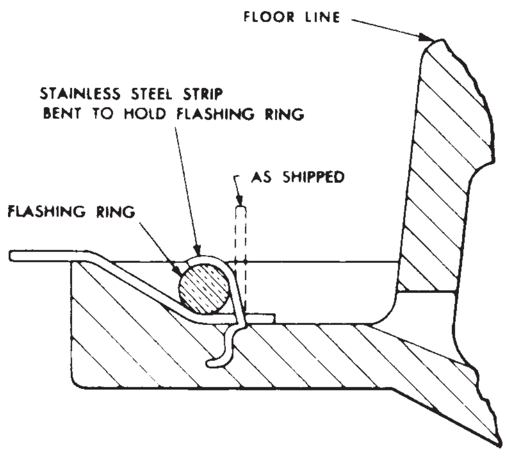
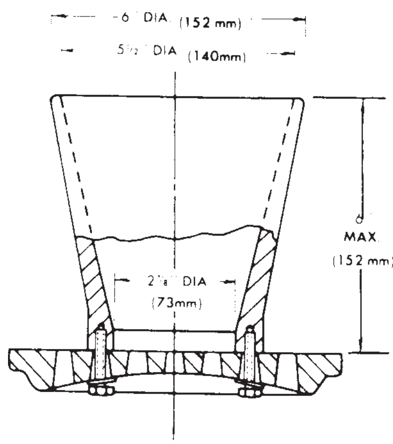


FIG. 67 Method of Installation



NOTE 1—1 in. = 25.4 mm.

FIG. 68 Floor Drain Funnel Attachment

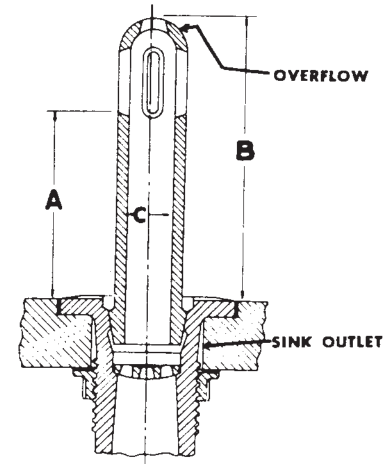


TABLE 3 *Continued*

Plate No.	A, in.[A]	B, in.[A]	C, in.
1	2	4⅛	1
2	4	6⅛	1
3	6	8⅛	1
4	8	10⅛	1
5	0	2⅛	1

[A]Dimensions A and B will vary depending upon the sink strainer in which overflow is placed, depth of counterbars, and so forth. Dimension B is given only as a guide.

NOTE 1—1 in. = 25.4 mm.

FIG. 69 No. 1, 2, 3, 4, and 5 Overflows

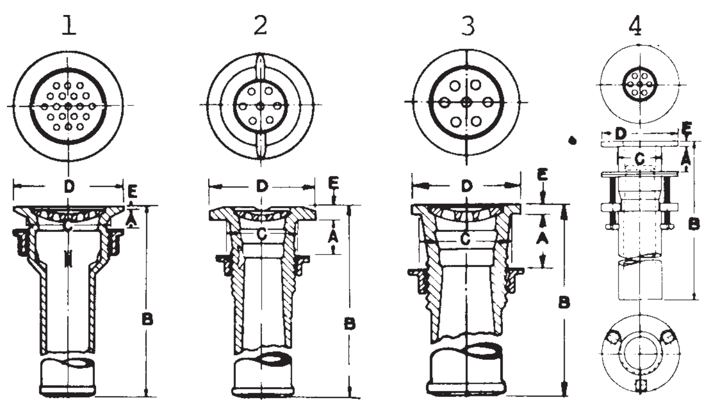


Plate No.	Size, in.	A, in.	B, in.	C, in.	D, in.	E, in.
1	1½ or 2	¾ to 1¼	10	3½	4⅜	⅛
2	1½ or 2	1 to 2	10	2½	3⅞	7⁄16
3	1½ or 2	1 to 2	10	2½	3	¼
4	1½	0 to 2	10¼		35⁄16	¼

NOTE 1—Furnished with flat loose strainer plates.
NOTE 2—1 in. = 25.4 mm.

FIG. 70 Sink Outlet

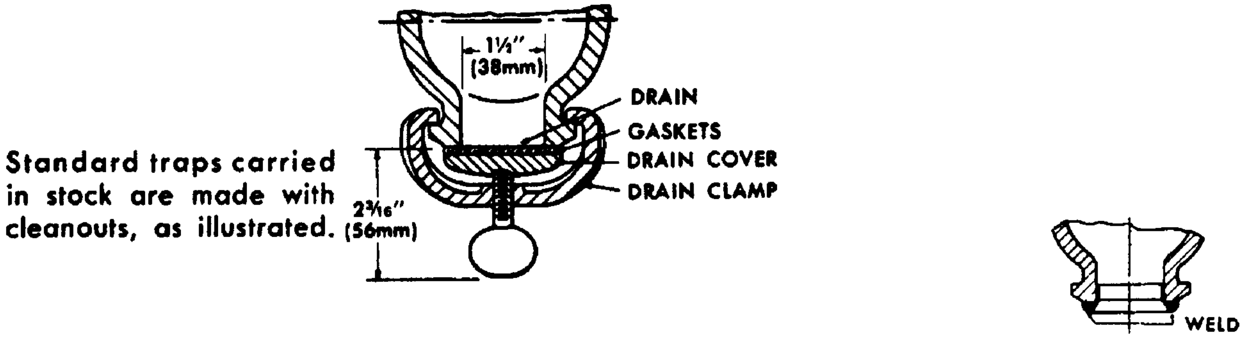


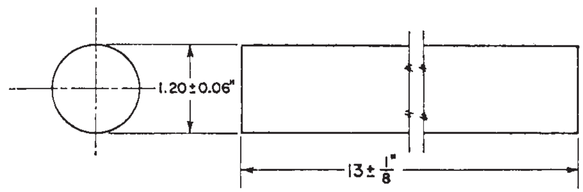
TABLE 3 *Continued*

Size, in.	Diameter of Drain, in.	A, in.
Under 6	1½	2³⁄₁₆
6 and over	2¼	2⁹⁄₁₆

NOTE 1—Traps can be supplied without cleanouts, as shown in the figure.

NOTE 2—1 in. = 25.4 mm.

FIG. 71 Detailed Cross Section of Cleanout



Metric Equivalents				
in.	0.06	⅛	1.20	13
mm	1.5	3.2	130.5	330.2

NOTE 1—It is recommended that the casting be mold-cooled to below 1000°F (540°C) before shakeout, and that the test bars be stress-relieved before transverse testing.

FIG. 72 Transverse Bend Test Bar Dimensions

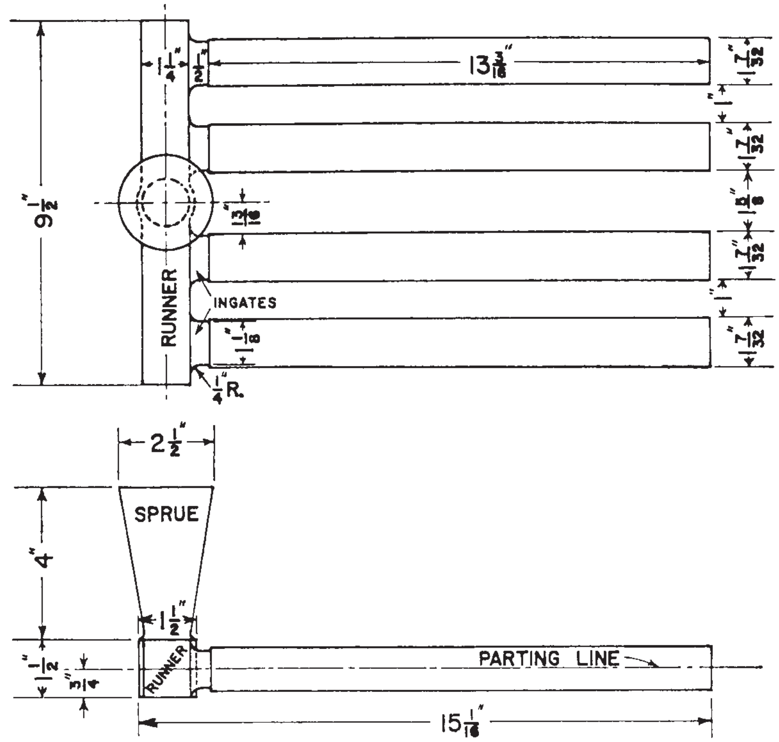


TABLE 3 *Continued*

Metric Equivalents														
in.	¼	½	¾	13⁄16	1	1⅛	17⁄32	1¼	1½	1⅝	2½	9½	133⁄16	151⁄16
mm	6.4	12.7	19.0	20.6	25.4	28.6	31.0	31.8	38.1	41.3	63.5	241.3	335.0	382.6

FIG. 73 Suggested Pattern for Transverse Bend Test Bar, Cast Horizontally, 1.20 in. (30.5 mm) in Diameter

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Standard Specification for Ferritic Ductile Iron Castings Suitable for Low-Temperature Service[1]

This standard is issued under the fixed designation A 874/A 874M; 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 ductile iron castings suitable for service at temperatures of −40°F [–40°C] and above.

1.2 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 shall be used independently of the other. Combining values from the two systems may result in nonconformance with the specification.

1.3 The following precautionary statement pertains only to the test methods portion, Section 11, 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 247 Test Method for Evaluating the Microstructure of Graphite in Iron Castings[2]

E 8 Test Methods for Tension Testing of Metallic Materials[3]

E 30 Test Methods for Chemical Analysis of Steel, Cast Iron, Open-Hearth Iron, and Wrought Iron[4]

E 59 Practice for Sampling Steel and Iron for Determination of Chemical Composition[4]

E 94 Guide for Radiographic Testing[5]

E 165 Test Method for Liquid Penetrant Examination[5]

E 351 Test Methods for Chemical Analysis of Cast Iron—All Types[4]

E 562 Practice for Determining Volume Fraction by Systematic Manual Point Count[3]

E 689 Reference Radiographs for Ductile Iron Castings[5]

E 709 Guide for Magnetic Particle Examination[5]

3. Ordering Information

3.1 Orders for material under this specification shall include the following applicable information:

3.1.1 Drawing, catalog number, or part identification,

3.1.2 Quantity (weight or number of pieces),

3.1.3 ASTM designation and year of issue,

3.1.4 Marking instructions (see Section 15),

3.1.5 Place of inspection (see 13.1),

3.1.6 Limits on residual elements (see 5.2),

3.1.7 Visual and dimensional acceptance standard (see 7.1),

3.1.8 Sampling plan (see Section 9), and

3.1.9 Supplementary requirements.

4. Materials and Manufacture

4.1 Castings may be supplied either as cast or heat treated and shall have essentially a ferritic structure that contains no massive carbides.

5. Chemical Composition

5.1 The iron shall conform to the requirements for chemical composition shown in Table 1.

5.2 By agreement between the manufacturer and purchaser, analysis may be required and limits established for elements not specified in Table 1.

6. Mechanical and Microstructural Properties

6.1 *Tensile Properties*—The iron shall conform to the requirements for tensile properties shown in Table 2.

6.2 *Microstructure*—Graphite contained in the microstructure shall be evaluated in accordance with Test Method A 247. The percent of each graphite type shall be estimated, and the total of all estimates shall equal 100 %. The total percent of Types 1 and 2 graphite shall be a minimum of 90 %.

7. Workmanship, Finish, and Appearance

7.1 The surface of the casting shall be examined visually and shall be free from adhering sand, scale, cracks, and hot tears. Other surface discontinuities shall meet visual and dimensional acceptance standards specified in the order.

7.2 Conditioning of castings is permitted to the extent that the removal of metal does not extend into the envelope of the finished container and does not alter the properties of the metal

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[1] This specification is under the jurisdiction of ASTM Committee A-4 on Iron Castings and is the direct responsibility of Subcommittee A04.02 on Malleable and Ductile Iron Castings.

Current edition approved Oct. 10, 1998. Published February 1999.

[2] *Annual Book of ASTM Standards*, Vol 01.02.

[3] *Annual Book of ASTM Standards*, Vol 03.01.

[4] *Annual Book of ASTM Standards*, Vol 03.05.

[5] *Annual Book of ASTM Standards*, Vol 03.03.

TABLE 1 Chemical Composition

Element	Minimum, %	Maximum, %
Total carbon	3.0	3.7
Carbon equivalent (carbon + ⅓ silicon)	. . .	4.5
Silicon	1.2	2.3
Phosphorous	. . .	0.03
Magnesium	. . .	0.07
Manganese	. . .	0.25
Copper	. . .	0.1
Nickel	. . .	1.0
Chromium	. . .	0.07

remaining in the finished container.

8. Repair

8.1 Castings shall not be repaired by plugging, welding, brazing, impregnation, or any other means.

9. Sampling

9.1 Test coupons will be obtained from the casting. The location in the casting from which the test coupons are obtained and the number obtained from each location shall be agreed upon between the manufacturer and purchaser.

9.2 Metallographic samples shall be obtained from the same location as the mechanical test coupons.

9.3 Nondestructive examination methods for estimating microstructure may be used to supplement the destructive examination sampling plan.

9.4 Sampling for chemical analysis shall be in accordance with Practice E 59.

9.4.1 The chemical analysis for total carbon shall be made on either chilled cast pencil-type specimens or thin wafers approximately 1⁄32 in. [0.8 mm] thick cut from test coupons.

10. Number of Tests and Retests

10.1 The number of tension tests and the number of microstructural examinations shall be agreed upon between the manufacturer and purchaser.

10.2 If any tension test specimen shows obvious defects, it may be discarded and another from the same coupon may be tested.

11. Test Methods

11.1 Conduct the tension test in accordance with Test Methods E 8.

TABLE 2 Tensile Properties

Tensile Strength, min, psi [MPa]	Yield Strength, min, psi [MPa]	Elongation in 2 in. [50 mm], min, %
45 000 [300]	30 000 [200]	12 [12]

11.2 Determine the yield strength using one of the following methods:

11.2.1 The 0.2 % offset method, or

11.2.2 Extension under load method where the yield strength may be determined as the stress producing an elongation under load of 0.330 %, that is, 0.0066 in. [0.165 mm] in a gage length of 2 in. [50 mm].

11.3 Determine the percent of each graphite nodule type by manual coating, semi-automatic, or automatic image analysis methods. The manual count method shall prevail when the results of other methods differ. Magnification shall be at 100 ×.

11.4 Spectrometric methods may be used for chemical analysis. Should a dispute arise concerning chemical composition, use Test Methods E 351 and E 30 for referee methods.

12. Records

12.1 Records of the chemical composition, mechanical properties, and the metallographic examination shall be systematically made and maintained.

13. Inspection

13.1 Unless otherwise specified in the contract or purchase order, the manufacturer shall perform all of the tests and inspections required by the specification.

13.2 All tests and inspections shall be made at the place of manufacture or a mutually agreed upon location.

13.3 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 manufacturer shall afford the inspector all reasonable facilities to satisfy that the material is being furnished in accordance with these specifications. The inspector representing the purchaser shall not interfere unnecessarily with the operation of the works.

14. Certification

14.1 The manufacturer's certification shall be furnished to the purchaser stating the material was manufactured, sampled, tested, and inspected in accordance with this specification (including the year of issue) and was found to meet the requirement(s). In addition, a test report shall be included with the certification giving the results of all tests performed including chemical analysis.

15. Product Marking

15.1 The casting shall be identified and shall be marked in accordance with instructions issued by the purchaser.

SUPPLEMENTARY REQUIREMENTS

Supplementary requirements shall be applied only when specified by the purchaser. Details of the supplementary requirements shall be agreed upon by the manufacturer and purchaser. The specified tests shall be performed by the manufacturer prior to shipment of the castings.

S1. Magnetic Particle Examination

S1.1 Castings shall be examined for surface discontinuities by magnetic particle examination. The examination shall be in accordance with Guide E 709. The extent of examination and the basis for acceptance shall be agreed upon between the manufacturer and purchaser.

S2. Ultrasonic Examination

S2.1 Castings shall be examined for internal defects by ultrasonic examination. The examination procedures and acceptance criteria shall be agreed upon between the manufacturer and purchaser.

S3. Liquid Penetrant Examination

S3.1 Castings shall be examined for surface discontinuities by means of liquid penetrant examination. The examination shall be in accordance with Test Method E 165. Areas to be inspected, methods and types of liquid penetrants to be used, developing procedure, and basis for acceptance shall be agreed upon between the manufacturer and purchaser.

S4. Radiographic Examination

S4.1 Castings shall be examined for internal defects by means of X-rays or gamma rays. The procedure shall be in accordance with Guide E 94, and types and degrees of discontinuities considered shall be judged by Reference Radiographs E 689. The extent of examination and basis for acceptance shall be agreed upon between the manufacturer and purchaser.

S5. Fracture Toughness

S5.1 Fracture toughness testing shall be performed on samples removed from the casting. The method of fracture toughness testing, the location from which the samples are removed, the number of tests performed, and the acceptance requirements shall be agreed upon between the manufacturer and purchaser.

S6. Nodule Count

S6.1 The nodule count per unit area shall be determined by examining 100 × micrographs.[6] The samples for the micrographs shall be removed from the casting at locations agreed upon. The inspection method and the acceptance requirements shall be agreed upon between the manufacturer and purchaser. Practice E 562 may be used for guidance.

[6] Electric Power Research Institute Project 2813-1, "Relationships Between Ductile Iron Fracture Toughness and Microstructure," December 1986, provides background information.

Designation: A 888 – 04

Standard Specification for Hubless Cast Iron Soil Pipe and Fittings for Sanitary and Storm Drain, Waste, and Vent Piping Applications[1]

This standard is issued under the fixed designation A 888; 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 hubless cast iron soil pipe and fittings for use in gravity flow applications. It establishes standards covering material, manufacture, mechanical and chemical properties, dimensions, coating, test methods, inspection, certification and product marking for hubless cast iron soil pipe and fittings. These pipe and fittings are intended for non-pressure applications, as the selection of the proper size for sanitary drain, waste, vent, and storm drain systems allows free air space for gravity drainage.

1.2 The EDP/ASA numbers indicated in this section represent a Uniform Industry Code adopted by the American Supply Association (ASA). A group designation prefix, 022, is assigned to hubless products, followed by the four-digit identification assigned to individual items and a check digit. This system has been instituted to facilitate EDP control through distribution channels, and be used universally in ordering and specifying product items. Those items with no EDP numbers are either new, special or transitory and will be assigned numbers on subsequent prints of this specification.

1.3 This specification covers pipe and fittings of the following patterns and applies to any other patterns that conform with the applicable requirements given herein.[2]

1.3.1 *Lengths*:

	Figures
EDP/ASA Identification Numbers for Hubless Pipe	Fig. 1
10 ft (3.0 m) in sizes and 5 ft. (1.5 m) 1½ , 2, 3, 4, 5, 6, 8, 10, 12, and 15 inch.	Fig. 1, Fig. 2
Method of Specifying Fittings	Fig. 3

1.3.2 *Fittings*:

Quarter Bend	Fig. 5
Quarter Bend, Reducing	Fig. 6
Quarter Bend, With Side Opening	Fig. 7
Quarter Bend, With Heel Opening	Fig. 8
Quarter Bend, Tapped	Fig. 9
Quarter Bend, Double	Fig. 10
Quarter Bend, Long	Fig. 11
Short Sweep	Fig. 12
Long Sweep	Fig. 13
Long Sweep, Reducing	Fig. 14
Fifth Bend	Fig. 15
Sixth Bend	Fig. 16
Eighth Bend	Fig. 17
Eighth Bend Long	Fig. 18
Sixteenth Bend	Fig. 19
Sanitary Tee	Fig. 20
Sanitary Tee With Side Opening	Fig. 21
Sanitary Tee With 2 in. Side Opening R or L/R and L	Fig. 22
Sanitary Tee, New Orleans Special With Side Opening	Fig. 23
Sanitary Tee With 45° Side Openings and New Orleans	Fig. 24
Sanitary Special Tee Tapped	Fig. 25
Sanitary Tapped Tee, Horizontal Twin	Fig. 26
Sanitary Tapped Tee, Double Vertical	Fig. 27
Y Branch	Fig. 28
Y Branch, Double	Fig. 29
Y Branch, Upright	Fig. 30
Upright Y Wide Center Florida Special	Fig. 31
Y Branch, Combination ⅛ Bend	Fig. 32
Y Branch, Combination ⅛ Bend Double	Fig. 33
Sanitary Cross	Fig. 34
Sanitary Cross With Side Opening	Fig. 35
Sanitary Cross, New Orleans, With Side Openings	Fig. 36
Sanitary Cross, New Orleans, With 45° Special and Regular Side Openings	Fig. 37
Sanitary Cross, Tapped	Fig. 38
Test Tee	Fig. 39
Tapped, Extension Piece	Fig. 40
Increaser-Reducer	Fig. 41
Increaser-Reducer, Short	Fig. 42
Tapped Adapter	Fig. 43
Blind Plug	Fig. 44
Iron Body Cleanout-Tapped	Fig. 45
P Trap	Fig. 46
P Trap, Long	Fig. 47
P Trap, Long-Tapped	Fig. 48
P Trap, Deep Seal	Fig. 49
P Trap, Reducing	Fig. 50
P Trap, With Primer	Fig. 51
P Trap, With Tapped Inlet	Fig. 52
Hub Adapter	Fig. 53
Tapped Inlet, Double	Fig. 54
Modified Combination Wye and ⅛ Bend, Double	Fig. 55
Modified Combination Wye and ⅛ Bend, Double, Extended	Fig. 56
Regular or Extended Left or Right Regular or Extended Double	Fig. 57
Regular or Extended Left or Right Regular or Extended Double	Fig. 58
Two-Way Cleanout	Fig. 59
Twin Cleanout	Fig. 60
Closet Bend, Regular and Reducing	Fig. 61
Closet Flange	Fig. 62
Tapping Bosses	Fig. 63

[1] This specification is under the jurisdiction of ASTM Committee A04 on Iron Castings and is under the direct responsibility of Subcommittee A04.12 on Pipes and Tubes.

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[2] Reprinted with permission from Cast Iron Soil Pipe Institute.

1.4 The values stated in inch-pound units shall be regarded as the standard. The values given in parentheses shall be for information only. Metric conversions in Table 1 and Table 2 are to two decimal places; all other metric conversions are rounded to the nearest whole number.

1.5 The committee with jurisdiction over this standard is aware of another comparable standard published by the Cast Iron Soil Pipe Institute, CISPI 301.

NOTE 1—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.

2. Referenced Documents [3]

2.1 *ASTM Standards:*

A 48 Specification for Gray Iron Castings

A 644 Terminology Relating to Iron Castings

C 564 Specification for Rubber Gaskets for Cast Iron Soil Pipe and Fittings

E 8 Test Methods for Tension Testing of Metallic Materials

2.2 *Federal Standard:*

Fed. Std. No. 123 Marking for Shipment (Civil Agencies)[4]

2.3 *Military Standard:*

MIL-STD-129 Marking for Shipment and Storage[4]

2.4 *ANSI/ASME Standard:*

B2.1 Pipe Threads[5]

2.5

Handbook 28, Screw Thread Standards for Federal Services[6]

2.6 *Other Documents:*

Uniform Freight Classification Rules[7]

National Motor Freight Classification Rules[8]

Cast Iron Soil Pipe Institute (CISPI) Specification 301[9]

3. Terminology

3.1 *Abbreviations:*

3.2 *AC*—above center

ADAPTR—adapter

&—and

ASA—American Supply Association

ASSY—assembly

BD—bend

CARL—Carlson

CF—Carlson fitting

CLO—closet

CO—cleanout

COMB—combination

CRS—cross

DB—double

DBL—double

EDP—electronic data processing

EXT—extended, extension

F—figure

FER—ferrule

FLNG—flange

FTG—fitting

HI—high

HOR—horizontal

INC—increaser, increasing

L—left hand

L/—less

LG—long

LH—left hand

LNG—long

/MAIN—on main

MN—on main

NO—New Orleans

R—right hand

RAD—radius

RED—reducer, reducing

REV—revent

RH—right hand

SAN—sanitary

SD—side

SL & NOTCH—slotted and notched

SO—side openings

ST—sanitary tap

T—tee

TAP—tap, tapped

TOT—tap on top

TP—tap, tapped

V—vent

VERT—vertical

W/—with

Y—wye

3.3 *Definitions of Terms Specific to This Standard:*

3.3.1 *manufacturer*—the entity that casts the pipe and fittings covered by this standard.

4. Materials and Manufacture

4.1 The pipe and fittings shall be iron castings suitable for installation and service for sanitary drain, waste, and vent piping applications. They shall meet all applicable requirements and tests given herein.

4.2 The castings shall be made of cast iron, produced by an established commercial method that provides adequate control over chemical and mechanical properties.

4.3 Cast iron is a generic term for a series of alloys as defined in Terminology A 644, and it includes gray iron as well as ductile iron. The castings shall be sound, true to pattern, and of compact close grain that permits drilling and cutting by ordinary methods. The interior surface shall be reasonably

[3] 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.

[4] Available from Standardization Documents, Order Desk, Building 4, Section D, 700 Robbins Ave., Philadelphia, PA 19111–5094, Attn: NPODS.

[5] Available from the American National Standards Institute, 25 W. 43rd St., 4th Floor, New York, NY 10036.

[6] Available from National Institute of Standards and Technology, U.S. Department of Commerce, Gaithersburg, MD 20899.

[7] Available from the Uniform Classification Commission, Room 1106, 222 S. Riverside Plaza, Chicago, IL 60606.

[8] Available from National Motor Freight Inc., 1616 P. St., N. W., Washington, DC 20036.

[9] Available from Cast Iron Soil Pipe Institute, 5959 Shallowford Rd., Chattanooga, TN 37421.

smooth and free from defects that would make the castings unfit for the use for which they are intended.

5. Mechanical Properties

5.1 *Mechanical Tests for Gray Iron*— When requested, tests shall be performed to determine mechanical properties of the gray iron used in the manufacture of gray iron soil pipe and fittings. Either transverse (flexure) test bars or tension test specimens shall be employed.

5.1.1 *Tensile Strength Test*—The tensile strength shall be not less than 21 000 psi (145 MPa).

6. Dimensions and Permissible Variations

6.1 *Pipe*:

6.1.1 *Ends of Pipe*—The end of pipe shall be cast with or without a spigot bead. The pipe shall be cast in one piece.

6.1.2 *Dimensions of Pipe*—Pipe shall be 10 ft (3 m) long or 5 ft (1.5 m) long with the dimensions and tolerances specified in Fig. 1 and Fig. 2. (The laying length of pipe is the same as actual length.)

6.1.3 *Straightness of Pipe*—Pipe shall be straight to the extent that for 10 ft (3 m) lengths, deflections in the barrel shall not exceed ⅝ in. (16 mm). For 5 ft (1.5 m) lengths, deflections in the barrel shall not exceed 5⁄16 in (8 mm).

6.2 *Fittings*:

6.2.1 *Dimensions of Fittings*—All fittings shall conform to the dimensions and tolerances specified in Fig. 1 and Fig. 2 as applicable. Fittings of the patterns specified herein shall conform to the applicable dimensions in Figs. 6-63, inclusive. Fittings not listed shall conform to Fig. 1 for wall thickness and dimension R for the minimum radius of any drain inlets that any such fittings provide.

6.2.2 *Ends of Fittings*—Ends shall have spigot beads as shown in Fig. 1 and Fig. 2. Positioning lugs shall be cast on fittings. Positioning lugs shall be as described in Fig. 2 or continuous around circumference of the fitting. Exception: where permitted in **Figures 3–76**, spigot beads and gasket positioning lugs shall be optional depending on casting method used. It is permissible to increase the wall thickness on the inside surface of fitting ends. The increased thickness shall not reduce the minimum *B* dimension in Table 1 in excess of 0.06 in and shall not extend more than 4 ¼ in from the plain end. The increased thickness shall be tapered and shall offer no obstruction to flow.

6.2.3 *Pipe Threads*—Screw plugs and tapped openings in fittings shall have taper pipe threads in accordance with ANSI/ASME Standard 2.1.

6.2.4 Internal threads shall be chamfered at the entering end approximately to the major diameter of the thread, at an angle of approximately 45° with the axis of the thread for easy entrance in making a joint and for protection of the thread. The chamfer shall be concentric with the thread and shall be included in the measurement of the thread length.

TABLE 1 EDP Identification Numbers for Hubless Pipe

NOTE 1— When ordering by these EDP numbers, be sure to include the check (√) digit following the item number (022 0126 7). This check digit is verification of the group and item number you select.

Manufacturer's Item	Code			Description[A]
	Group	Item No.	√	
				10 ft (3 m) length
Hubless pipe (see Fig. 1.)		0156	4	1½
		0158	0	2½
		0160	6	3
	022	0162	2	4
		0164	8	5
		0168	9	6
		0170	5	8
		0171	3	10
		0172	7	12
		0173	1	15

[A] EDP numbers for fittings will appear in each of the respective tables.

7. Methods of Specifying Fittings

7.1 *Method of Specifying Sizes of Fittings of More than One Size*—The sizes shall be designated by the order of listing, as follows:

7.1.1 *Branch and Tapped Fittings*:

7.1.1.1 *Size of Run*—The run shall be that portion of the fitting which forms part of the main pipe line.

7.1.1.2 *Size of Branch*:

7.2 *Methods of Specifying Hand of Fittings with Side Inlets*—When placed in the position described below. If the side inlet appears on the right, it shall be a right-hand fitting; if on the left, it shall be a left-hand fitting.

7.2.1 *Branch Fittings*—The branch shall be placed toward the observer and the outlet end of the run lower than the branch.

7.3 The fitting illustrated in Fig. 3 has a right-hand inlet. Left-hand fittings have these openings on the side opposite to that shown. Inlets on fittings shall be made with or without spigot bead and positioning lug.

8. Coating

8.1 The pipe and fittings shall be furnished coated. The pipe and fittings shall be uniformly coated with a material suitable for the purpose that is adherent, not brittle, and without a tendency to scale. The coating shall not contain asbestos above current MSDS reportable levels. Material safety data sheets shall be furnished by the coating manufacturer when requested. The coating shall be evenly and smoothly applied to all surfaces, except in threaded openings.

9. Sampling

9.1 Chemical and mechanical tests shall be made regularly and at sufficiently close intervals for adequate determinations of the significant chemical constituents and properties of the cast iron. Records of chemical analysis shall be maintained by the manufacturer. Copies of these analyses shall be furnished to the purchaser when requested.

9.2 A lot shall consist of one of the following:

9.2.1 All the metal poured from a single heating is a batch type furnace.

9.2.2 All the metal from two or more batch type melting furnaces poured into a single ladle or a single casting.

9.2.3 All the metal poured from a continuous melting furnace for a given period of time between changes in charge, processing conditions, or aim-for chemistry or 4 hours, whichever is the shorter period.

9.2.3.1 The purchaser shall be permitted to agree to extend the 4 hour time period to 8 hours if the manufacturer is able to demonstrate sufficient process control to warrant such an extension.

10. Test Methods

10.1 *Gray Iron*:

10.1.1 *Tensile Strength Test*—Test bars shall be cast in accordance with the requirements of Specification A 48. The test bar dimensions and drawing are found in Fig. 4. The tensile strength shall be determined in accordance with Test Methods E 8.

10.1.2 Tension test reports shall include breaking load of test bars, machined diameter of test bar, and calculated tensile strength.

11. Inspection

11.1 *Inspection and Test by the Manufacturer*—Pipe and fittings shall be inspected to verify compliance with this standard. The manufacturer shall maintain a record of all inspections.

11.2 *Pipe Inspection*—At regular intervals (not to exceed 12 h) during the course of production, sample pieces of each size of pipe or pipes being produced shall be selected randomly for inspection. Each pipe selected shall be measured by suitable gauges and all dimensions detailed in Fig. 1 of this standard verified to comply with the requirements of this standard. The inspection records shall be maintained by the manufacturer for a period of seven years.

11.3 *Fitting Inspection*—At regular intervals (not to exceed twelve hours) during the course of production, sample pieces of each size and configuration of fitting being produced shall be selected randomly for inspection. Each fitting selected shall be measured by suitable gauges to verify that the laying length (as detailed in figures 4-76), and all applicable dimensions detailed in Fig. 1 and Fig. 2 of this standard comply with the requirements of this standard. The inspection records shall be maintained by the manufacturer for a period of seven years.

11.4 *Marking Inspection*—Inspection shall include verification that the markings on pipe and fittings comply with Section 13 of this standard.

12. Certification

12.1 Upon request the purchaser shall be furnished certification, by the manufacturer, stating samples representing each lot have been tested and inspected as indicated in this specification and the requirements have been met. If required by the purchaser, certification shall be accompanied by test reports as prepared in accordance with Sections 10 and 11 of this standard. Tension test reports shall include breaking load machined diameters of test bars, and calculated tensile strength. Certification shall include legal name and address of the manufacturer.

13. Product Marking

13.1 Each length of pipe and each fitting shall be plainly marked with the country of origin and the manufacturer's name or manufacturer's registered trade-mark by which the manufacturer can be readily identified after installation. The marking shall be adequate identification of the manufacturer of the pipe and fittings if it readily identifies the manufacturer to the end user of the product.

13.1.1 *Pipe Markings*—The pipe shall be marked continuously on the barrel with a minimum of 0.75 in. (19 mm) lettering starting within 3 in. of either end of the pipe. Each pipe shall be marked with the date of manufacture. The marking shall be stenciled on the pipe or otherwise applied so as to be clear and legible.

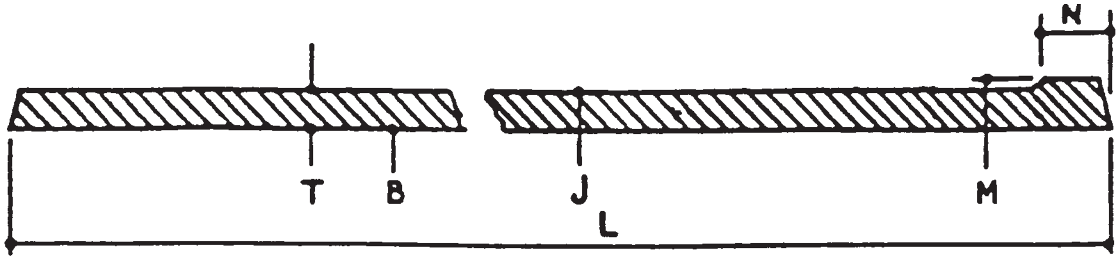
13.1.2 On fittings, the marking shall not be located within the "W" dimension, as shown in Fig. 2. Cast markings shall be raised from the wall of the fitting unless otherwise noted.

14. Packaging and Package Marking

14.1 *Government Procurement*—Unless otherwise specified in the contract, the material shall be packaged in accordance with the supplier's standard practice, which will be acceptable to the carrier at lowest rates. Containers and packing shall comply with Uniform Freight Classification Rules or National Motor Freight Classification Rules. Marking for shipment of such material shall be in accordance with Fed. Std. No. 123 for civil agencies and MIL-STD-129 for military agencies.

15. Keywords

15.1 cast iron; hubless pipe and fittings; no-hub pipe and fittings; soil pipe

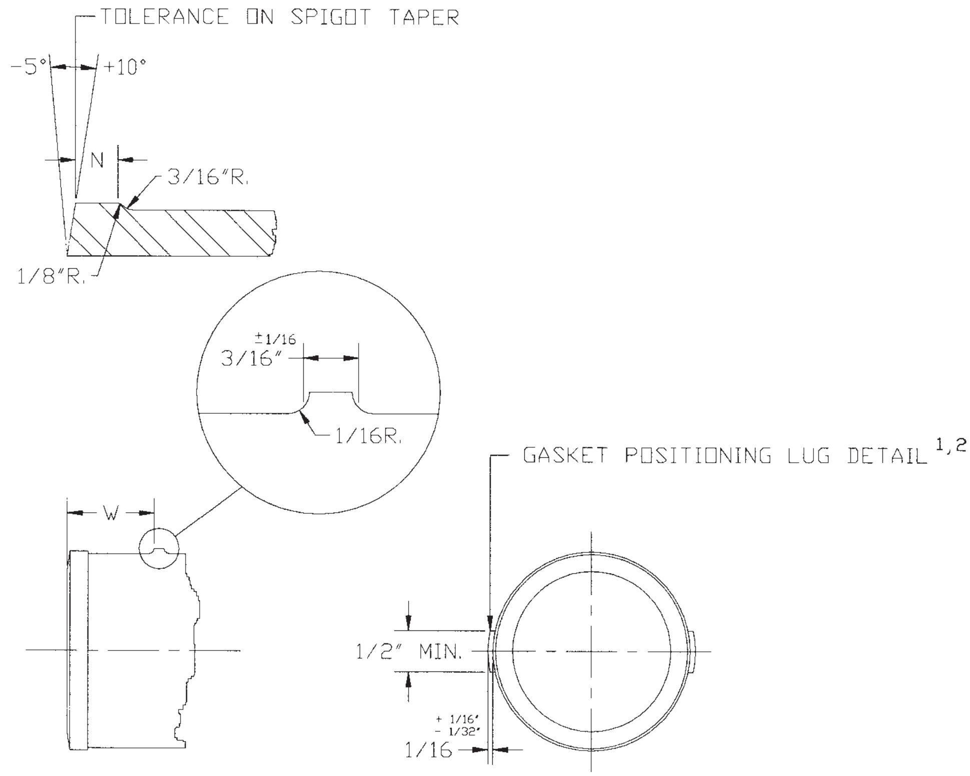


*Pipe shall be with or without a spigot bead.

Size	Barrel		Spigot		Barrel Thickness, T		Gasket Positioning Lug[A]	Laying Length, L[B]
	Inside Diameter	Outside Diameter	Outside Diameter	Bead Width[A]				
	B	J	M	N, ± 0.13 (3.3)	Nominal	Minimum	W	10 ft ± 0.50 in. (3.0480 m ± 13 mm)
1½	1.50 ± 0.09	1.90 ± 0.06	1.96 ± 0.06	0.25	0.16	0.13	1.13	120
	(38.1 ± 2.29)	(48.26 ± 1.52)	(49.78±1.52)	(6.35)		(3.3)	(28.7)	(3048)
2	1.96 ± 0.09	2.35± 0.09	2.41 ± 0.09	0.25	0.16	0.13	1.13	120
	(49.8 ± 2.29)	(59.69 ± 2.29)	(61.21 ± 2.29)	(6.35)		(3.3)	(28.7)	(3048)
3	2.96 ± 0.09	3.35± 0.09	3.41 ± 0.09	0.25	0.16	0.13	1.13	120
	(75.2 ± 2.29)	(85.09 ± 2.29)	(86.61 ± 2.29)	(6.35)		(3.3)	(28.7)	(3048)
4	3.94 ± 0.09	4.38 + 0.09 − 0.05	4.44 ± 0.09	0.31	0.19	0.15	1.13	120
	(100.08 ± 2.29)	(111.25 + 2.29) (−1.27)	(112.78 ± 2.29)	(7.87)		(3.81)	(28.7)	(3048)
5	4.94 ± 0.09	5.30 + 0.09 − 0.05	5.36 ± 0.09	0.31	0.19	0.15	1.50	120
	(125.48 ± 2.29)	(134.62 + 2.29) (−1.27)	(136.14 ± 2.29)	(7.87)		(3.81)	(38.1)	(3048)
6	5.94 ± 0.09	6.30 + 0.09 − 0.05	6.36 ± 0.09	0.31	0.19	0.15	1.50	120
	(150.88 ± 2.29)	(160.02 + 2.29) (−1.27)	(161.54 ± 2.29)	(7.87)		(3.81)	(38.1)	(3048)
8	7.94 ± 0.13	8.38 + 0.13 − 0.09	8.44 ± 0.09	0.31	0.23	0.17	2.00	120
	(201.68 ± 3.3)	(212.85 + 3.3) (−2.29)	(214.38 ± 2.29)	(7.87)		(4.32)	(50.8)	(3048)
10	10.00 ± 0.13	10.56 ± 0.09	10.62 ± 0.09	0.31	0.28	0.22	2.00	120
	(254 ± 3.3)	(268.22 ± 2.29)	(269.75 ± 2.29)	(7.87)		(5.59)	(50.8)	(3048)
12	11.94 ± 0.9	12.50 ± .09	12.62 ± .09	0.31	0.28	.22	2.75	120
	(303.28 ± 2.29)	(317.5 ± 2.29)	(320.55 ± 2.29)	(7.87)		(5.59)	(69.85)	(3048)
15	15.11 ± .09	15.83 ± .09	16.12 ± .09	0.31	0.36	.30	2.75	120
	(383.79 ± 2.29)	(402.08 ± 2.29)	(409.45 ± 2.29)	(7.87)		(7.62)	(69.85)	(3048)

[A] See Fig. 2 for details of the spigot and gasket positioning lug.
[B] Laying lengths as listed in Fig. 1 shall be for pipe only, and such pipe shall be 10 ft (3m) long. Laying length for fittings are listed in the applicable tables.

FIG. 1 Dimensions and Tolerances in Inches (Millimetres) of Spigots and Barrels for Hubless Pipe and Fittings



NOTE 1—Pipe shall be cast with or without the gasket positioning lugs. These lugs, as illustrated above, shall be cast as illustrated or be continuous around the entire circumference.

NOTE 2—Gasket positioning lugs shall be cast on all fittings except as otherwise noted. These lugs, as illustrated above, shall be cast as illustrated or be continuous around the entire circumference.

Size, in.	Spigot Detail, N in. (mm) ±0.13 (3.3)	Gasket Lug Location, W in. (mm) ±0.13 (3.3)
1½	0.25 (6)	1.13 (29)
2	0.25 (6)	1.13 (29)
3	0.25 (6)	1.13 (29)
4	0.25 (6)	1.13 (29)
5	0.31 (8)	1.50 (38)
6	0.31 (8)	1.50 (38)
8	0.31 (8)	2.00 (51)
10	0.31 (8)	2.00 (51)
12	0.31 (8)	2.75 (70)
15	0.31 (8)	2.75 (70)

FIG. 2 Details of Spigot Bead and Gasket Positioning Lug

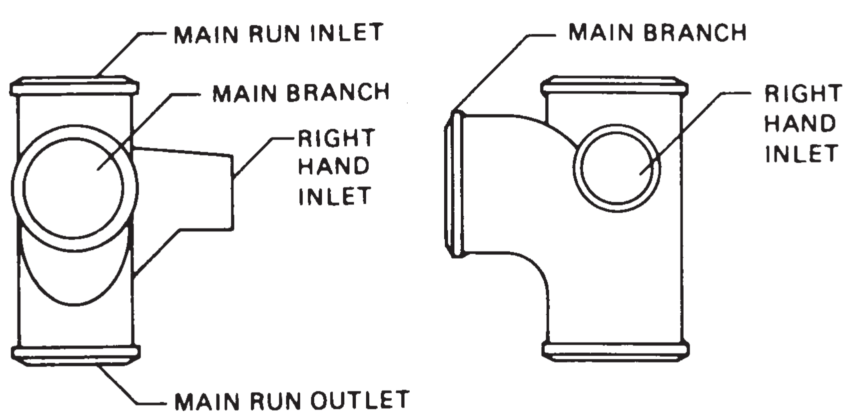
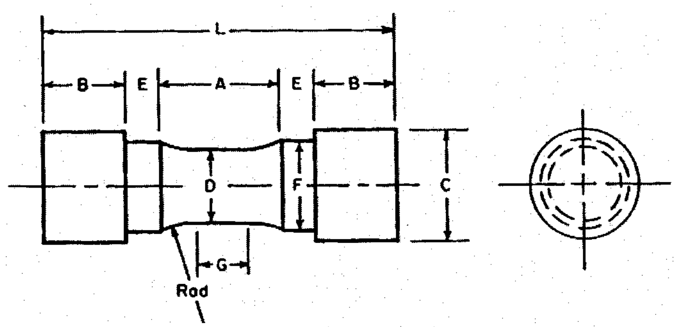


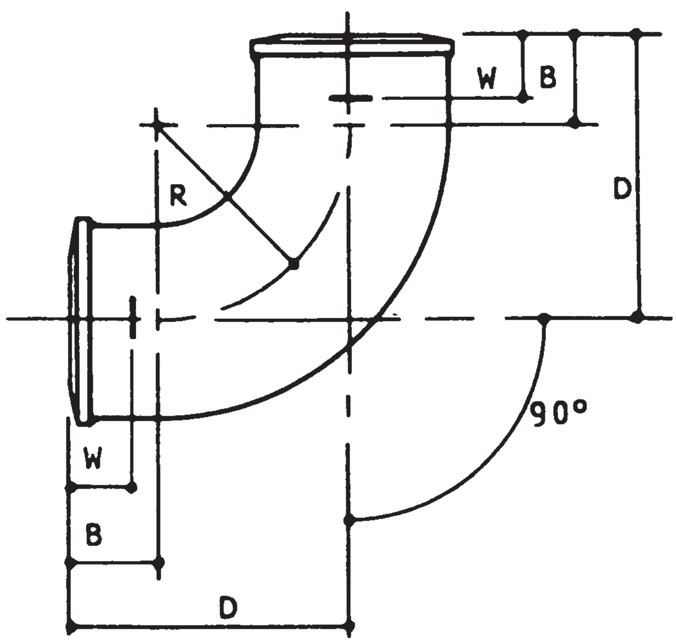
FIG. 3 Specifying Hand of Fittings with Side Inlets or Outlets



Dimensions, in (mm)	Tension Test Specimen B
G — Length of parallel, min	0.75 (19)
D — Diameter	0.750 + 0.015 (19.0 + 0.38)
R — Radius of fillet, min	1 (25)
A — Length of reduced section, min	1½ (38)
L — Overall length, min	4 (100)
C — Diameter of end section, approx	1¼ (32)
E — Length of shoulder, min	¼ (6)
F — Diameter of shoulder	⁵⁄₁₆ + ¹⁄₆₄ (25 + 0.4)
B — Length of end section	[A]

[A] Optional to fit holders on testing machine. If threaded, root diameter shall not be less than dimension F.

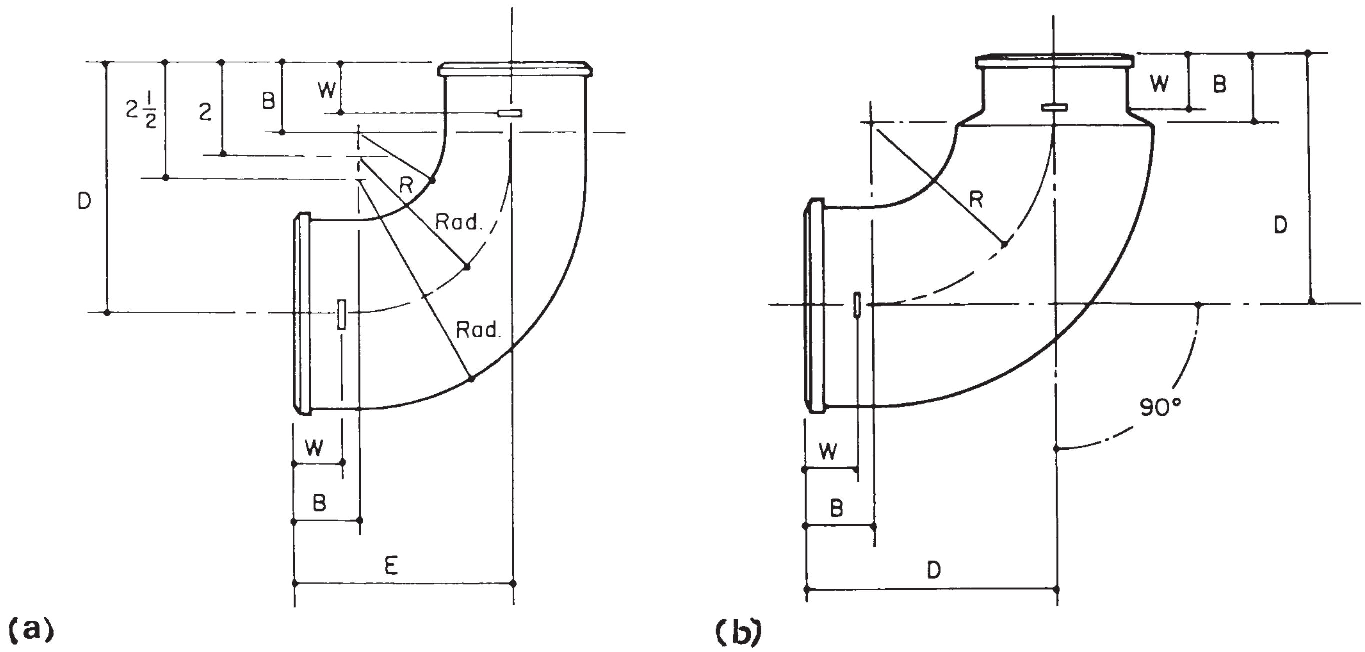
FIG. 4 Sample Test Bar



ASA Code Group 022		Size, in.	Dimensions, in. (mm)[A]			
Item No.	√		B	$D^{B}\pm$⅛ (3.2)	R	W
0188	7	1½	1½ (38)	4¼ (108)	2¾ (70)	1⅛ (29)
0190	3	2	1½ (38)	4½ (114)	3 (76)	1⅛ (29)
0192	9	3	1½ (38)	5 (127)	3½ (89)	1⅛ (29)
0194	5	4	1½ (38)	5½ (140)	4 (102)	1⅛ (29)
0196	0	5	2 (51)	6½ (165)	4½ (114)	1½ (38)
0198	6	6	2 (51)	7 (178)	5 (127)	1½ (38)
0200	0	8	2½ (64)	8½ (216)	6 (152)	2 (51)

[A] For details of barrel, spigot, and gasket positioning lug, see Fig. 1 and Fig. 2.
[B] Dimension D is laying length.

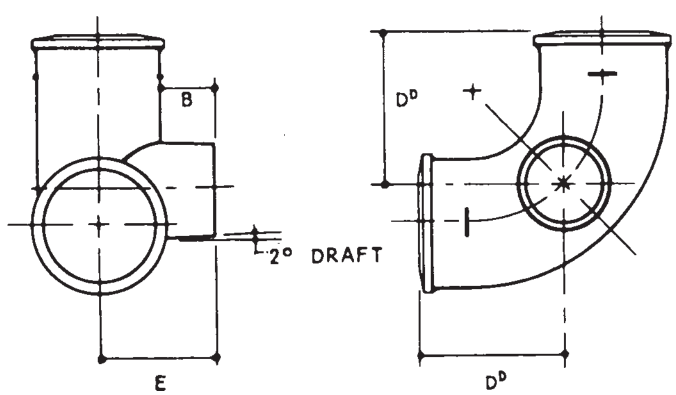
FIG. 5 ¼ Bend (corresponds to Table 5 of CISPI Specification 301)



	ASA Code Group 022		Sizes, in.	Dimensions, in. (mm)[A]				
	Item No.	√		B	R	D[B] ±1⁄8 (3.2)	E[B] ±1⁄8 (3.2)	W
Fig. (a)	0218	2	4 by 3	1½ (38)	3½ (89)	5½ (140)	5 (127)	1⅛ (29)
Fig. (b)	0218	2	4 by 3	1½ (38)	4 (102)	5½ (140)	...	1⅛ (29)

[A] For details of barrel, spigot, and gasket positioning lug, see Fig. 1 and Fig. 2.
[B] Dimensions D and E are laying lengths.

FIG. 6 Reducing ¼ Bend (corresponds to Tables 6 and 7 of CISPI Specification 301)



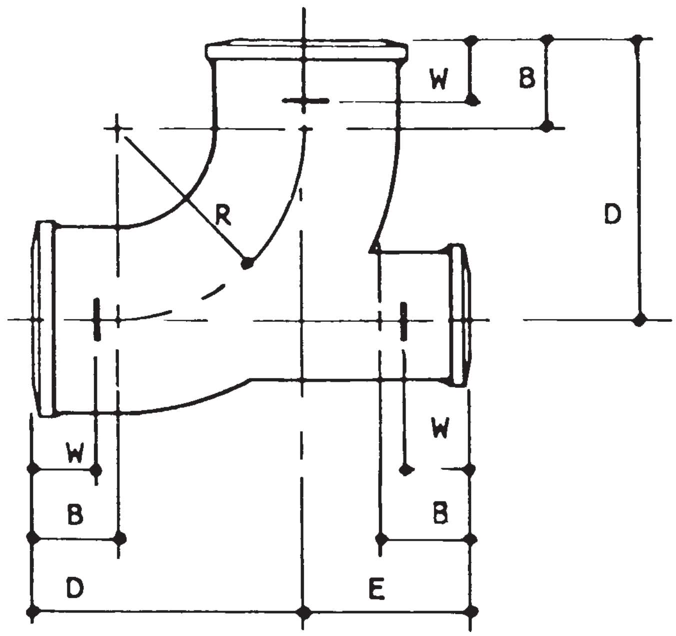
NOTE 1—For details of ¼ bend, see Fig. 5.

NOTE 2—Inclusion of spigot bead and positioning lug optional with manufacturer based on casting method used.

ASA Code Group 022		Sizes, in.	Dimensions, in. (mm)[A]		
Item No.	√		B	E[B] ±1⁄8 (3.2)	D[B]
0236	4	3 by 2	1½ (38)	3¼ (83)	4 (102)
0238	0	4 by 2	1½ (38)	3¾ (95)	4 5⁄16 (110)

[A] For details of barrel, spigot, and gasket positioning lug, see Fig. 1 and Fig. 2.
[B] Dimension E is laying length.

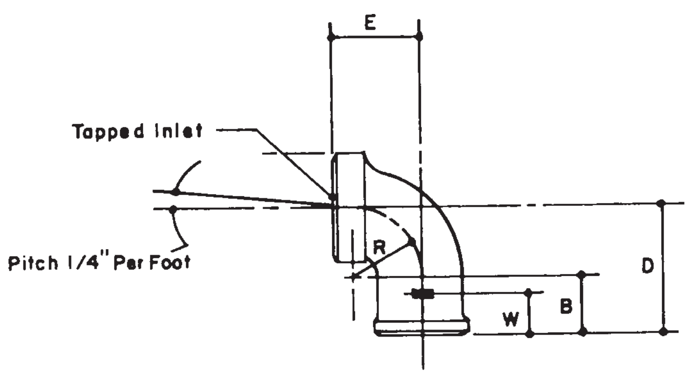
FIG. 7 ¼ Bend With Side Opening (corresponds to Table 8 of CISPI Specification 301)



ASA Code Group 022		Size, in.	Dimensions, in. (mm)[A]				
Item No.	√		B	D[B] ±⅛ (3.2)	E[B]±⅛ (3.2)	R	W
0280	2	3 by 2	1½ (38)	5 (127)	2⅞ (73)	3½ (89)	1⅛ (29)
0282	8	4 by 2	1½ (38)	5½ (140)	3¼ (83)	4 (102)	1⅛ (29)

[A] For details of barrel, spigot, and gasket positioning lug, see Fig. 1 and Fig. 2.
[B] Dimensions D and E are laying lengths.

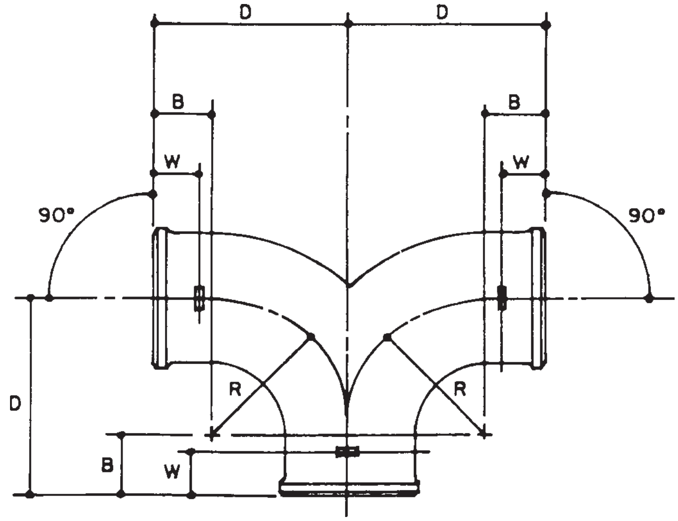
FIG. 8 ¼ Bend With Heel Opening (corresponds to Table 9 of CISPI Specification 301)



ASA Code Group 022		Size, in.	Dimensions, in. (mm)[A]					
Item No.	√		B	E	D[B] ±⅛ (3.2)	R	IPS Tapping[C]	W
0324	8	1½ by 1¼	1½ (38)	2 (51)	3 (76)	1¾ (44)	1¼ (32)	1⅛ (29)
0326	3	1½ by 1½	1½ (38)	2 (51)	3 (76)	1¾ (44)	1½ (38)	1⅛ (29)
0328	9	2 by 1¼	1½ (38)	2¼ (57)	3¼ (83)	1¾ (44)	1¼ (32)	1⅛ (29)
0330	5	2 by 1½	1½ (38)	2¼ (57)	3¼ (83)	1¾ (44)	1½ (38)	1⅛ (29)
		2 by 2	1½ (38)	2¼ (57)	3¼ (83)	1¾ (44)	2 (51)	1⅛ (29)

[A] For details of barrel, spigot, and gasket positioning lug, see Fig. 1 and Fig. 2.
[B] Dimension D is laying length.
[C] For details of tapping bosses, see Fig. 63.

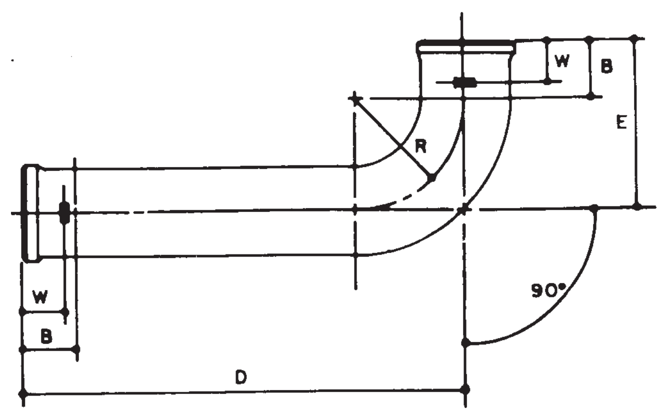
FIG. 9 Tapped ¼ Bend (corresponds to Table 11 of CISPI Specification 301)



ASA Code Group 022		Size, in.	Dimensions, in. (mm)[A]			
Item No.	√		D[B] ±⅛ (3.2)	R	B	W
0402	2	2	4½ (114)	3 (76)	1½ (38)	1⅛ (29)
0404	8	3	5 (127)	3½ (89)	1½ (38)	1⅛ (29)
0406	3	4	5½ (140)	4 (102)	1½ (38)	1⅛ (29)

[A] For details of barrel, spigot, and gasket positioning lug, see Fig. 1 and Fig. 2.
[B] Dimension D is laying length.

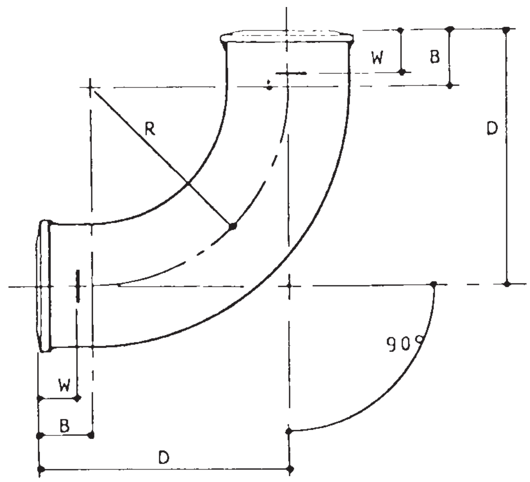
FIG. 10 Double ¼ Bend (corresponds to Table 13 of CISPI Specification 301)



ASA Code Group 022		Size, in.	Dimensions, in. (mm)[A]				
Item No.	√		B	E[B]±⅛ (3.2)	D[B]±⅛ (3.2)	R	W
0424	6	2 by 12	1½ (38)	4½ (114)	12 (305)	3 (76)	1⅛ (29)
		2 by 14	1½ (38)	4½ (114)	14 (356)	3 (76)	1⅛ (29)
0423	8	2 by 16	1½ (38)	4½ (114)	16 (406)	3 (76)	1⅛ (29)
0425	3	2 by 18	1½ (38)	4½ (114)	18 (457)	3 (76)	1⅛ (29)
		2 by 24	1½ (38)	4½ (114)	24 (610)	3 (76)	1⅛ (29)
0426	1	3 by 12	1½ (38)	5 (127)	12 (305)	3½ (89)	1⅛ (29)
0427	9	3 by 18	1½ (38)	5 (127)	18 (457)	3½ (89)	1⅛ (29)
0428	7	4 by 12	1½ (38)	5½ (140)	12 (305)	4 (102)	1⅛ (29)
0431	1	4 by 18	1½ (38)	5½ (140)	18 (457)	4 (102)	1⅛ (29)

[A] For details of barrel, spigot, and gasket positioning lug, see Fig. 1 and Fig. 2.
[B] Dimensions D and E are laying lengths.

FIG. 11 Long ¼ Bend (corresponds to Table 14 of CISPI Specification 301)



ASA Code Group 022		Size, in.	Dimensions, in. (mm)[A]			
Item No.	√		B	D[B] ±⅛ (3.2)	R	W
0462	6	2	1½ (38)	6½ (165)	5 (127)	1⅛ (29)
0464	2	3	1½ (38)	7 (178)	5½ (140)	1⅛ (29)
0468	3	4	1½ (38)	7½ (191)	6 (152)	1⅛ (29)
0470	9	5	2 (51)	8½ (216)	6½ (165)	1½ (38)
0472	5	6	2 (51)	9 (229)	7 (178)	1½ (38)
0474	1	8	2½ (64)	10½ (267)	8 (203)	2 (51)
0475	8	10	3 (76)	12 (305)	9 (229)	2 (51)
0476	8	12	3 ¼ (83)	13 ¼ (337)	10 (254)	2 ¾ (70)
0477	8	15	3 ¼ (83)	14 ¾ (375)	11 ½ (292)	2 ¾ (70)

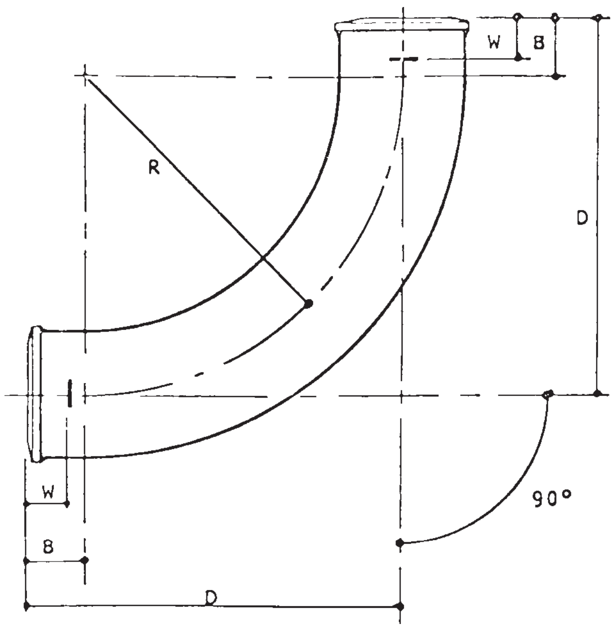
Extended Pattern

ASA Code Group 022		Size, in.	Dimensions, in. (mm)[A]				
Item No.	√		B	D[B] ±⅛ (3.2)	E[B] ±⅛ (3.2)	R	W
0478	7	2 by 12	1½ [38]	6½ [165]	12 [305]	5 [127]	1⅛ [29]
0479	7	2 by 14	1½ [38]	6½ [165]	14 [356]	5 [127]	1⅛ [29]
0480	7	2 by 16	1½ [38]	6½ [165]	16 [406]	5 [127]	1⅛ [29]
0481	7	2 by 18	1½ [38]	6½ [165]	18 [457]	5 [127]	1⅛ [29]
0482	7	2 by 24	1½ [38]	6½ [165]	24 [610]	5 [127]	1⅛ [29]
0483	7	2 by 34	1½ [38]	6½ [165]	34 [864]	5 [127]	1⅛ [29]

Note: Dimensions D and E are laying lengths on extended pattern fittings.

[A] For details of barrel, spigot, and gasket positioning lug, see Fig. 1 and Fig. 2.
[B] Dimension D is laying length.

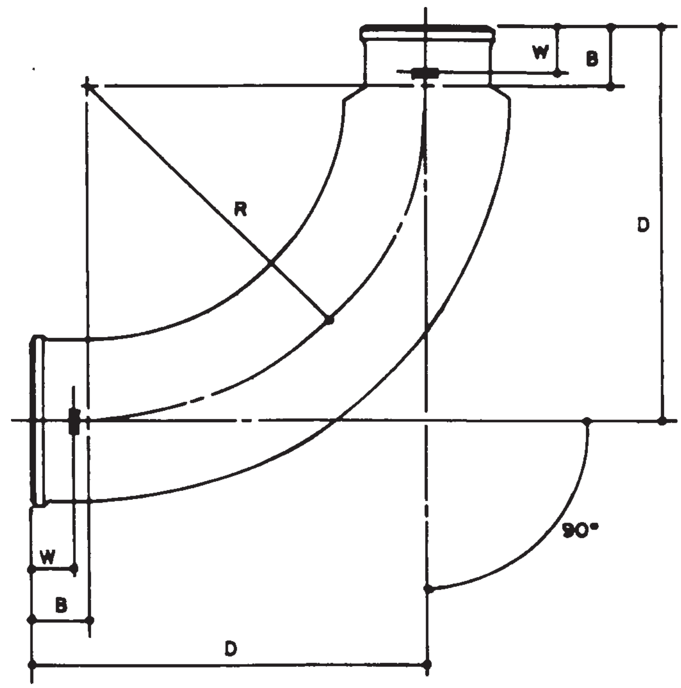
FIG. 12 Short Sweep (corresponds to Table 15 of CISPI Specification 301)



ASA Code Group 022		Size, in.	Dimensions, in. (mm)[A]			
Item No.	√		B	D[B] ±⅛ (3.2)	R	W
0492	3	1½	1½ (38)	9¼ (235)	7¾ (197)	1⅛ (29)
0494	9	2	1½ (38)	9½ (241)	8 (203)	1⅛ (29)
0496	4	3	1½ (38)	10 (254)	8½ (216)	1⅛ (29)
0498	0	4	1½ (38)	10½ (267)	9 (229)	1⅛ (29)
0500	3	5	2 (51)	11½ (292)	9½ (241)	1½ (38)
0502	9	6	2 (51)	12 (305)	10 (254)	1½ (38)

[A] For details of barrel, spigot, and gasket positioning lug, see Fig. 1 and Fig. 2.
[B] Dimension D is laying length.

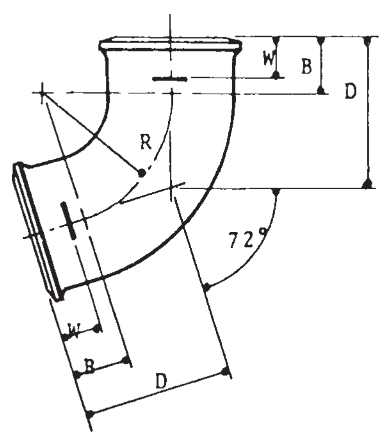
FIG. 13 Long Sweep (corresponds to Table 17 of CISPI Specification 301)



ASA Code Group 022		Size, in.	Dimensions, in. (mm)[A]			
Item No.	√		B	D[B] ±⅛ (3.2)	R	W
0516	9	3 by 2	1½ (38)	10 (254)	8½ (216)	1⅛ (29)
0518	5	4 by 3	1½ (38)	10½ (267)	9 (229)	1⅛ (29)

[A] For details of barrel, spigot, and gasket positioning lug, see Fig. 1 and Fig. 2.
[B] Dimension D is laying length.

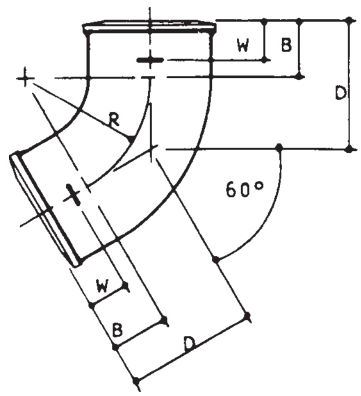
FIG. 14 Reducing Long Sweep (corresponds to Table 18 of CISPI Specification 301)



ASA Code Group 022		Size, in.	Dimensions, in. (mm)[A]			
Item No.	√		B	D[B] ±⅛ (3.2)	R	W
0536	7	2	1½ (38)	3¹¹⁄₁₆ (94)	3 (76)	1⅛ (29)
0538	3	3	1½ (38)	4¹⁄₁₆ (103)	3½ (89)	1⅛ (29)
0540	9	4	1½ (38)	4⁷⁄₁₆ (113)	4 (102)	1⅛ (29)

[A] For details of barrel, spigot, and gasket positioning lug, see Fig. 1 and Fig. 2.
[B] Dimension D is laying length.

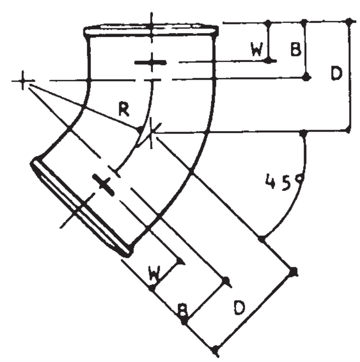
FIG. 15 ⅕ Bend (corresponds to Table 19 of CISPI Specification 301)



ASA Code Group 022		Size, in.	Dimensions, in. (mm)[A]			
Item No.	√		B	D[B] ±1⁄8 (3.2)	R	W
0570	6	2	1½ (38)	3¼ (83)	3 (76)	1⅛ (29)
0572	2	3	1½ (38)	3½ (89)	3½ (89)	1⅛ (29)
0574	8	4	1½ (38)	3 13⁄16 (97)	4 (102)	1⅛ (29)

[A] For details of barrel, spigot, and gasket positioning lug, see Fig. 1 and Fig. 2.
[B] Dimension D is laying length.

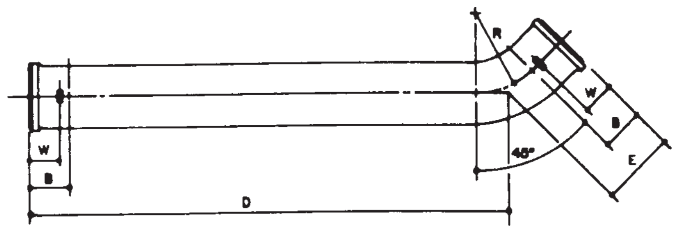
FIG. 16 ⅙ Bend (corresponds to Table 20 of CISPI Specification 301)



ASA Code Group 022		Size, in.	Dimensions, in. (mm)[A]			
Item No.	√		B	D[B] ±1⁄8 (3.2)	R	W
0604	3	1½	1½ (38)	2⅝ (67)	2¾ (70)	1⅛ (29)
0606	8	2	1½ (38)	2¾ (70)	3 (76)	1⅛ (29)
0608	4	3	1½ (38)	3 (76)	3½ (89)	1⅛ (29)
0610	0	4	1½ (38)	3⅛ (79)	4 (102)	1⅛ (29)
0612	6	5	2 (51)	3⅞ (98)	4½ (114)	1½ (38)
0614	2	6	2 (51)	4 1⁄16 (103)	5 (127)	1½ (38)
0616	7	8	2½ (64)	5 (127)	6 (152)	2 (51)
0617	5	10	3 (76)	5 15⁄16 (151)	7 (178)	2 (51)
0618	5	12	3 ¼ (83)	6 9⁄16 (167)	8 (203)	2 ¾ (70)
0619	5	15	3 ¼ (83)	7 3⁄16 (183)	9 ½ (241)	2 ¾ (70)

[A] For details of barrel, spigot, and gasket positioning lug, see Fig. 1 and Fig. 2.
[B] Dimension D is laying length.

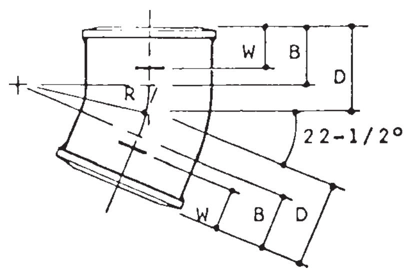
FIG. 17 ⅛ Bend (corresponds to Table 21 of CISPI Specification 301)



ASA Code Group 022		Size, in.	Dimensions, in. (mm)[A]				
Item No.	√		B	E[B]±1⁄8 (3.2)	D[B]±1⁄8 (3.2)	R	W
0638	1	2 by 6	1½ (38)	2¾ (70)	6 (152)	3 (76)	1⅛ (29)
		2 by 12	1½ (38)	2¾ (70)	12 (305)	3 (76)	1⅛ (29)
		2 by 14	1½ (38)	2¾ (70)	14 (356)	3 (76)	1⅛ (29)
0641	5	2 by 16	1½ (38)	2¾ (70)	16 (406)	3 (76)	1⅛ (29)
0643	1	2 by 18	1½ (38)	2¾ (70)	18 (457)	3 (76)	1⅛ (29)
0640	7	3 by 12	1½ (38)	3 (76)	12 (305)	3½ (89)	1⅛ (29)
0644	9	3 by 18	1½ (38)	3 (76)	18 (457)	3½ (89)	1⅛ (29)
0642	3	4 by 12	1½ (38)	3⅛ (79)	12 (305)	4 (102)	1⅛ (29)

[A] For details of barrel, spigot, and gasket positioning lug, see Fig. 1 and Fig. 2.
[B] Dimensions D and E are laying lengths.

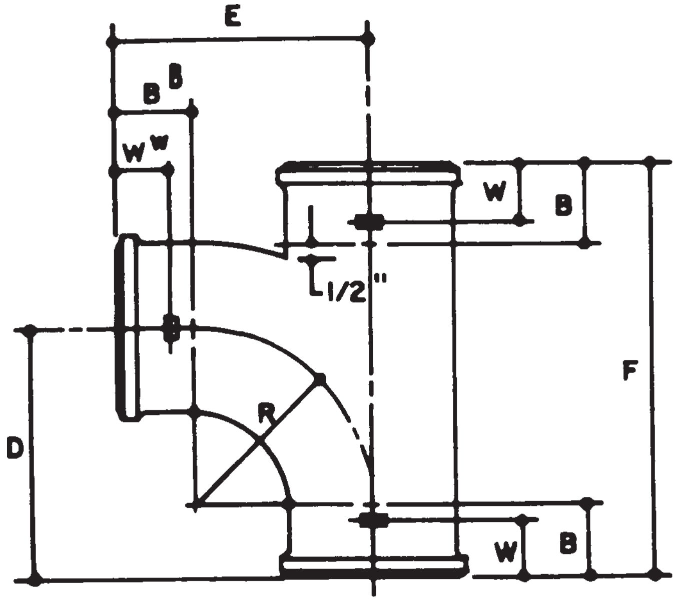
FIG. 18 Long ⅛ Bend (corresponds to Table 22 of CISPI Specification 301)



ASA Code Group 022		Size, in.	Dimensions, in. (mm)[A]			
Item No.	√		B	D[B]±1⁄8 (3.2)	R	W
0676	1	1½	1½ (38)	2⅛ (54)	2¾ (70)	1⅛ (29)
0678	7	2	1½ (38)	2⅛ (54)	3 (76)	1⅛ (29)
0680	3	3	1½ (38)	2¼ (57)	3½ (89)	1⅛ (29)
0682	9	4	1½ (38)	2 5⁄16 (59)	4 (102)	1⅛ (29)
0684	5	5	2 (51)	2⅞ (73)	4½ (114)	1½ (38)
0686	0	6	2 (51)	3 (76)	5 (127)	1½ (38)
0688	6	8	2½ (64)	3¾ (95)	6 (152)	2 (51)

[A] For details of barrel, spigot, and gasket positioning lug, see Fig. 1 and Fig. 2.
[B] Dimension D is laying length.

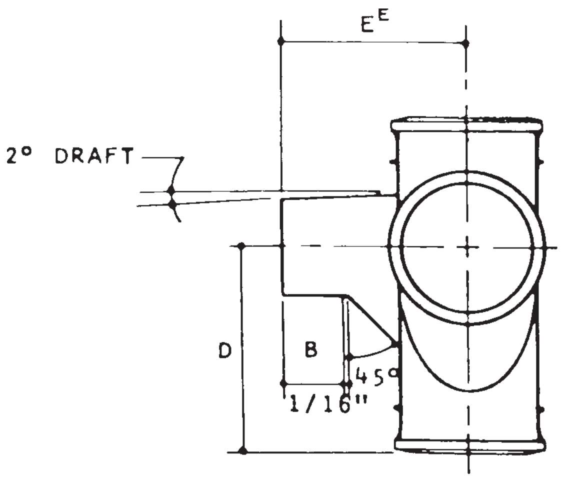
FIG. 19 1⁄16 Bend (corresponds to Table 23 of CISPI Specification 301)



ASA Code Group 022		Size, in.	Dimensions, in. (mm)[A]							
Item No.	√		B	E[B] ±⅛ (3.2)	F[B] ±⅛ (3.2)	D	R	W	W^W	B^B
0806	4	1½	1½ (38)	4¼ (108)	6½ (165)	4¼ (108)	2¾ (70)	1⅛ (29)	1⅛ (29)	1½ (38)
0808	0	2 by 1½	1½ (38)	4½ (114)	6⅝ (168)	4¼ (108)	2¾ (70)	1⅛ (29)	1⅛ (29)	1½ (38)
0810	6	2	1½ (38)	4½ (114)	6⅞ (175)	4½ (114)	3 (76)	1⅛ (29)	1⅛ (29)	1½ (38)
0812	2	3 by 1½	1½ (38)	5 (127)	6½ (165)	4¼ (108)	2¾ (70)	1⅛ (29)	1⅛ (29)	1½ (38)
0814	8	3 by 2	1½ (38)	5 (127)	6⅞ (175)	4½ (114)	3 (76)	1⅛ (29)	1⅛ (29)	1½ (38)
0816	3	3	1½ (38)	5 (127)	8 (203)	5 (127)	3½ (89)	1⅛ (29)	1⅛ (29)	1½ (38)
0818	9	4 by 2	1½ (38)	5½ (140)	6⅞ (175)	4½ (114)	3 (76)	1⅛ (29)	1⅛ (29)	1½ (38)
0820	5	4 by 3	1½ (38)	5½ (140)	8 (203)	5 (127)	3½ (89)	1⅛ (29)	1⅛ (29)	1½ (38)
0822	1	4	1½ (38)	5½ (140)	9⅛ (232)	5½ (140)	4 (102)	1⅛ (29)	1⅛ (29)	1½ (38)
0824	7	5 by 2	2 (51)	6½ (165)	8½ (216)	5 (127)	3 (76)	1½ (38)	1⅛ (29)	1½ (38)
0826	2	5 by 3	2 (51)	6 (152)	9 5/16 (237)	5½ (140)	3½ (89)	1½ (38)	1⅛ (29)	1½ (38)
0828	8	5 by 4	2 (51)	6 (152)	10 13/32 (264)	6 (152)	4 (102)	1½ (38)	1⅛ (29)	1½ (38)
0830	4	5	2 (51)	6½ (165)	11 7/16 (291)	6½ (165)	4½ (114)	1½ (38)	1½ (38)	2 (51)
0832	0	6 by 2	2 (51)	6½ (165)	8 3/16 (208)	5 (127)	3 (76)	1½ (38)	1⅛ (29)	1½ (38)
0838	0	6 by 3	2 (51)	6½ (165)	9 3/16 (233)	5½ (140)	3½ (89)	1½ (38)	1⅛ (29)	1½ (38)
0834	6	6 by 4	2 (51)	6½ (165)	10 1/16 (256)	6 (152)	4 (102)	1½ (38)	1⅛ (29)	1½ (38)
0835	3	6 by 5	2 (51)	7 (178)	11½ (292)	6½ (165)	4½ (114)	1½ (38)	1½ (38)	2 (51)
0836	1	6	2 (51)	7 (178)	12½ (318)	7 (178)	5 (127)	1½ (38)	1½ (38)	2 (51)
0850	2	8 by 2	2½ (64)	7½ (190)	9 5/16 (237)	5½ (140)	3 (76)	2 (51)	1⅛ (29)	1½ (38)
0848	3	8 by 3	2½ (64)	7½ (190)	10⅜ (264)	6 (152)	3½ (89)	2 (51)	1⅛ (29)	1½ (38)
0846	4	8 by 4	2½ (64)	7½ (190)	11½ (292)	6½ (165)	4 (102)	2 (51)	1⅛ (29)	1½ (38)
0844	5	8 by 5	2½ (64)	8 (203)	12½ (318)	7 (178)	4½ (114)	2 (51)	1½ (38)	2 (51)
0842	6	8 by 6	2½ (64)	8 (203)	13½ (343)	7½ (191)	5 (127)	2 (51)	1½ (38)	2 (51)
0840	1	8	2½ (64)	8½ (216)	15½ (395)	8½ (216)	6 (152)	2 (51)	2 (51)	2½ (64)

[A] For details of barrel, spigot, and gasket positioning lug, see Fig. 1 and Fig. 2.
[B] Dimensions E and F are laying lengths.

FIG. 20 Sanitary Tee Branch (corresponds to Table 24 of CISPI Specification 301)



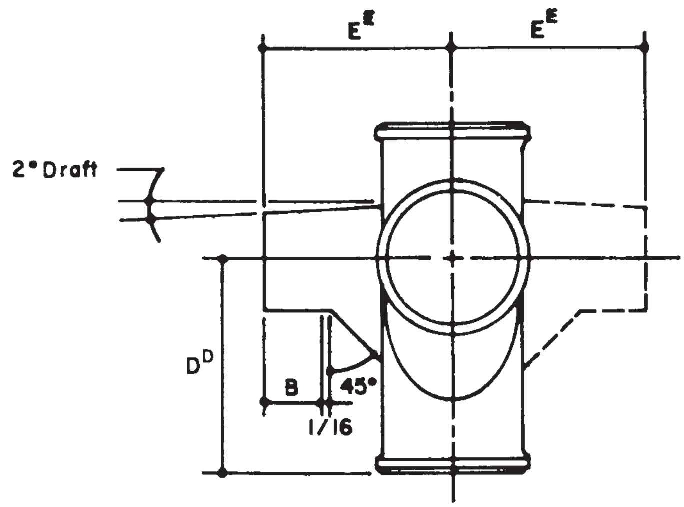
NOTE 1—Sanitary Tee branch with side inlet; illustration shows left hand. Can be furnished left or right hand.

NOTE 2—Inclusion of spigot bead and positioning lug optional with manufacturer based on casting method used.

ASA Code Group 022		Size, in.	Dimensions, in. (mm)[A,B]		
Item No.	√		B	$E^{EC}\pm 1/8$ (3.2)	D
0976	5	3 by 3 by 2 LH	1½ (38)	4 7/16 (113)	5 (127)
0986	4	3 by 3 by 2 RH	1½ (38)	4 7/16 (113)	5 (127)
0978	1	4 by 2 by 2 LH	1½ (38)	3¼ (83)	4½ (114)
0988	0	4 by 2 by 2 RH	1½ (38)	3¼ (83)	4½ (114)
0980	7	4 by 3 by 2 LH	1½ (38)	4 15/16 (125)	5 (127)
0990	6	4 by 3 by 2 RH	1½ (38)	4 15/16 (125)	5 (127)
0982	3	4 by 4 by 2 LH	1½ (38)	4 15/16 (125)	5½ (140)
0992	2	4 by 4 by 2 RH	1½ (38)	4 15/16 (125)	5½ (140)

[A] For details of barrel, spigot, and gasket positioning lug, see Fig. 1 and Fig. 2.
[B] For details of sanitary Tee branch, see Fig. 20.
[C] Dimension E^E is laying length.

FIG. 21 Sanitary Tee With Right or Left Side Opening (corresponds to Table 28 of CISPI Specification 301)



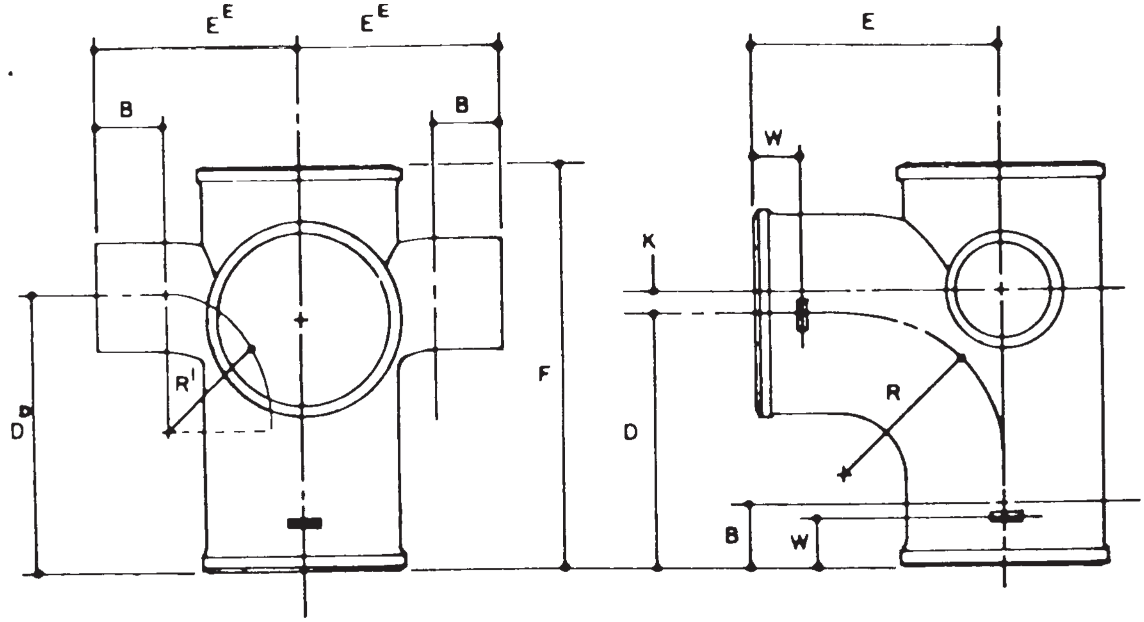
NOTE 1—Sanitary Tee branch with side inlet; illustration shows left hand. Can be furnished left or right hand.

NOTE 2—Inclusion of spigot bead and positioning lug optional with manufacturer based on casting method used.

ASA Code Group 022		Size, in.	Dimensions, in. (mm)[A,B]		
Item No.	√		B	$E^{EC}\pm 1/8$ (3.2)	D
1030	0	3 by 3 by 2 LH	1½ (38)	4 7/16 (113)	5 (127)
1034	2	3 by 3 by 2 RH	1½ (38)	4 7/16 (113)	5 (127)
1037	5	3 by 3 by 2 R&L	1½ (38)	4 7/16 (113)	5 (127)
1032	6	4 by 4 by 2 LH	1½ (38)	4 15/16 (125)	5½ (140)
1036	7	4 by 4 by 2 RH	1½ (38)	4 15/16 (125)	5½ (140
1038	3	4 by 4 by 2 R&L	1½ (38)	4 15/16 (125)	5½ (140)

[A] For details of barrel, spigot, and gasket positioning lug, see Fig. 1 and Fig. 2.
[B] For details of sanitary Tee branch, see Fig. 20.
[C] Dimension E^E is laying length.

FIG. 22 Sanitary Tee With 2-in. Side Opening Right or Left/Right and Left (corresponds to Table 29 of CISPI Specification 301)

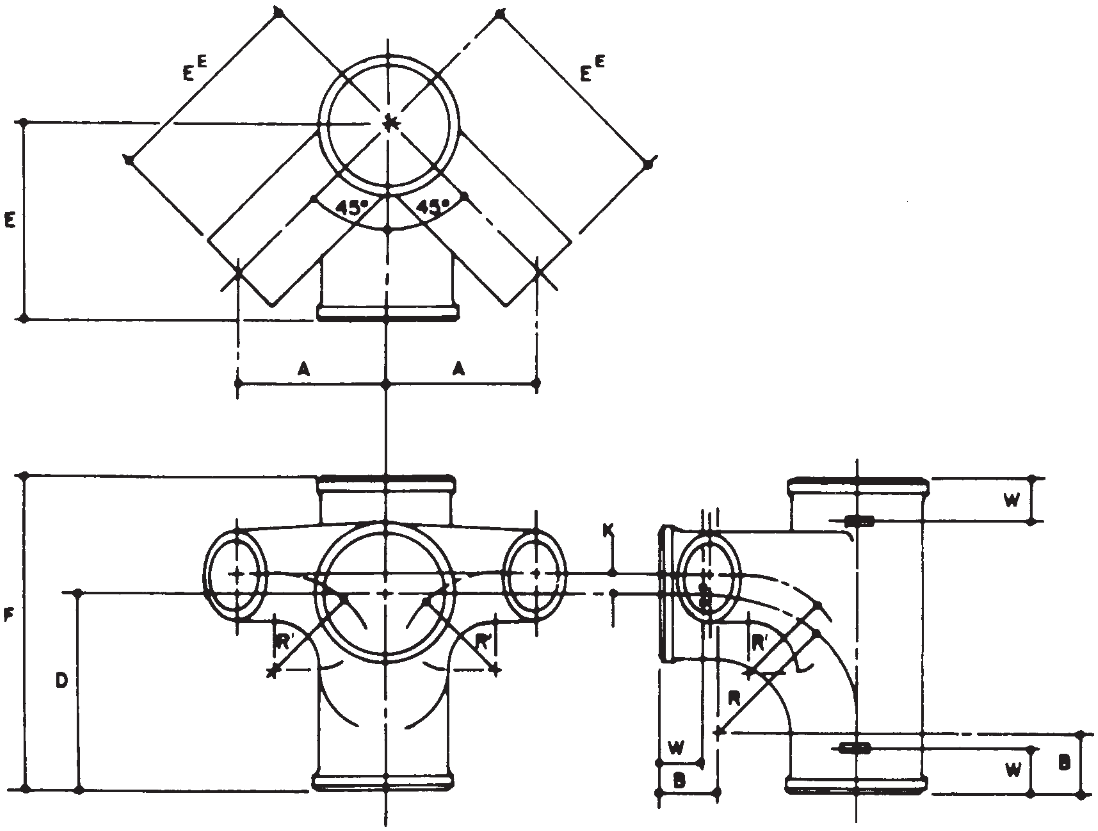


NOTE 1—Inclusion of spigot bead positioning lug optional with manufacturer based on casting methods used.

ASA Code Group 022		Size, in.	Dimensions, in. (mm)^A									
Item No.	√		B	E^{EB}±⅛ (3.2)	E^B ±⅛ (3.2)	F^B±⅛ (3.2)	D	D^D	K	R^A	R	W
1058	1	3 by 3 by 2 LH	1½ (38)	4½ (114)	5 (127)	8½ (216)	5 (127)	6 (152)	1 (25)	3 (76)	3½ (89)	1⅛ (29)
1062	3	3 by 3 by 2 RH	1½ (38)	4½ (114)	5 (127)	8½ (216)	5 (127)	6 (152)	1 (25)	3 (76)	3½ (89)	1⅛ (29)
1066	4	3 by 3 by 2 R&L	1½ (38)	4½ (114)	5 (127)	8½ (216)	5 (127)	6 (152)	1 (25)	3 (76)	3½ (89)	1⅛ (29)
1060	7	4 by 4 by 2 LH	1½ (38)	5 (127)	5½ (140)	9⅛ (232)	5½ (140)	6½ (165)	1 (25)	3 (76)	4 (102)	1⅛ (29)
1064	9	4 by 4 by 2 RH	1½ (38)	5 (127)	5½ (140)	9⅛ (232)	5½ (140)	6½ (165)	1 (25)	3 (76)	4 (102)	1⅛ (29)
1068	0	4 by 4 by 2 R&L	1½ (38)	5 (127)	5½ (140)	9⅛ (232)	5½ (140)	6½ (165)	1 (25)	3 (76)	4 (102)	1⅛ (29)

^{A} For details of barrel, spigot, and gasket positioning lug, see Fig. 1 and Fig. 2.
^{B} Dimensions E, F, and E ^{E} are laying lengths.

FIG. 23 Sanitary Tee With Side Opening Above Center Right and Left—Right or Left (New Orleans Special) (corresponds to Table 30 of CISPI Specification 301)

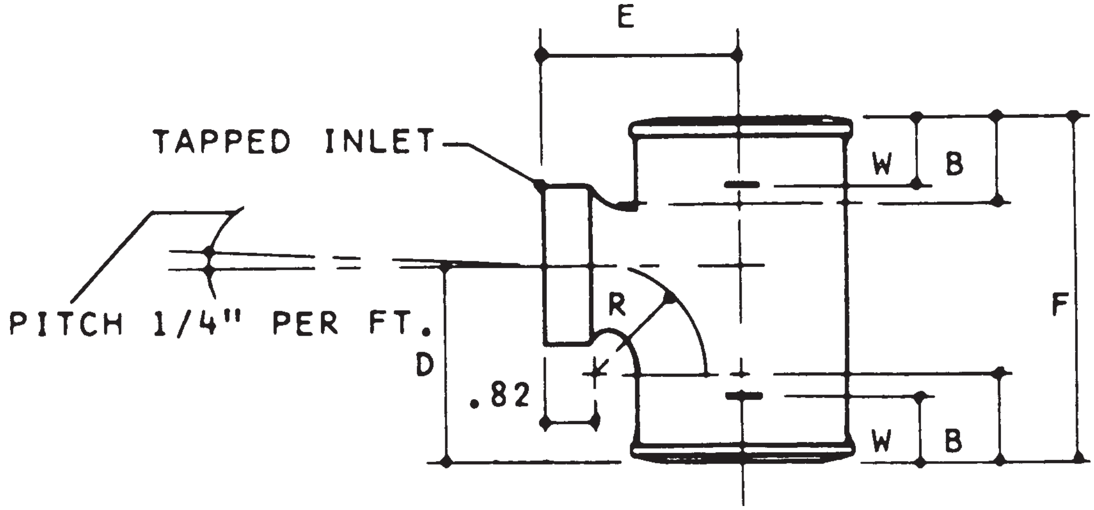


NOTE 1—Inclusion of spigot bead and positioning lug optional with manufacturer based on casting methods used.
NOTE 2—For details of Sanitary Tee ranch, see Fig. 20.

ASA Code Group 022		Size, in.	Dimensions, in. (mm)^A									
Item No.	√		A	B	E^{EB} ±1⁄8 (3.2)	E^B ±1⁄8 (3.2)	F^B ±1⁄8 (3.2)	D	K	R	R′	W
1086	2	3 by 3 by 2 LH	3¾ (95)	1½ (38)	5⅜ (137)	5 (127)	8 (203)	5 (127)	½ (13)	3½ (89)	3 (76)	1⅛ (29)
1090	4	3 by 3 by 2 RH	3¾ (95)	1½ (38)	5⅜ (137)	5 (127)	8 (203)	5 (127)	½ (13)	3½ (89)	3 (76)	1⅛ (29)
1094	6	3 by 3 by 2 by 2 R&L	3¾ (95)	1½ (38)	5⅜ (137)	5 (127)	8 (203)	5 (127)	½ (13)	3½ (89)	3 (76)	1⅛ (29)
							F^B N.O. ±1⁄8 (3.2)		KNO			
1122	5	3 by 3 by 2 LH	3¾ (95)	1½ (38)	5⅜ (137)	5 (127)	8½ (216)	5 (127)	1 (25)	3½ (89)	3 (76)	1⅛ (29)
1126	6	3 by 3 by 2 RH	3¾ (95)	1½ (38)	5⅜ (137)	5 (127)	8½ (216)	5 (127)	1 (25)	3½ (89)	3 (76)	1⅛ (29)
1130	8	3 by 3 by 2 R&L	3¾ (95)	1½ (38)	5⅜ (137)	5 (127)	8½ (216)	5 (127)	1 (25)	3½ (89)	3 (76)	1⅛ (29)
1124	1	4 by 4 by 2 LH	4⁵⁄₁₆ (110)	1½ (38)	6⅛ (156)	5½ (140)	9⅛ (232)	5½ (140)	1 (25)	4 (102)	3 (76)	1⅛ (29)
1128	2	4 by 4 by 2 RH	4⁵⁄₁₆ (110)	1½ (38)	6⅛ (156)	5½ (140)	9⅛ (232)	5½ (140)	1 (25)	4 (102)	3 (76)	1⅛ (29)
1132	4	4 by 4 by 2 R&L	4⁵⁄₁₆ (110)	1½ (38)	6⅛ (156)	5½ (140)	9⅛ (232)	5½ (140)	1 (25)	4 (102)	3 (76)	1⅛ (29)

^{A} For details of barrel, spigot, and gasket positioning lug, see Fig. 1 and Fig. 2.
^{B} Dimensions E, F, and E ^{E} are laying lengths.

FIG. 24 Sanitary Tee With 45° Slide Openings Above Center Right or Left or Right and Left^B and New Orleans Specials (corresponds to Table 31 of CISPI Specification 301)



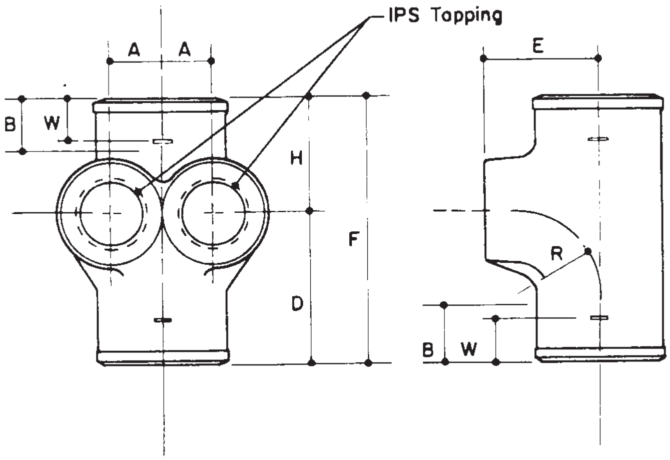
ASA Code Group 022		Size, in.	Dimensions, in. (mm)[A]						
Item No.	√		B	E	F[B] ±⅛ (3.2)	D	R	IPS Tapping[C]	W
1208	2	1½ by 1¼	1½ (38)	2⁹⁄₁₆ (65)	5¹¹⁄₁₆ (144)	3¼ (83)	1¾ (44)	1¼ (32)	1⅛ (29)
1210	8	1½ by 1½	1½ (38)	2⁹⁄₁₆ (65)	5¹¹⁄₁₆ (144)	3¼ (83)	1¾ (44)	1½ (38)	1⅛ (29)
1212	4	2 by 1¼	1½ (38)	2¹³⁄₁₆ (71)	5¹¹⁄₁₆ (144)	3¼ (83)	1¾ (44)	1¼ (32)	1⅛ (29)
1214	0	2 by 1½	1½ (38)	2¹³⁄₁₆ (71)	5¹¹⁄₁₆ (144)	3¼ (83)	1¾ (44)	1½ (38)	1⅛ (29)
1216	5	2 by 2	1½ (38)	3¹⁄₁₆ (78)	6⅜ (162)	3¾ (95)	2¼ (57)	2 (51)	1⅛ (29)
1218	1	3 by 1¼	1½ (38)	3⁵⁄₁₆ (84)	5¹¹⁄₁₆ (144)	3¼ (83)	1¾ (44)	1¼ (32)	1⅛ (29)
1220	7	3 by 1½	1½ (38)	3⁵⁄₁₆ (84)	5¹¹⁄₁₆ (144)	3¼ (83)	1¾ (44)	1½ (38)	1⅛ (29)
1222	3	3 by 2	1½ (38)	3⁹⁄₁₆ (90)	6⅜ (162)	3¾ (95)	2¼ (57)	2 (51)	1⅛ (29)
1223	1	3 by 3	1½ (38)	4³⁄₁₆ (106)	8 (203)	4⅞ (124)	3½ (89)	3 (76)	1⅛ (29)
1224	9	4 by 1¼	1½ (38)	3¹³⁄₁₆ (97)	5¹¹⁄₁₆ (144)	3¼ (83)	1¾ (44)	1¼ (32)	1⅛ (29)
1226	4	4 by 1½	1½ (38)	3¹³⁄₁₆ (97)	5¹¹⁄₁₆ (144)	3¼ (83)	1¾ (44)	1½ (38)	1⅛ (29)
1228	0	4 by 2	1½ (38)	4¹⁄₁₆ (103)	6⅜ (162)	3¾ (95)	2¼ (57)	2 (51)	1⅛ (29)
1231	4	5 by 1¼	2 (51)	4⁵⁄₁₆ (109)	6¹¹⁄₁₆ (170)	3¾ (95)	1¾ (44)	1¼ (32)	1½ (38)
1232	2	5 by 1½	2 (51)	4⁵⁄₁₆ (109)	6¹¹⁄₁₆ (170)	3¾ (95)	1¾ (44)	1½ (38)	1½ (38)
1233	0	5 by 2	2 (51)	4⁹⁄₁₆ (109)	7¹⁵⁄₁₆ (202)	4¼ (108)	2¼ (57)	2 (51)	1½ (38)

Extended Patterns

ASA Code Group 022		Size, in.	Dimensions, in. (mm)[A]						
Item No.	√		B	E	F[B] ±⅛ (3.2)	D	R	IPS Tapping[C]	W
1236	0	2 by 1½	1½ (38)	2¹³⁄₁₆ (71)	22⅞	20¹⁵⁄₁₆	1¾ (44)	1½ (38)	1⅛ (29)
1237	0	2 by 1½	1½ (38)	2¹³⁄₁₆ (71)	31 [787]	29¹⁄₁₆	1¾ (44)	1½ (38)	1⅛ (29)
1238	0	2 by 2	1½ (38)	3¹⁄₁₆ (78)	31 [787]	28⅜	2¼ (57)	2 (51)	1⅛ (29)
1239	0	2 by 2	1½ (38)	3¹⁄₁₆ (78)	22⅞	28⅜	2¼ (57)	2 (51)	1⅛ (29)

[A] For details of barrel, spigot, and gasket positioning lug, see Fig. 1 and Fig. 2.
[B] Dimension F is laying length.
[C] For details of tapping bosses, see Fig. 63.

FIG. 25 Sanitary Tapped Tee (corresponds to Table 32 of CISPI Specification 301)

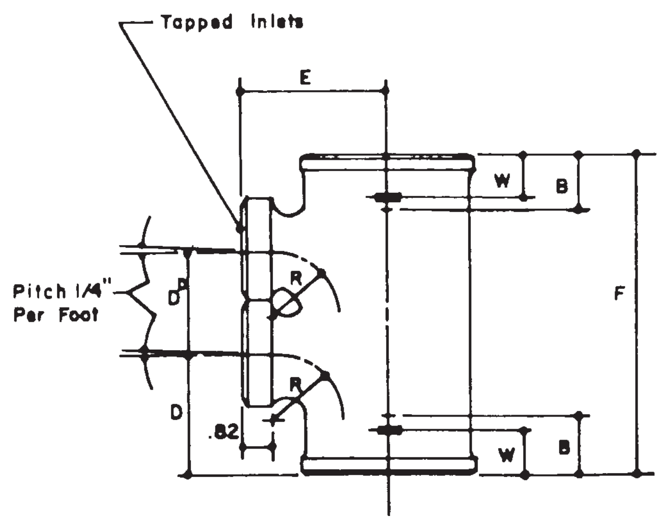


NOTE 1—Horizontal inlet waste bosses to be tapped at an angle of ¼ in. (6 mm) per foot to provide flow.

ASA Code Group 022		Size, in.	Dimensions, in. (mm)[A]								
Item No.	√		B	H	E	F[B]±⅛ (3.2)	D	A	R	W	IPS Tapping[C]
1290	0	2 by 1½	1½ (38)	3 (76)	2½ (64)	7 (178)	4 (102)	1⅜ (35)	2¼ (57)	1⅛ (29)	1½ (38)
1292	6	3 by 1½	1½ (38)	3 (76)	3 (76)	7 (178)	4 (102)	1⅜ (35)	2¼ (57)	1⅛ (29)	1½ (38)
1294	2	4 by 1½	1½ (38)	3 (76)	3½ (89)	7 (178)	4 (102)	1⅜ (35)	2¼ (57)	1⅛ (29)	1½ (38)

[A] For details of barrel, spigot, and gasket positioning lug, see Fig. 1 and Fig. 2.
[B] Dimension F is laying length.
[C] For details of tapping bosses, see Fig. 63.

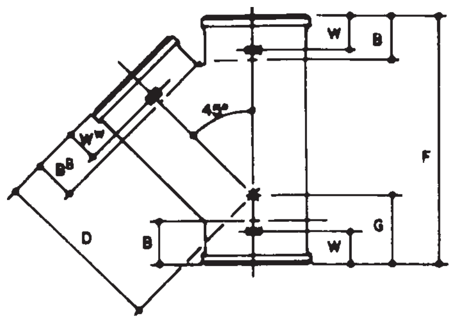
FIG. 26 Horizontal Twin Sanitary Tapped Tee (corresponds to Table 37 of CISPI Specification 301)



ASA Code Group 022		Size, in.	Dimensions, in. (mm)[A]							
Item No.	√		B	E	F[B] ±⅛ (3.2)	D	D[D]	R	IPS Tapping[C]	W
1304	9	2 by 1½	1½ (38)	2$\frac{13}{16}$ (71)	8$\frac{7}{16}$ (214)	3¼ (83)	2¾ (70)	1¾ (44)	1½ (38)	1⅛ (29)
1306	4	3 by 1½	1½ (38)	3$\frac{5}{16}$ (84)	8$\frac{7}{16}$ (214)	3¼ (83)	2¾ (70)	1¾ (44)	1½ (38)	1⅛ (29)

[A] For details of barrel, spigot, and gasket positioning lug, see Fig. 1 and Fig. 2.
[B] Dimension F is laying length.
[C] For details of tapping bosses, see Fig. 63.

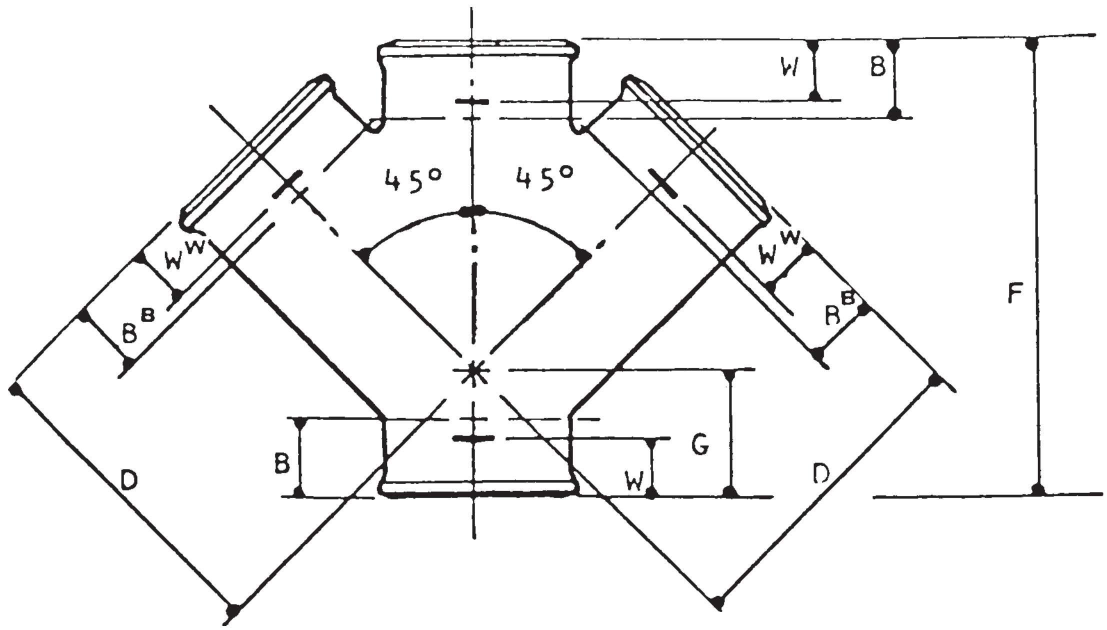
FIG. 27 Double Vertical Sanitary Tapped Tee (corresponds to Table 38 of CISPI Specification 301)



ASA Code Group 022		Size, in.	Dimensions, in. (mm)[A]						
Item No.	√		B	B[B]	D[B] ±⅛ (3.2)	F[B] ±⅛ (3.2)	G	W	W[W]
1312	2	1½	1½ (38)	1½ (38)	4 (102)	6 (152)	2 (51)	1⅛ (29)	1⅛ (29)
1314	8	2	1½ (38)	1½ (38)	4⅝ (117)	6⅝ (168)	2 (51)	1⅛ (29)	1⅛ (29)
1315	3	3 by 1½	1½ (38)	1½ (38)	4⅝ (117)	6⅝ (168)		1⅛ (29)	1⅛ (29)
1316	3	3 by 2	1½ (38)	1½ (38)	5 5/16 (135)	6⅝ (168)	1½ (38)	1⅛ (29)	1⅛ (29)
1318	9	3	1½ (38)	1½ (38)	5¾ (146)	8 (203)	2¼ (57)	1⅛ (29)	1⅛ (29)
1320	5	4 by 2	1½ (38)	1½ (38)	6 (152)	6⅝ (168)	1 (25)	1⅛ (29)	1⅛ (29)
1322	1	4 by 3	1½ (38)	1½ (38)	6½ (165)	8 (203)	1 11/16 (43)	1⅛ (29)	1⅛ (29)
1324	7	4	1½ (38)	1½ (38)	7 1/16 (179)	9½ (241)	2 7/16 (62)	1⅛ (29)	1⅛ (29)
1326	2	5 by 2	2 (51)	1½ (38)	7½ (191)	8 1/16 (205)	15/16 (24)	1½ (38)	1⅛ (29)
1328	8	5 by 3	2 (51)	1½ (38)	8 (203)	9 11/16 (246)	1 11/16 (43)	1½ (38)	1⅛ (29)
1330	4	5 by 4	2 (51)	1½ (38)	8½ (216)	11 3/16 (284)	2 7/16 (62)	1½ (38)	1⅛ (29)
1332	0	5	2 (51)	2 (51)	9½ (241)	12⅝ (321)	3⅛ (79)	1½ (38)	1½ (38)
1334	6	6 by 2	2 (51)	1½ (38)	8¼ (210)	8 5/16 (211)	½ (13)	1½ (38)	1⅛ (29)
1336	1	6 by 3	2 (51)	1½ (38)	8¾ (222)	9¾ (248)	1¼ (32)	1½ (38)	1⅛ (29)
1338	7	6 by 4	2 (51)	1½ (38)	9¼ (235)	11 3/16 (284)	1 15/16 (49)	1½ (38)	1⅛ (29)
1340	3	6 by 5	2 (51)	2 (51)	10¼ (260)	12½ (318)	2 9/16 (65)	1½ (38)	1½ (38)
1342	9	6	2 (51)	2 (51)	10¾ (273)	14 1/16 (357)	3 5/16 (84)	1½ (38)	1½ (38)
1344	5	8 by 2	2½ (64)	2¼ (57)	9⅜ (238)	8½ (216)	9/16 (14)	2 (25)	1⅛ (29)
1346	0	8 by 3	2½ (64)	2¼ (57)	9 13/16 (249)	9 15/16 (252)	⅛ (3)	2 (25)	1⅛ (29)
1348	6	8 by 4	2½ (64)	2¼ (57)	10⅜ (264)	11 7/16 (291)	15/16 (24)	2 (25)	1⅛ (29)
1350	2	8 by 5	2½ (64)	2¾ (70)	11⅜ (289)	12 13/16 (325)	1⅝ (41)	2 (25)	1½ (38)
1352	8	8 by 6	2½ (64)	2¾ (70)	11 13/16 (300)	14 3/16 (360)	2 5/16 (59)	2 (25)	1½ (38)
1354	4	8	2½ (64)	3¼ (83)	13⅜ (340)	17⅛ (435)	3¾ (95)	2 (25)	2 (51)
1357	7	10 by 4	3 (76)	1½ (38)	11 11/16 (297)	12⅝ (321)	¾ (19)	2 (25)	1⅛ (29)
1359	3	10 by 6	3 (76)	2 (51)	13⅛ (333)	15 7/16 (392)	2 3/16 (56)	2 (25)	1½ (38)
1360	0	10 by 8	3 (76)	2½ (64)	14 11/16 (373)	18⅜ (467)	3⅝ (92)	2 (25)	2 (51)
1361	9	10	3 (76)	3¾ (95)	16½ (419)	21½ (546)	5 1/16 (129)	2 (25)	2 (51)
1362	9	12	3¼ (83)	3¼ (83)	19¾ (502)	25½ (648)	5¾ (146)	2¾ (70)	2¾ (70)
1363	9	15	3¼ (83)	3¼ (83)	23¼ (591)	30 (762)	6¾ (171)	2¾ (70)	2¾ (70)

[A] For details of barrel, spigot, and gasket positioning lug, see Fig. 1 and Fig. 2.
[B] Dimensions D and F are laying lengths.

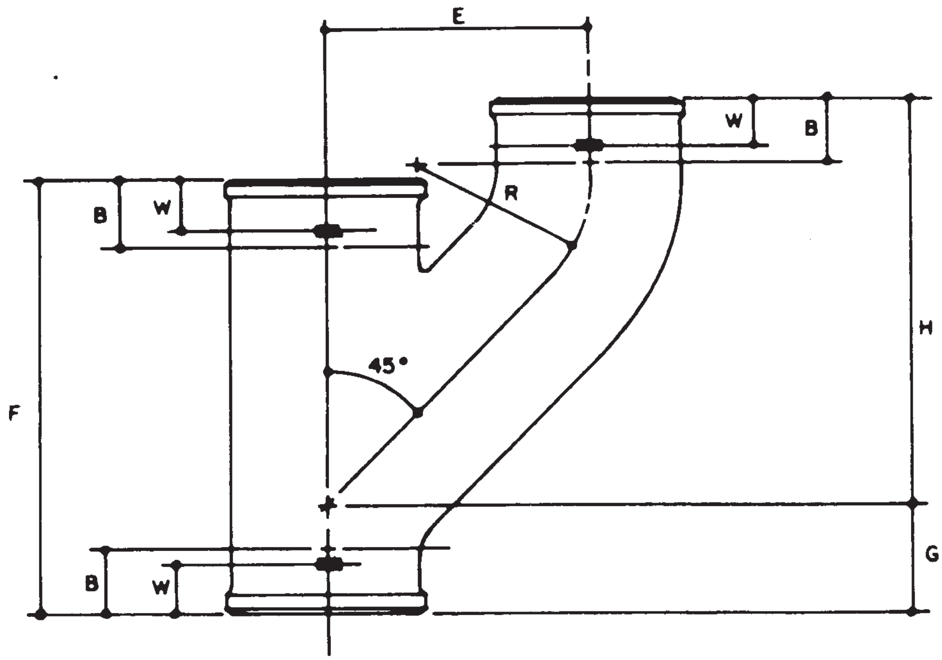
FIG. 28 Wye (corresponds to Table 39 of CISPI Specification 301)



ASA Code Group 022		Size, in.	Dimensions, in. (mm)^A						
Item No.	√		B	B^B	D^B ±1⁄8 (3.2)	F^B ±1⁄8 (3.2)	G	W	W^W
1538	2	2	1½ (38)	1½ (38)	4⅝ (117)	6⅝ (168)	2 (51)	1⅛ (29)	1⅛ (29)
1540	8	3 by 2	1½ (38)	1½ (38)	55⁄16 (135)	6⅝ (168)	1½ (38)	1⅛ (29)	1⅛ (29)
1542	4	3	1½ (38)	1½ (38)	5¾ (146)	8 (203)	2¼ (57)	1⅛ (29)	1⅛ (29)
1544	0	4 by 2	1½ (38)	1½ (38)	6 (152)	6⅝ (168)	1 (25)	1⅛ (29)	1⅛ (29)
1546	5	4 by 3	1½ (38)	1½ (38)	6½ (165)	8 (203)	111⁄16 (43)	1⅛ (29)	1⅛ (29)
1548	1	4	1¼ (32)	1½ (38)	71⁄16 (179)	9½ (241)	27⁄16 (62)	1⅛ (29)	1⅛ (29)
1550	7	5 by 4	2 (51)	1½ (38)	8½ (216)	113⁄16 (284)	27⁄16 (62)	1½ (38)	1⅛ (29)
1552	3	6 by 4	2 (51)	1½ (38)	9¼ (235)	113⁄16 (284)	115⁄16 (49)	1½ (38)	1⅛ (29)
1554	9	6	2 (51)	2 (51)	10¾ (273)	141⁄16 (357)	35⁄16 (84)	1½ (38)	1½ (38)
1556	3	8 by 4	2½ (64)	2¼ (57)	10⅜ (264)	117⁄16 (291)	15⁄16 (24)	2 (51)	1⅛ (29)
1557	1	8 by 6	2½ (64)	2¾ (70)	1113⁄16 (300)	143⁄16 (360)	25⁄16 (59)	2 (51)	1½ (38)
1558	0	8	2½ (64)	3¼ (83)	13⅜ (340)	17⅛ (435)	3¾ (95)	2 (51)	2 (51)

^{A} For details of barrel, spigot, and gasket positioning lug, see Fig. 1 and Fig. 2.
^{B} Dimensions D and F are laying lengths.

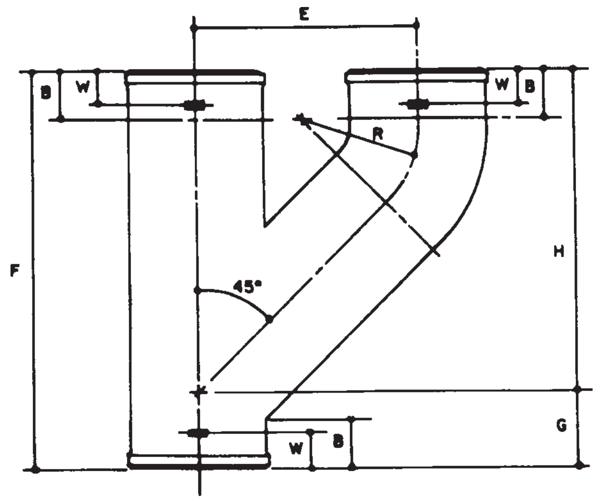
FIG. 29 Double Wye (corresponds to Table 42 of CISPI Specification 301)



ASA Code Group 022		Size, in.	Dimensions, in. (mm)A						
Item No.	√		B	H	E	FB (±1⁄8)	G	R	W
1646	3	2	1½ (38)	8¼ (210)	5½ (140)	7 (178)	2 (51)	3 (76)	1⅛ (29)
1648	9	3 by 2	1½ (38)	8 3⁄16 (208)	5½ (140)	7 (178)	1½ (38)	3 (76)	1⅛ (29)
1650	5	3	1½ (38)	8 7⁄16 (214)	5½ (140)	8⅜ (86)	2 3⁄16 (56)	3½ (89)	1⅛ (29)
1652	1	4 by 2	1½ (38)	8¼ (210)	5½ (140)	7 (178)	1 (25)	3 (76)	1⅛ (29)
1654	7	4 by 3	1½ (38)	8 7⁄16 (214)	5½ (140)	8⅜ (86)	1 11⁄16 (43)	3½ (89)	1⅛ (29)
1656	2	4	1½ (38)	9⅛ (232)	6 (152)	9¾ (248)	2 7⁄16 (62)	4 (102)	1⅛ (29)
1658	4	5 by 2	1½ (38)	9	6¾	8	2 (51)	3 (76)	1½
1660	8	5 by 3	1½ (38)	8¼ (210)	6¼	9⅝	2⅜	3½ (89)	1½
1662	6	5	1½ (38)	11 7⁄16	7⅛	12 11⁄16	2¾	4½	1½

A For details of barrel, spigot, and gasket positioning lug, see Fig. 1 and Fig. 2.
B Dimension F is laying length.

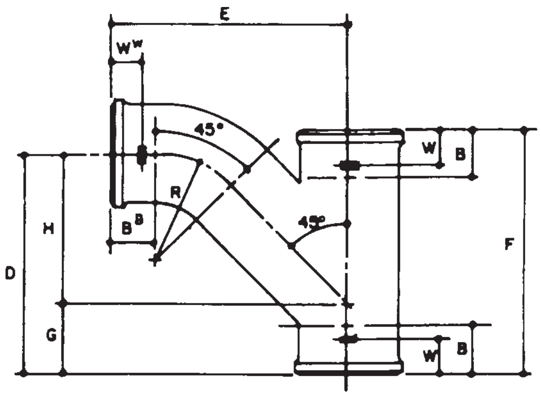
FIG. 30 Upright Wye (corresponds to Table 45 of CISPI Specification 301)



ASA Code Group 022		Size, in.	Dimensions, in. (mm)[A]						
Item No.	√		B	H	E	F[B] ± ⅛ (3.2)	G	R	W
022 9000	5	3 by 3	1½ (38)	10 (254)	7 (178)	12¼ (311)	2¼ (57)	3½ (89)	1⅛ (29)
022 9001	3	4 by 3	1½ (38)	10 (254)	7 (178)	11 11⁄16 (297)	1 11⁄16 (43)	3½ (89)	1⅛ (29)
022 9002	1	4 by 4	1½ (38)	10⅛ (257)	7 (178)	12 9⁄16 (319)	2 7⁄16 (62)	4 (102)	1⅛ (29)

[A] For details of barrel, spigot, and gasket positioning lug, see Fig. 1 and Fig. 2.
[B] Dimensions F is laying length.

FIG. 31 Upright Wye Wide Center—Florida Special (corresponds to Table 46 of CISPI Specification 301)



ASA Code Group 022			Dimensions, in. (mm)^A									
Item No.	√	Size, in.	B	B^B	D	E^B ±1⁄8 (3.2)	F^B ±1⁄8 (3.2)	G	H	R	W	W^W
1694	3	1½	1½ (38)	1½ (38)	4¾ (121)	5⅜ (137)	6 (152)	2 (51)	2¾ (70)	2¾ (70)	1⅛ (29)	1⅛ (29)
1696	8	2 by 1½	1½ (38)	1½ (38)	5 (127)	5⅞ (149)	6 (152)	2 (51)	3 (76)	2¾ (70)	1⅛ (29)	1⅛ (29)
1698	4	2	1½ (38)	1½ (38)	5⅜ (137)	6⅛ (156)	6⅝ (168)	2 (51)	3⅜ (86)	3 (76)	1⅛ (29)	1⅛ (29)
1700	8	3 by 2	1½ (38)	1½ (38)	5½ (140)	6¾ (171)	6⅝ (168)	1½ (38)	4 (102)	3 (76)	1⅛ (29)	1⅛ (29)
1702	4	3	1½ (38)	1½ (38)	7 5⁄16 (186)	8 (203)	8 (203)	2¼ (57)	5 1⁄16 (129)	3½ (89)	1⅛ (29)	1⅛ (29)
1704	0	4 by 2	1½ (38)	1½ (38)	5½ (140)	7¼ (184)	6⅝ (168)	1 (25)	4½ (114)	3 (76)	1⅛ (29)	1⅛ (29)
1706	5	4 by 3	1½ (38)	1½ (38)	7¼ (184)	8½ (216)	8 (203)	1 11⁄16 (49)	5 9⁄16 (141)	3½ (89)	1⅛ (29)	1⅛ (29)
1708	1	4	1½ (38)	1½ (38)	9¼ (235)	10 (254)	9½ (241)	2 7⁄16 (62)	6 13⁄16 (173)	4 (102)	1⅛ (29)	1⅛ (29)
1710	7	5 by 2	2 (51)	1½ (38)	5 15⁄16 (151)	7¾ (197)	8 1⁄16 (205)	15⁄16 (24)	5 (127)	3 (76)	1½ (38)	1⅛ (29)
1712	3	5 by 3	2 (51)	1½ (38)	7¾ (197)	9 (229)	9 11⁄16 (246)	1 11⁄16 (43)	6 1⁄16 (154)	3½ (89)	1½ (38)	1⅛ (29)
1714	9	5 by 4	2 (51)	1½ (38)	9¾ (248)	10½ (267)	11 3⁄16 (284)	2 7⁄16 (62)	7 5⁄16 (186)	4 (102)	1½ (38)	1⅛ (29)
1716	4	5	2 (51)	2 (51)	11¾ (298)	12½ (318)	12⅝ (321)	3⅛ (79)	8⅝ (219)	4½ (114)	1½ (38)	1½ (38)
1718	0	6 by 2	2 (51)	6 (152)	8¼ (210)	8 5⁄16 (211)	½ (13)	5½ (140)	3 (76)	1½ (38)	1½ (38)	1⅛ (29)
1720	6	6 by 3	2 (51)	1½ (38)	7 13⁄16 (198)	9½ (241)	9¾ (248)	1¼ (32)	6 9⁄16 (167)	3½ (89)	1½ (38)	1⅛ (29)
1722	2	6 by 4	2 (51)	1½ (38)	9¾ (248)	11 (279)	11 3⁄16 (284)	1 15⁄16 (49)	7 13⁄16 (198)	4 (102)	1½ (38)	1⅛ (29)
1724	8	6 by 5	2 (51)	2 (51)	14 11⁄16 (373)	13 (330)	12½ (318)	2 9⁄16 (65)	9⅛ (232)	4½ (114)	1½ (38)	1½ (38)
1726	3	6	2 (51)	2 (51)	13⅝ (346)	14⅜ (365)	14 1⁄16 (357)	3 5⁄16 (84)	10 5⁄16 (262)	5 (127)	1½ (38)	1½ (38)
1728	9	8 by 4	2½ (64)	1½ (38)	9 7⁄16 (240)	11 5⁄16 (287)	11 3⁄16 (284)	⅞ (22)	8 9⁄16 (217)	4 (102)	2 (51)	1⅛ (29)
1730	5	8 by 5	2½ (64)	2 (51)	10 15⁄16 (278)	12 13⁄16 (325)	12 11⁄16 (322)	1⅝ (41)	9 5⁄16 (237)	4½ (114)	2 (51)	1½ (38)
1732	1	8 by 6	2½ (64)	2 (51)	12 (305)	13⅜ (340)	13 15⁄16 (354)	2¼ (57)	9¾ (248)	5 (127)	2 (51)	1½ (38)
1734	7	8	2½ (64)	2½ (64)	14¾ (375)	15 9⁄16 (395)	16 15⁄16 (430)	3¾ (95)	11 (279)	6 (152)	2 (51)	2 (51)

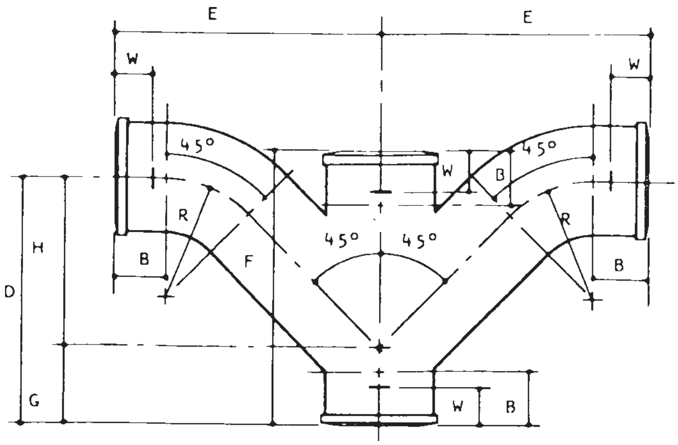
Extended Pattern

ASA Code Group 022			Dimensions, in. (mm)^A									
Item No.	√	Size, in.	B	B^B	D	E^B ±1⁄8 (3.2)	F^B ±1⁄8 (3.2)	G	H	R	W	W^W
1738	1	1½	2	1½ (38)	16¾	6⅛	18	13⅜	3⅜ (86)	3 (76)	1⅛ (29)	1⅛ (29)
1740	3	2 by 1½	2	1½ (38)	22¾	6⅛	24	19⅜	3⅜ (86)	3 (76)	1⅛ (29)	1⅛ (29)
1742	5	2	2	1½ (38)	34¾	6⅛	36	26¾	3⅜ (86)	3 (76)	1⅛ (29)	1⅛ (29)
1744	7	3 by 2	3 by 2	1½ (38)	34	6¾ (171)	36	30	4 (102)	3 (76)	1⅛ (29)	1⅛ (29)

^A For details of barrel, spigot, and gasket positioning lug, see Fig. 1 and Fig. 2.

^B Dimensions E and F are laying lengths.

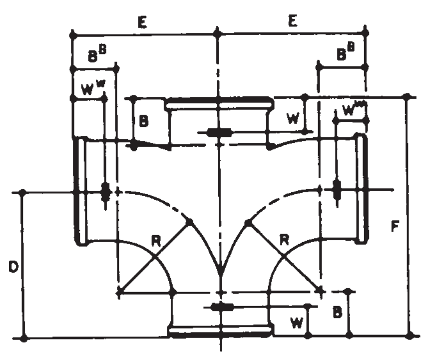
FIG. 32 Combination Wye and ⅛ Bend (corresponds to Table 47 of CISPI Specification 301)



ASA Code Group 022		Size, in.	Dimensions, in. (mm)^A							
Item No.	√		B	D	E^B ±⅛ (3.2)	F^B ±⅛ (3.2)	G	H	R	W
1802	2	2	1½ (38)	5⅜ (137)	6⅛ (156)	6⅝ (168)	2 (51)	3⅜ (86)	3 (76)	1⅛ (29)
1804	8	3 by 2	1½ (38)	5½ (140)	6¾ (171)	6⅝ (168)	1½ (38)	4 (102)	3 (76)	1⅛ (29)
1806	3	3	1½ (38)	7 5/16 (186)	8 (203)	8 (203)	2¼ (57)	5 1/16 (129)	3½ (89)	1⅛ (29)
1808	9	4 by 2	1½ (38)	5½ (140)	7¼ (184)	6⅝ (168)	1 (25)	4½ (114)	3 (76)	1⅛ (29)
1810	5	4 by 3	1½ (38)	7¼ (184)	8½ (216)	8 (203)	1 11/16 (43)	5 9/16 (141)	3½ (89)	1⅛ (29)
1812	1	4	1½ (38)	9¼ (235)	10 (254)	9½ (241)	2 7/16 (62)	6 13/16 (173)	4 (102)	1⅛ (29)

^{A} For details of barrel, spigot, and gasket positioning lug, see Fig. 1 and Fig. 2.
^{B} Dimensions E and F are laying lengths.

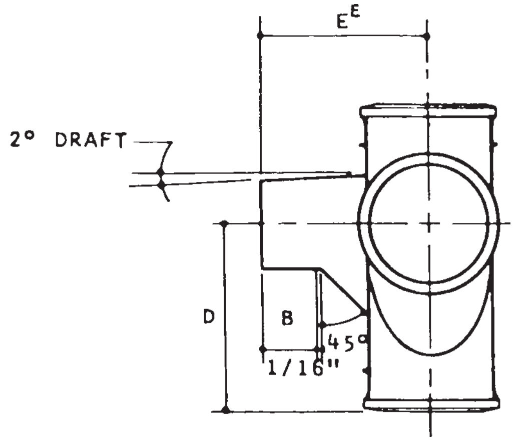
FIG. 33 Combination Wye and ⅛ Bend, Double (corresponds to Table 50 of CISPI Specification 301)



ASA Code Group 022		Size, in.	Dimensions, in. (mm)^A							
Item No.	√		B	E^B±⅛ (3.2)	F^B ±⅛ (3.2)	D	R	W	W^W	W^B
1850	1	1½	1½ (38)	4¼ (108)	6½ (165)	4¼ (108)	2¾ (70)	1⅛ (29)	1⅛ (29)	1½ (38)
1852	7	2	1½ (38)	4½ (114)	6⅞ (175)	4½ (114)	3 (76)	1⅛ (29)	1⅛ (29)	1½ (38)
1854	3	3 by 2	1½ (38)	5 (127)	6⅞ (175)	4½ (114)	3 (76)	1⅛ (29)	1⅛ (29)	1½ (38)
1856	8	3	1½ (38)	5 (127)	8 (203)	5 (127)	3½ (89)	1⅛ (29)	1⅛ (29)	1½ (38)
1958	4	4 by 2	1½ (38)	5½ (140)	6⅞ (175)	4½ (114)	3 (76)	1⅛ (29)	1⅛ (29)	1½ (38)
1860	0	4 by 3	1½ (38)	5½ (140)	8 (203)	5 (127)	3½ (89)	1⅛ (29)	1⅛ (29)	1½ (38)
1862	6	4	1½ (38)	5½ (140)	9⅛ (232)	5½ (140)	4 (102)	1⅛ (29)	1⅛ (29)	1½ (38)
1868	3	6 by 2	2 (51)	6½ (165)	8 3/16 (208)	5 (127)	3 (76)	1½ (38)	1⅛ (29)	1½ (38)
1864	2	6 by 4	2 (51)	6½ (165)	10 1/16 (256)	6 (152)	4 (102)	1½ (38)	1⅛ (29)	1½ (38)
1867	5	6	2 (51)	7 (178)	12½ (318)	7 (178)	5 (127)	1½ (38)	1½ (38)	2 (51)
1874	1	8 by 4	2½ (64)	7½ (191)	11½ (292)	6½ (165)	4 (102)	2 (51)	1⅛ (29)	1½ (38)
1878	2	8	2½ (64)	8½ (216)	15½ (394)	8½ (216)	6 (152)	2 (51)	2 (51)	2½ (64)

^{A} For details of barrel, spigot, and gasket positioning lug, see Fig. 1 and Fig. 2.
^{B} Dimensions E and F are laying lengths.

FIG. 34 Sanitary Cross (corresponds to Table 51 of CISPI Specification 301)

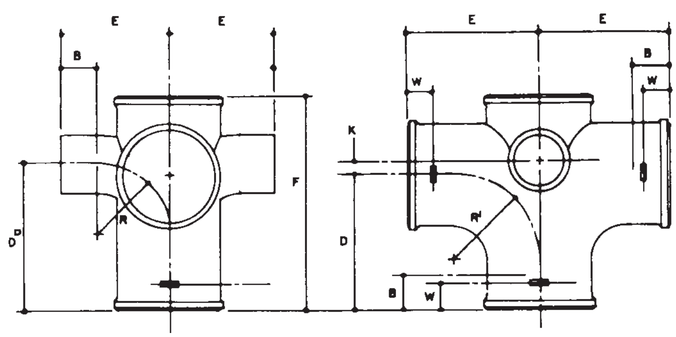


NOTE 1—Inclusion of spigot bead and positioning lug optional with manufacturer based on casting method used.

ASA Code Group 022		Size, in.	Dimensions, in. (mm)[A,B]		
Item No.	√		B	E^EC ±⅛ (3.2)	D
1898	0	3 by 3 by 2	1½ (38)	4 7⁄16 (113)	5 (127)
1900	4	4 by 4 by 2	1½ (38)	4 15⁄16 (125)	5½ (140)

[A] For details of barrel, spigot, and gasket positioning lug, see Fig. 1 and Fig. 2.
[B] For details of sanitary cross, see Fig. 34.
[C] Dimension E [E] is laying length.

FIG. 35 Sanitary Cross With Side Opening (corresponds to Table 52 of CISPI Specification 301)

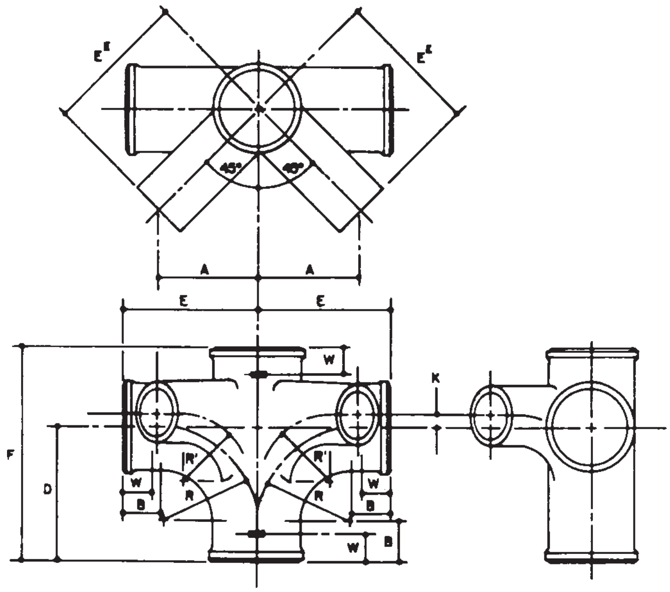


NOTE 1—Inclusion of spigot bead and positioning lug optional with manufacturer based on casting method used.

ASA Code Group 022		Size, in.	Dimensions, in. (mm)[A]									
Item No.	√		B	E^EB ±⅛ (3.2)	E^B ±⅛ (3.2)	F^B ±⅛ (3.2)	D	D^D	K	R	R′	W
1982	2	3 by 3 by 2	1½ (38)	4½ (114)	5 (127)	8½ (216)	5 (127)	6 (152)	1 (25)	3 (76)	3½ (89)	1⅛ (29)
1984	8	4 by 4 by 2	1½ (38)	5 (127)	5½ (140)	9⅛ (232)	5½ (140)	6½ (165)	1 (25)	3 (76)	4 (102)	1⅛ (29)

[A] For details of barrel, spigot, and gasket positioning lug, see Fig. 1 and Fig. 2.
[B] Dimensions E, F, and E^E are laying lengths.

FIG. 36 Sanitary Cross With Side Openings Above Center (New Orleans) (corresponds to Table 55 of CISPI Specification 301)

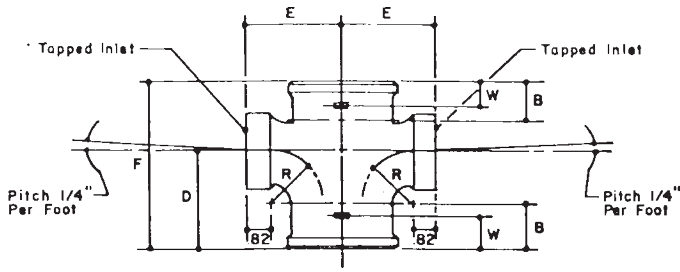


NOTE 1—Inclusion of spigot bead and positioning lug shall be optional with manufacturer based on casting method used.\
NOTE 2—For details of sanitary cross, see Fig. 34.

ASA Code Group 022		Size, in.	Dimensions, in. (mm)^A											
Item No.	√		A	B	E^{EB}±⅛ (3.2)	E^B±⅛ (3.2)	F^B ±⅛ (3.2)	F^B N.O.	D	K	K N.O.	R	R′	W
1994	7	3 by 3 by 2	3¾ (95)	1½ (38)	5⅜ (137)	5 (127)	8 (203)	8½ (216)	5 (127)	1 (25)	1 (25)	3½ (89)	3 (76)	1⅛ (29)
2000	2	4 by 4 by 2	4 5/16 (110)	1½ (38)	6⅛ (156)	5½ (140)	9⅛ (232)	9⅛ (232)	5½ (140)	½ (13)	1 (25)	4 (102)	3 (76)	1⅛ (29)

^{A} For details of barrel, spigot, and gasket positioning lug, see Fig. 1 and Fig. 2.
^{B} Dimensions E, F, and E^E are laying lengths.

FIG. 37 Sanitary Cross With Two 45° Side Openings on Same Side (Regular and New Orleans Special) (corresponds to Table 56 of CISPI Specification 301)



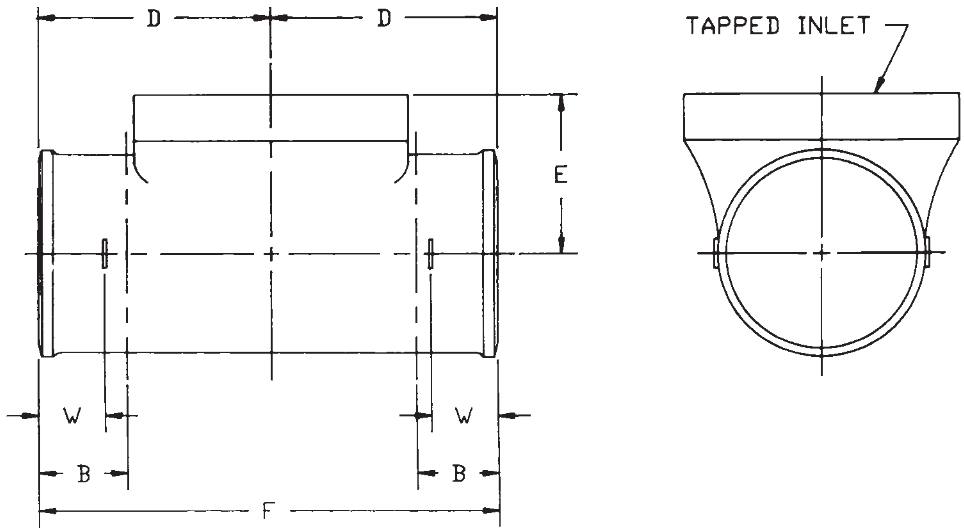
ASA Code Group 022 Item No.	√	Size, in.	Dimensions, in. (mm)[A] B	E	F[B] ±⅛ (3.2)	D	R	IPS Tapping[C]	W
2012	7	1½ by 1½	1½ (38)	2 9/16 (65)	5 11/16 (144)	3¼ (83)	1¾ (44)	1½ (38)	1⅛ (29)
2014	3	2 by 1¼	1½ (38)	2 13/16 (71)	5 11/16 (144)	3¼ (83)	1¾ (44)	1¼ (32)	1⅛ (29)
2016	8	2 by 1½	1½ (38)	2 13/16 (71)	5 11/16 (144)	3¼ (83)	1¾ (44)	1½ (38)	1⅛ (29)
2018	4	2 by 2	1½ (38)	3 1/16 (78)	6⅜ (162)	3¾ (95)	2¼ (57)	2 (51)	1⅛ (29)
2020	0	3 by 1¼	1½ (38)	3 5/16 (84)	5 11/16 (144)	3¼ (83)	1¾ (44)	1¼ (32)	1⅛ (29)
2022	6	3 by 1½	1½ (38)	3 5/16 (84)	5 11/16 (144)	3¼ (83)	1¾ (44)	1½ (38)	1⅛ (29)
2024	2	3 by 2	1½ (38)	3 9/16 (90)	6⅜ (162)	3¾ (95)	2¼ (57)	2 (51)	1⅛ (29)
2026	7	4 by 1¼	1½ (38)	3 13/16 (97)	5 11/16 (144)	3¼ (83)	1¾ (44)	1¼ (32)	1⅛ (29)
2028	3	4 by 1½	1½ (38)	3 13/16 (97)	5 11/16 (144)	3¼ (83)	1¾ (44)	1½ (38)	1⅛ (29)
2030	9	4 by 2	1½ (38)	4 1/16 (103)	5⅞ (149)	3¾ (95)	2¼ (57)	2 (51)	1⅛ (29)
2034	1	6 by 1½	2 (51)	4 13/16 (122)	6 11/16 (170)	3¾ (95)	1¾ (44)	1½ (38)	1½ (38)
2036	6	6 by 2	2 (51)	5 1/16 (129)	7 7/16 (189)	4¼ (108)	2¼ (57)	2 (51)	1½ (38)

Extended Patterns

ASA Code Group 022 Item No.	√	Size, in.	Dimensions, in. (mm)[A] B	E	F[B] ±⅛ (3.2)	D	R	IPS Tapping[C]	W
2038	9	2 by 1½ by 22⅞	1½ (38)	2 13/16 (71)	22⅞	19⅝	1¾ (44)	1½ (38)	1⅛ (29)
2040	3	2 by 1½ by 31	1½ (38)	2 13/16 (71)	31	27¾	1¾ (44)	1½ (38)	1⅛ (29)
2041	4	2 by 2 by 22⅞	1½ (38)	3 1/16 (78)	22⅞		2¼ (57)	2 (51)	1⅛ (29)
2042	5	2 by 2 by 31	1½ (38)	3 1/16 (78)	31	27¼	2¼ (57)	2 (51)	1⅛ (29)

[A] For details of barrel, spigot, and gasket positioning lug, see Fig. 1 and Fig. 2.
[B] Dimension F is laying length.
[C] For details of tapping bosses, see Fig. 63.

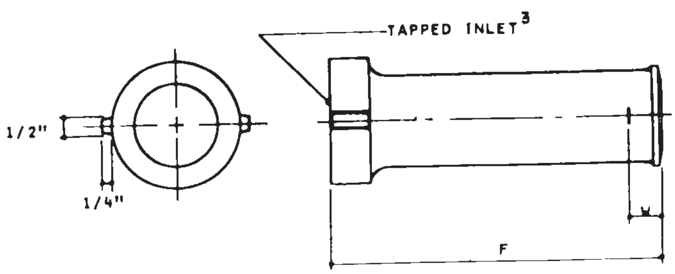
FIG. 38 Sanitary Cross, Tapped (corresponds to Table 57 of CISPI Specification 301)



ASA Code Group 022		Size, in.	Dimensions, in. (mm)[A]					
Item No.	√		B	E	F[B] ±1⁄8 (3.2)	D	IPS Tapping[C]	W
2046	5	2	1½ (38)	2 (51)	6⅜ (162)	3³⁄₁₆ (81)	2 (51)	1⅛ (29)
2048	1	3	1½ (38)	2¹¹⁄₁₆ (68)	7¾ (197)	3⅞ (98)	3 (76)	1⅛ (29)
8278	8	4	1½ (38)	3 (76)	8⅞ (225)	4⁷⁄₁₆ (113)	3½ (89)	1⅛ (29)
2050	7	4	1½ (38)	3 (76)	8⅞ (225)	4⁷⁄₁₆ (113)	4 (102)	1⅛ (29)
2052	3	5	2 (51)	4½ (114)	11½ (292)	5¾ (146)	5 (127)	1½ (38)
2054	9	6	2 (51)	5 (127)	12½ (318)	6¼ (159)	6 (152)	1½ (38)
2056	4	8	2 (51)	6 (152)	15¼ (387)	7⅝ (194)	8 (203)	2 (51)
2058	0	10	4 (102)	6½ (165)	20 (508)	10 (254)	10 (254)	2 (51)

[A] For details of barrel, spigot, and gasket positioning lug, see Fig. 1 and Fig. 2.
[B] Dimension F is laying length.
[C] For details of tapping bosses, see Fig. 63.

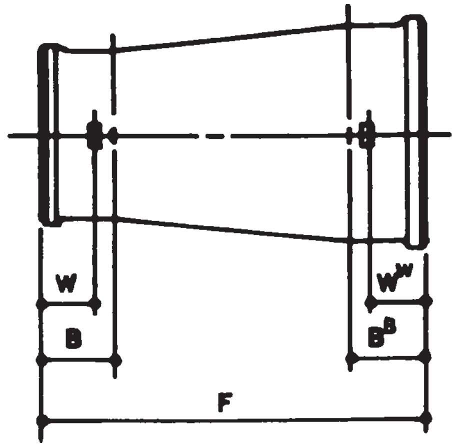
FIG. 39 Test Tee (corresponds to Table 58 of CISPI Specification 301)



ASA Code Group 022		Size, in.	Dimensions, in. (mm)[A]		
Item No.	√		F[B]±1⁄8 (3.2)	IPS[C] Tapping √	W
2100	0	3	12 (305)	3 (76)	1⅛ (29)

[A] For details of barrel, spigot, and gasket positioning lug, see Fig. 1 and Fig. 2.
[B] Dimension F is laying length.
[C] For details of tapping bosses, see Fig. 63.

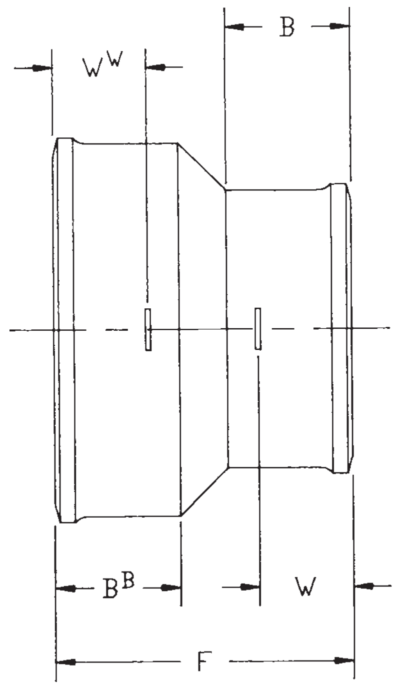
FIG. 40 Tapped Extension Piece (corresponds to Table 62 of CISPI Specification 301)



ASA Code Group 022		Size, in.	Dimensions, in. (mm)^A				
Item No.	√		B	B^B	F^B ±⅛ (3.2)	W	W^W
2124	0	2 by 3	1½ (38)	1½ (38)	8 (203)	1⅛ (29)	1⅛ (29)
2126	5	2 by 4	1½ (38)	1½ (38)	8 (203)	1⅛ (29)	1⅛ (29)
2128	1	3 by 4	1½ (38)	1½ (38)	8 (203)	1⅛ (29)	1⅛ (29)

^{A} For details of barrel, spigot, and gasket positioning lug, see Fig. 1 and Fig. 2.
^{B} Dimension F is laying length.

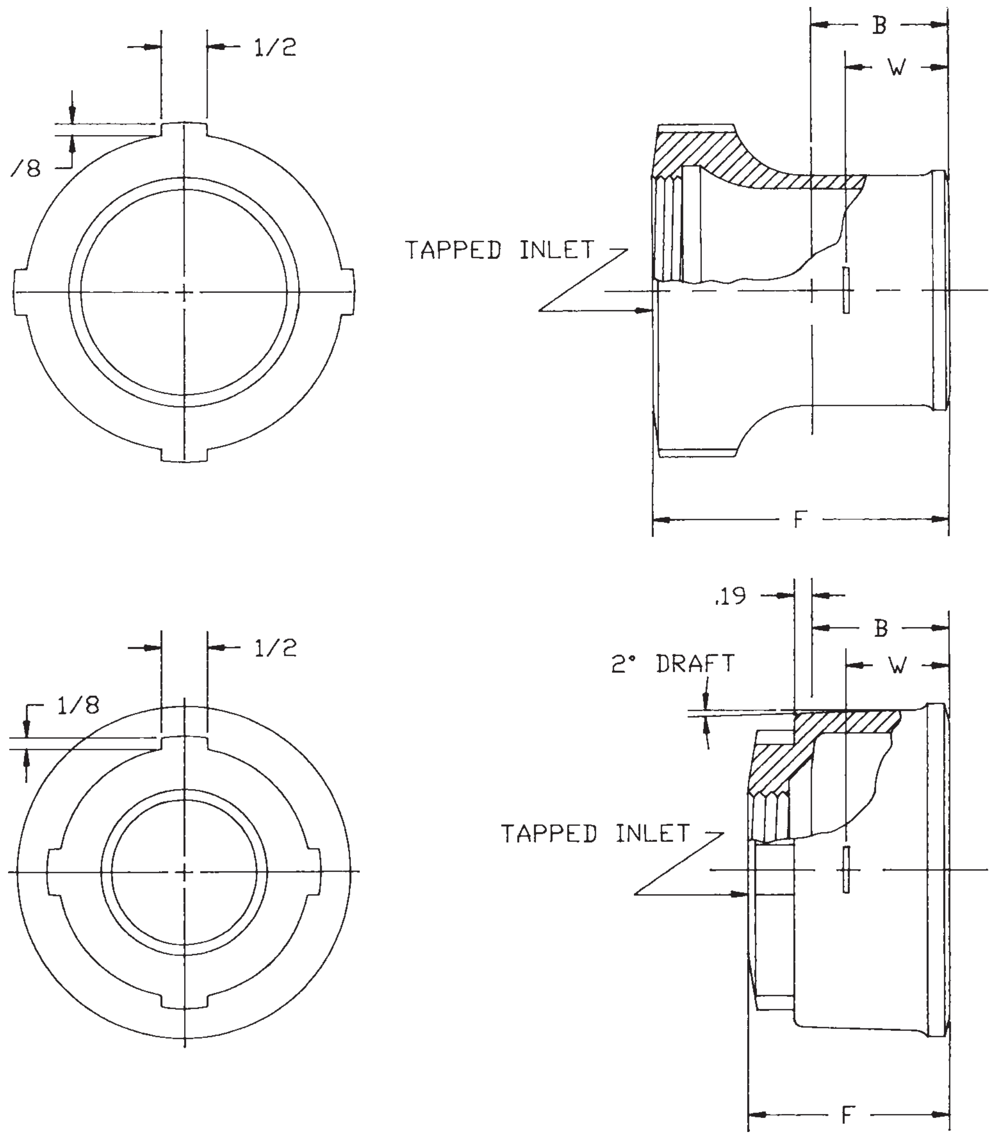
FIG. 41 Increaser-Reducer (corresponds to Table 63 of CISPI Specification 301)



ASA Code Group 022		Size, in.	Dimensions, in. (mm)[A]				
Item No.	√		B, Minimum	B[B], Minimum	F[B]±1⁄8 (3.2)	W	W[W]
2138	0	2 by 1½	1½ (38)	1½ (38)	3⅝ (92)	1⅛ (29)	1⅛ (29)
2140	6	3 by 2	1½ (38)	1½ (38)	3⅝ (92)	1⅛ (29)	1⅛ (29)
2142	2	4 by 2	1½ (38)	1½ (38)	3⅝ (92)	1⅛ (29)	1⅛ (29)
2144	8	4 by 3	1½ (38)	1½ (38)	3⅝ (92)	1⅛ (29)	1⅛ (29)
2146	3	5 by 2	1½ (38)	2 (51)	4 (102)	1⅛ (29)	1½ (38)
2148	9	5 by 3	1½ (38)	2 (51)	4 (102)	1⅛ (29)	1½ (38)
2150	5	5 by 4	1½ (38)	2 (51)	4 (102)	1⅛ (29)	1½ (38)
2152	1	6 by 2	1½ (38)	2 (51)	4 (102)	1⅛ (29)	1½ (38)
2154	7	6 by 3	1½ (38)	2 (51)	4 (102)	1⅛ (29)	1½ (38)
2156	2	6 by 4	1½ (38)	2 (51)	4 (102)	1⅛ (29)	1½ (38)
2158	8	6 by 5	2 (51)	2 (51)	4½ (114)	1½ (38)	1½ (38)
2160	4	8 by 2	1½ (38)	2 (51)	4½ (114)	1⅛ (29)	2 (51)
2162	0	8 by 3	1½ (38)	2 (51)	4½ (114)	1⅛ (29)	2 (51)
2164	6	8 by 4	1½ (38)	2 (51)	4½ (114)	1⅛ (29)	2 (51)
2166	1	8 by 5	2 (51)	2 (51)	5 (127)	1½ (38)	2 (51)
2168	7	8 by 6	2 (51)	2 (51)	5 (127)	1½ (38)	2 (51)
2172	9	10 by 4	1½ (38)	3 (76)	5½ (140)	1⅛ (29)	2 (51)
2174	5	10 by 6	2 (51)	3 (76)	6 (152)	1½ (38)	2 (51)
2175	2	10 by 8	2 (51)	3 (76)	6 (152)	2 (51)	2 (51)
2176	0	12 by 4	1 ½ (38)	3 ¼ (83)	6 ½ (165)	1 ⅛ (29)	2 ¾ (70)
2177	3	12 by 6	2 (51)	3 ¼ (83)	6 ½ (165)	1 ½ (38)	2 ¾ (70)
2178	9	12 by 8	2 ½ (64)	3 ¼ (83)	7 (178)	2 (51)	2 ¾ (70)
2179	6	12 by 10	3 (76)	3 ¼ (83)	7 ½ (191)	2 (51)	2 ¾ (70)
2180	8	15 by 4	1 ½ (38)	3 ¼ (83)	7 (178)	1 ⅛ (29)	2 ¾ (70)
2181	4	15 by 6	2 (51)	3 ¼ (83)	7 (178)	1 ½ (38)	2 ¾ (70)
2182	7	15 by 8	2 ½ (64)	3 ¼ (83)	7 (178)	2 (51)	2 ¾ (70)
2183	1	15 by 10	3 (76)	3 ¼ (83)	7 ½ (191)	2 (51)	2 ¾ (70)
2184	2	15 by 12	3 ¼ (83)	3 ¼ (83)	7 ¾ (197)	2 ¾ (70)	2 ¾ (70)

[A] For details of barrel, spigot, and gasket positioning lug, see Fig. 1 and Fig. 2.
[B] Dimension F is laying length.

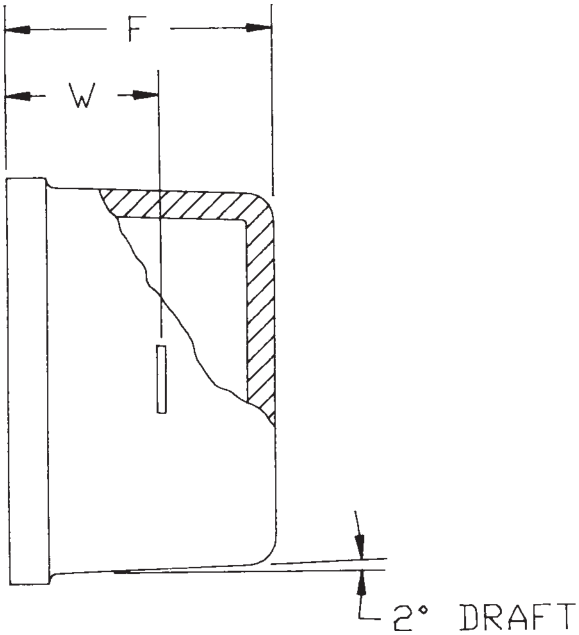
FIG. 42 Short, Increaser-Reducer (corresponds to Table 64 of CISPI Specification 301)



ASA Code Group 022		Size, in.	Dimensions, in. (mm)[A]			
Item No.	√		B	F	IPS Tapping[B]	W[C]
2236	2	1½ by 1¼	1½ (38)	2⅝ (67)	1¼ (32)	1⅛ (29)
2238	8	1½ by 1½	1½ (38)	2⅝ (67)	1½ (38)	1⅛ (29)
2240	4	2 by 1¼	1½ (38)	2 3/16 (56)	1¼ (32)	1⅛ (29)
2242	0	2 by 1½	1½ (38)	2 3/16 (56)	1½ (38)	1⅛ (29)
2244	6	2 by 2	1½ (38)	2⅝ (67)	2 (51)	1⅛ (29)
2246	1	3 by 1¼	1½ (38)	2 3/16 (56)	1¼ (32)	1⅛ (29)
2248	7	3 by 1½	1½ (38)	2 3/16 (56)	1½ (38)	1⅛ (29)
2250	3	3 by 2	1½ (38)	2 3/16 (56)	2 (51)	1⅛ (29)
2252	9	3 by 2½	1½ (38)	2 3/16 (56)	2½ (64)	1⅛ (29)
2254	5	4 by 3½	1½ (38)	2 3/16 (56)	3½ (89)	1⅛ (29)
2259	4	5 by 4	2 (51)	4½ (114)	4 (102)	1½ (38)
2262	8	6 by 5	2 (51)	4½ (114)	5 (127)	1½ (38)
2274	3	8 by 6	2 (51)	4½ (114)	6 (152)	2 (51)

[A] For details of barrel, spigot, and gasket positioning lug, see Fig. 1 and Fig. 2.
[B] For details of tapping bosses, see Fig. 63.
[C] Inclusion of spigot bead and positioning lug optional with manufacturer based on casting method used.

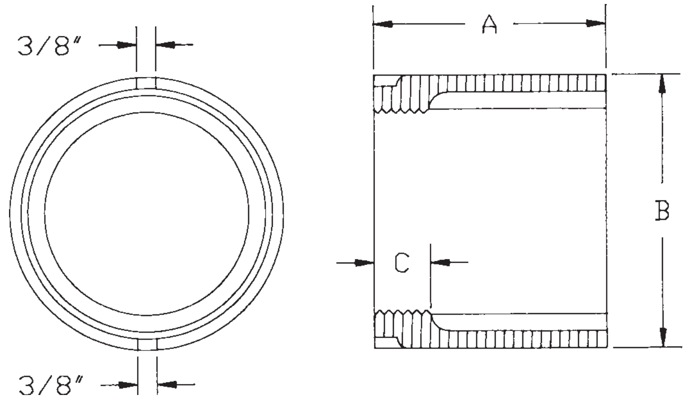
FIG. 43 Tapped Adapters (corresponds to Table 65 of CISPI Specification 301)



ASA Code Group 022		Size, in.	Dimensions, in. (mm)[A]	
Item No.	√		F[B] ±1⁄8 (3.2)	W[C]
2480	6	1½	1¾ (44)	1⅛ (29)
2482	2	2	1¾ (44)	1⅛ (29)
2484	8	3	1¾ (44)	1⅛ (29)
2486	3	4	1¾ (44)	1⅛ (29)
2488	9	5	1¾ (44)	1½ (38)
2490	5	6	1¾ (44)	1½ (38)
2492	1	8	2¼ (57)	2 (51)
2494	7	10	3 (76)	2 (51)
2495	7	12	3 ½ (89)	2 ¾ (70)
2496	7	15	3 ½ (89)	2 ¾ (70)

[A] For details of barrel and spigot, see Fig. 1 and Fig. 2.
[B] Dimension F is laying length.
[C] Inclusion of spigot bead and positioning lug optional with manufacturer based on casting method used.

FIG. 44 Blind Plug (corresponds to Table 66 of CISPI Specification 301)

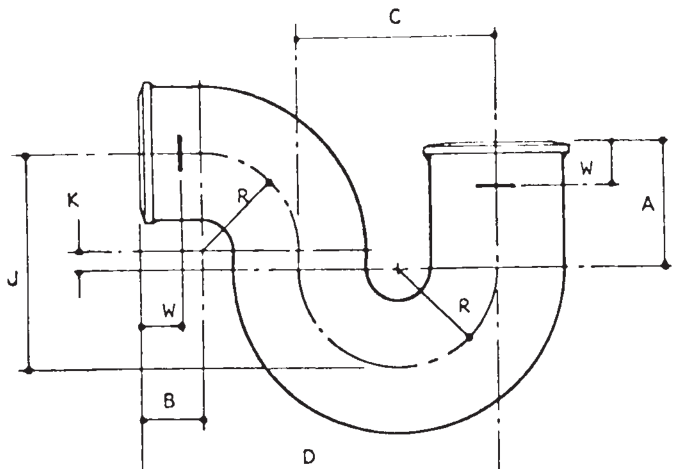


NOTE 1—Inclusion of spigot bead positioning lug optional with manufacturer based on casting method used.

ASA Code Group 022		Size, in.	Dimensions, in. (mm)[A]			
Item No.	√		A	B	C	IPS Tapping[B]
8564	1	3	2³⁄16 (56)	3⅜ (86)	¾ (19)	2½ (64)
8566	6	4	2³⁄16 (56)	4⁷⁄16 (113)	¾ (19)	3½ (89)
8568	2	5	4½ (114)	5⁵⁄16 (135)	1 (25)	4 (102)
8570	8	6	4½ (114)	6⁵⁄16 (160)	1 (25)	5 (127)
8572	4	8	...	8⅜ (213)	...	6 (152)

[A] For details of barrel and spigot, see Fig. 1 and Fig. 2.
[B] For details of tapping bosses, see Fig. 63.

FIG. 45 Iron Body Cleanout-Tapped (corresponds to Table 67 of CISPI Specification 301)

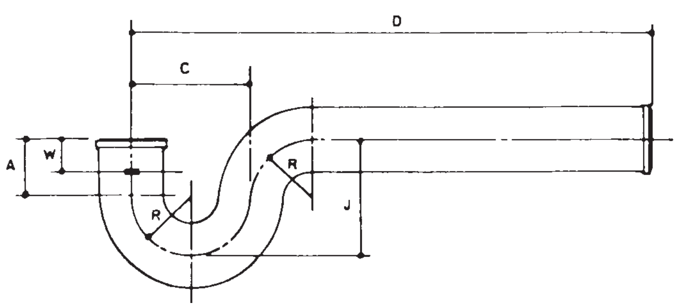


NOTE 1—A minimum water seal of 2 in. (51 mm) is provided for 2-in. size and smaller, 2½ in. (64 mm) for sizes 3 to 6 in. inclusive.

ASA Code Group 022		Size, in.	Dimensions, in. (mm)[A]							
Item No.	√		A	B	C	D[B]±⅛ (3.2)	J	K	R	W
2506	8	1½	2 (51)	1½ (38)	3½ (89)	6¾ (171)	3½ (89)	...	1¾ (44)	1⅛ (29)
2508	4	2	2 (51)	1½ (38)	4 (102)	7½ (191)	4 (102)	...	2 (51)	1⅛ (29)
2510	0	3	3¼ (83)	1½ (38)	5 (127)	9 (229)	5½ (140)	½ (13)	2½ (64)	1⅛ (29)
2512	6	4	4 (102)	1½ (38)	6 (152)	10½ (267)	6½ (165)	½ (13)	3 (76)	1⅛ (29)
2514	2	6	6 (152)	2 (51)	8 (203)	14 (356)	8½ (216)	½ (13)	4 (102)	1½ (38)

[A] For details of barrel, spigot, and gasket positioning lug, see Fig. 1 and Fig. 2.
[B] Dimension D is laying length.

FIG. 46 P Trap (corresponds to Table 68 of CISPI Specification 301)

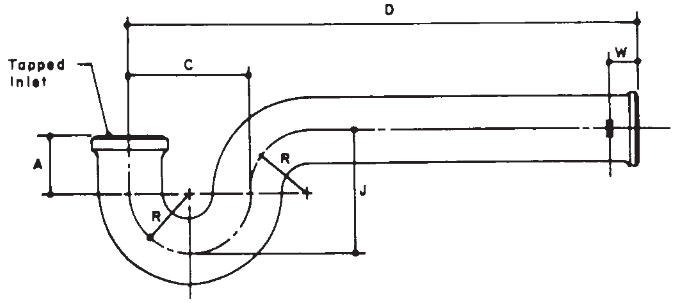


NOTE 1—A minimum water seal of 2 in. (51 mm) is provided for 2-in. size and smaller

ASA Code Group 022		Size, in.	Dimensions, in. (mm)[A]					
Item No.	√		A	C	D[B] ±⅛ (3.2)	J	R	W
2527	4	2 by 12	2 (51)	4 (102)	12 (305)	4 (102)	2 (51)	1⅛ (29)
2528	2	2 by 14	2 (51)	4 (102)	14 (356)	4 (102)	2 (51)	1⅛ (29)
2529	0	2 by 16	2 (51)	4 (102)	16 (406)	4 (102)	2 (51)	1⅛ (29)
2530	8	2 by 18	2 (51)	4 (102)	18 (457)	4 (102)	2 (51)	1⅛ (29)
2533	2	2 by 24	2 (51)	4 (102)	24 (610)	4 (102)	2 (51)	1⅛ (29)

[A] For details of barrel, spigot, and gasket positioning lug, see Fig. 1 and Fig. 2.
[B] Dimension D is laying length.

FIG. 47 Long P Trap (corresponds to Table 69 of CISPI Specification 301)

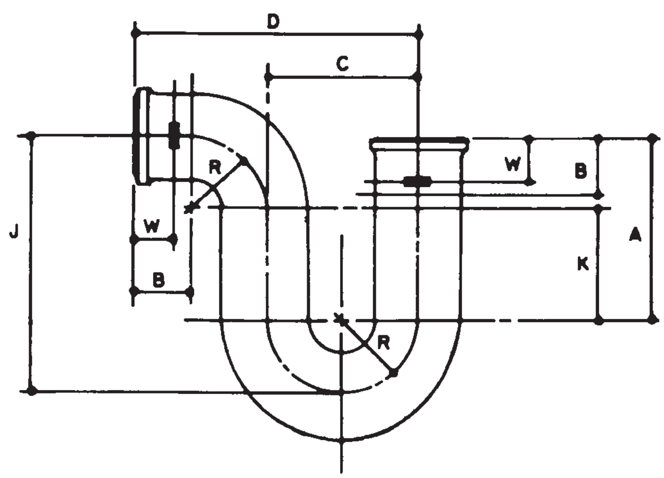


NOTE 1—A minimum water seal of 2 in. (51 mm) is provided for 2-in. size and smaller.

ASA Code Group 022		Size, in.	Dimensions, in. (mm)^A						
Item No.	√		A	C	D^B ±1⁄8 (3.2)	J	IPS Tapping^C	R	W
2535	7	2 by 1½ by 12	2 (51)	4 (102)	12 (305)	4 (102)	1½ (38)	2 (51)	1⅛ (29)
2536	5	2 by 2 by 12	2 (51)	4 (102)	12 (305)	4 (102)	2 (51)	2 (51)	1⅛ (29)
2538	1	2 by 1½ by 14	2 (51)	4 (102)	14 (356)	4 (102)	1½ (38)	2 (51)	1⅛ (29)
2539	9	2 by 2 by 14	2 (51)	4 (102)	14 (356)	4 (102)	2 (51)	2 (51)	1⅛ (29)
2541	5	2 by 1½ by 16	2 (51)	4 (102)	16 (406)	4 (102)	1½ (38)	2 (51)	1⅛ (29)
2542	3	2 by 2 by 16	2 (51)	4 (102)	16 (406)	4 (102)	2 (51)	2 (51)	1⅛ (29)
2544	9	2 by 1½ by 18	2 (51)	4 (102)	18 (457)	4 (102)	1½ (38)	2 (51)	1⅛ (29)
2546	4	2 by 2 by 18	2 (51)	4 (102)	18 (457)	4 (102)	2 (51)	2 (51)	1⅛ (29)

^{A} For details of barrel, spigot, and gasket positioning lug, see Fig. 1 and Fig. 2.
^{B} Dimension D is laying length.
^{C} For details of tapping bosses, see Fig. 63.

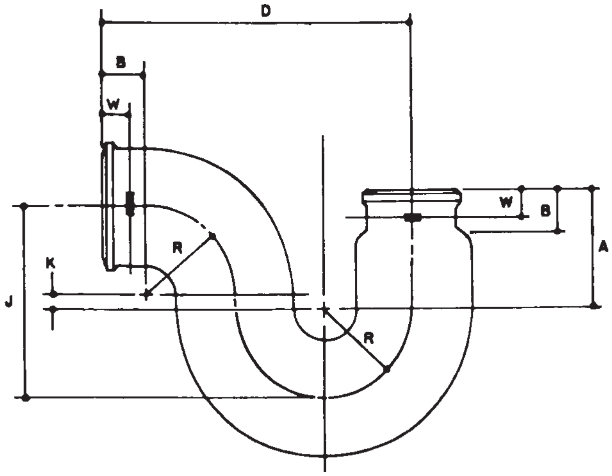
FIG. 48 Long P Trap, Tapped (corresponds to Table 70 of CISPI Specification 301)



ASA Code Group 022		Size, in.	Dimensions, in. (mm)^A								
Item No.	√		A	B	C	D^B±1⁄8 (3.2)	K	J	R	W	Seal
2564	7	2	5 (127)	1½ (38)	4 (102)	7½ (191)	3 (76)	7 (178)	2 (51)	1⅛ (29)	5 (127)
2566	2	3	4½ (114)	1½ (38)	5 (127)	9 (229)	2 (51)	7 (178)	2½ (64)	1⅛ (29)	4 (102)
2567	0	4	5 (127)	1½ (38)	6 (152)	10½ (267)	2 (51)	8 (203)	3 (76)	1⅛ (29)	4 (102)

^{A} For detail of barrel, spigot, and gasket positioning lug, see Fig. 1 and Fig. 2.
^{B} Dimension D is laying length.

FIG. 49 Deep Seal P Trap (corresponds to Table 71 of CISPI Specification 301)

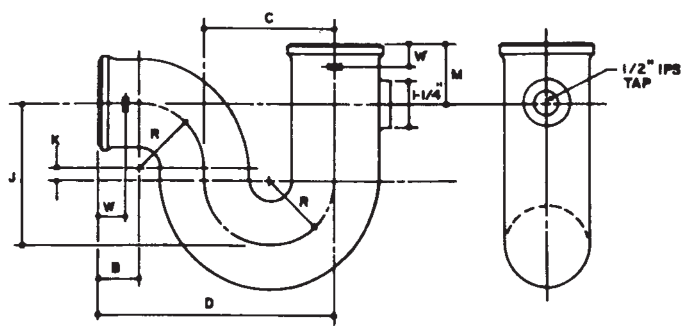


NOTE 1—A minimum water seal of 2½ in. (64 mm) is provided for sizes 3 and 4 in.

ASA Code Group 022		Size, in.	Dimensions, in. (mm)[A]							
Item No.	√		A	B	C	J	K	D[B] ±⅛ (3.2)	R	W
8548	4	3 by 2	3¼ (83)	1½ (38)	5 (127)	5½ (140)	½ (13)	9 (229)	2½ (64)	1⅛ (29)
8550	0	4 by 3	4 (102)	1½ (38)	6 (152)	6½ (165)	½ (13)	10½ (267)	3 (76)	1⅛ (29)

[A] For details of barrel, spigot, and gasket positioning lug, see Fig. 1 and Fig. 2.
[B] Dimension D is laying length.

FIG. 50 P Trap, Reducing (corresponds to Table 72 of CISPI Specification 301)

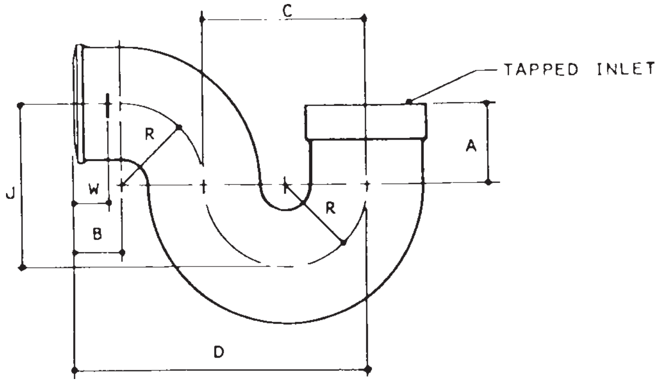


NOTE 1—A minimum water seal of 2 in. (51 mm) is provided for 2-in. size and smaller, 2½ in. (64 mm) for sizes 3 to 4 in. inclusive.

ASA Code Group 022		Size, in.	Dimensions, in. (mm)[A]									
Item No.	√		A	B	C	D[B]±⅛ (3.2)	J	K	R	W	M	IPS Tapping[C]
8530	2	2	2 (51)	1½ (38)	4 (102)	7½ (191)	4 (102)	0 (0)	2 (51)	1⅛ (29)	2 (51)	½ (13)
8532	8	3	3¼ (83)	1½ (38)	5 (127)	9 (229)	5½ (140)	½ (13)	2½ (64)	1⅛ (29)	2 (51)	½ (13)
8534	4	4	4 (102)	1½ (38)	6 (152)	10½ (267)	6½ (165)	½ (13)	3 (76)	1⅛ (29)	2 (51)	½ (13)

[A] For details of barrel, spigot, and gasket positioning lug, see Fig. 1 and Fig. 2.
[B] Dimension D is laying length.
[C] Minimum thickness of threaded section of primer tap is 0.21 in. (5.3 mm).

FIG. 51 P Trap with Primer (corresponds to Table 73 of CISPI Specification 301)

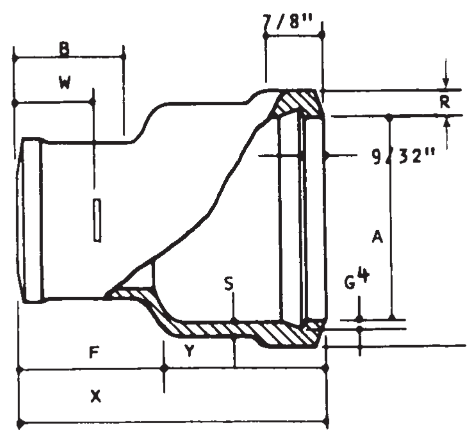


NOTE 1—A minimum water seal of 2 in. (51 mm) is provided for 2-in. size and smaller.

ASA Code Group 022		Size, in.	Dimensions, in. (mm)^A							
Item No.	√		A	B	C	D^B ±⅛ (3.2)	J	R	IPS Tapping^C	W
2580	3	1½ by 1¼	2 (51)	1½ (38)	3½ (89)	6¾ (171)	3½ (89)	1¾ (44)	1¼ (32)	1⅛ (29)
2582	9	1½ by 1½	2 (51)	1½ (38)	3½ (89)	6¾ (171)	3½ (89)	1¾ (44)	1½ (38)	1⅛ (29)
2584	5	2 by 1¼	2 (51)	1½ (38)	4 (102)	7½ (191)	4 (102)	2 (51)	1¼ (32)	1⅛ (29)
2586	0	2 by 1½	2 (51)	1½ (38)	4 (102)	7½ (191)	4 (102)	2 (51)	1½ (38)	1⅛ (29)
2588	6	2 by 2	2 (51)	1½ (38)	4 (102)	7½ (191)	4 (102)	2 (51)	2 (51)	1⅛ (29)

^{A} For details of barrel, spigot, and gasket positioning lug, see Fig. 1 and Fig. 2.
^{B} Dimension D is laying length.
^{C} For details of tapping bosses, see Fig. 63.

FIG. 52 P Trap With Tapped Inlet (corresponds to Table 74 of CISPI Specification 301)



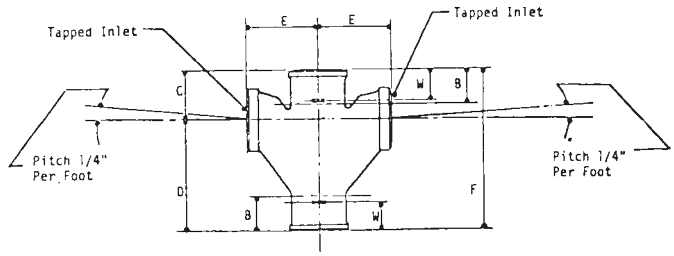
NOTE 1—Dimension G maximum 0.13, minimum 0.10.

ASA Code Group 022		Size, in.	Dimensions, in. (mm)^A					
			A					
Item No.	√		SV	XH	Tolerance	B	X ±⅛ (3.2)	R
2222	2	2	2.94 (74.7)	3.06 (77.7)	±0.06 (±1.52)	1½ (38)	4½ (114)	0.34 (8.64)
2224	8	3	3.94 (100.1)	4.19 (106.4)	−0.06 + 0.09 (−1.52 + 2.29)	1½ (38)	4¾ (121)	0.37 (9.40)
2226	3	4	4.94 (125.5)	5.19 (131.8)	−0.06 + 0.09 (−1.52 + 2.29)	1½ (38)	5¼ (133)	0.37 (9.40)

Size, in.	Dimensions, in. (mm)^A			
	S	W^B	F^C ±⅛ (3.2)	Y^D±1⁄16 (1.6)
2	0.13 (3.30)	1 ⅛ (29)	2 (51)	2 ½ (64)
3	0.16 (4.06)	1 ⅛ (29)	2 (51)	2 ¾ (70)
4	0.16 (4.06)	1 ⅛ (29)	2 ¼ (57)	3 (76)

^{A} For details of barrel and spigot, see Fig. 1 and Fig. 2.
^{B} Inclusion of spigot bead and positioning lug optional with manufacturer based on casting method used.
^{C} Dimension F is laying length.
^{D} Dimension Y is telescoping length.

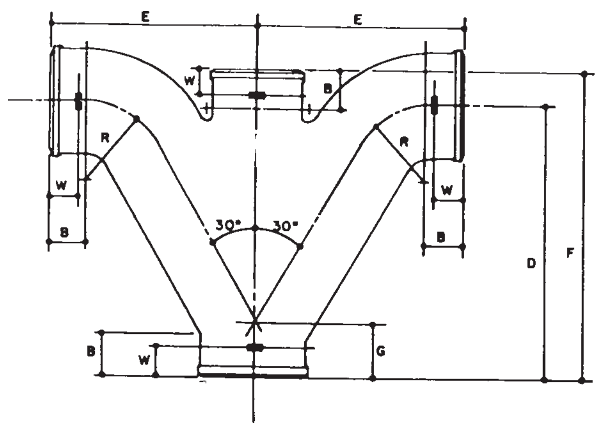
FIG. 53 Hub Adapter (corresponds to Table 75 of CISPI Specification 301)



ASA Code Group 022		Size, in.	Dimensions, in. (mm)[A]						
Item No.	√		B	C	D	F[B]±⅛ (3.2)	E	IPS Tapping[C]	W
8002	2	2 by 2 by 1½ by 1½	1½ (38)	2⅛ (54)	4⅞ (124)	7 (178)	3³⁄₁₆ (81)	1½ (38)	1⅛ (29)

[A] For details of barrel, spigot, and gasket positioning lug, see Fig. 1 and Fig. 2.
[B] Dimension F is laying length.
[C] For details of tapping bosses, see Fig. 63.

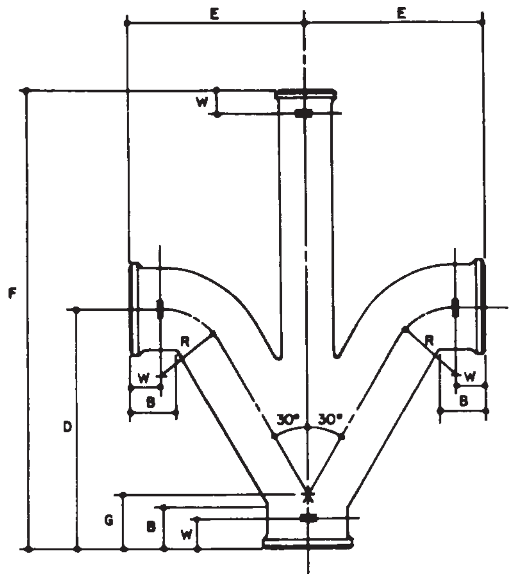
FIG. 54 Tapped Inlet, Double (corresponds to Table 76, Fig. 1A of CISPI Specification 301)



ASA Code Group 022		Size, in.	Dimensions, in. (mm)[A]						
Item No.	√		B	D	E[B] ±⅛ (3.2)	F[B]±⅛ (3.2)	G	R	W
8052	7	2	1½ (38)	6½ (165)	5 (127)	8 (203)	1¹³⁄₁₆ (46)	1⅜ (35)	1⅛ (29)
8054	3	3 by 2 by 3	1½ (38)	8⅞ (225)	6⁹⁄₁₆ (167)	9¼ (235)	2 (51)	2½ (64)	1⅛ (29)
8056	8	3	1½ (38)	8⅞ (225)	6⁹⁄₁₆ (167)	10⅛ (257)	2 (51)	2½ (64)	1⅛ (29)
8058	4	4 by 2 by 4	1½ (38)	10¼ (260)	7¾ (197)	11½ (292)	1¹⁵⁄₁₆ (49)	3 (76)	1⅛ (29)
8060	0	4 by 3 by 4	1½ (38)	10¼ (260)	7¾ (197)	11½ (292)	2¹⁄₁₆ (52)	3 (76)	1⅛ (29)
8062	6	4	1½ (38)	10¼ (260)	7¾ (197)	12 (305)	1¹⁵⁄₁₆ (49)	3 (76)	1⅛ (29)

[A] For details of barrel, spigot, and gasket positioning lug, see Fig. 1 and Fig. 2.
[B] Dimensions E and F are laying lengths.

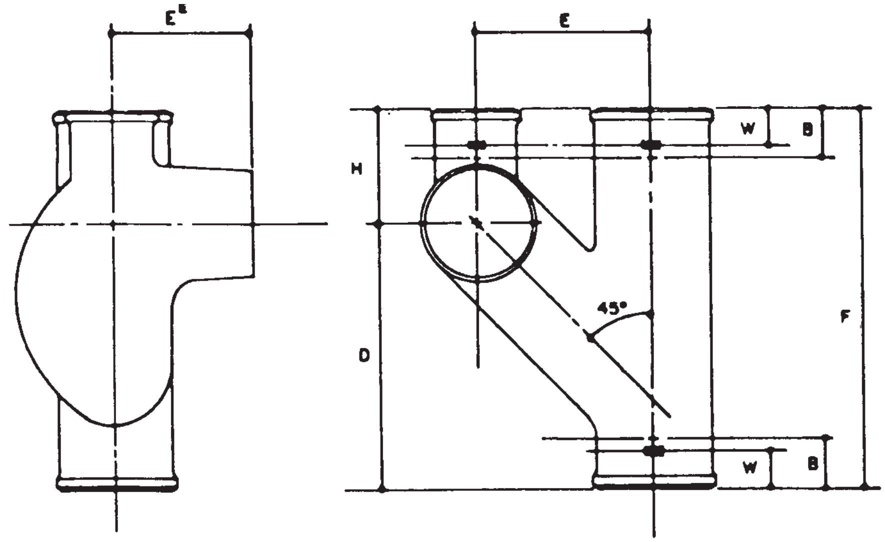
FIG. 55 Modified Combination Wye and ⅛ Bend, Double (corresponds to Table 80, Fig. 5 of CISPI Specification 301)



ASA Code Group 022		Size, in.	Dimensions, in. (mm)[A]						
Item No.	√		E[B] ±1⁄8 (3.2)	B	F[B]±1⁄8 (3.2)	G	D	R	W
8088	1	3 by 2 by 3	6 9⁄16 (167)	1½ (38)	16 7⁄8 (429)	2 (51)	8 7⁄8 (225)	2½ (64)	1 1⁄8 (29)
090	7	4 by 2 by 4	7 5⁄8 (194)	1½ (38)	18¾ (476)	1 15⁄16 (49)	10¼ (260)	3(76)	1 1⁄8 (29)

[A] For details of barrel, spigot, and gasket positioning lug, see Fig. 1 and Fig. 2.
[B] Dimensions E and F are laying lengths.

FIG. 56 Modified Combination Wye and 1⁄8 Bend, Double, Extended (corresponds to Table 80, Fig. 5, Extended, of CISPI Specification 301)

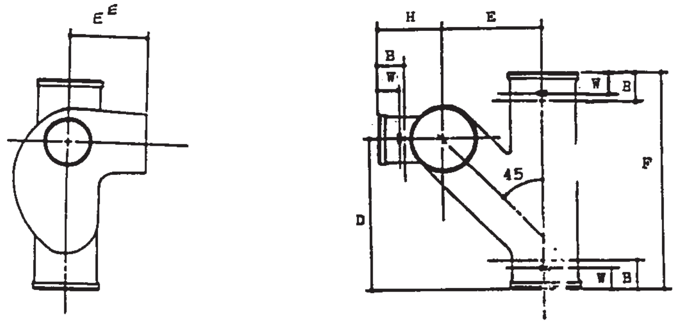


NOTE 1—On side opening, inclusion of spigot bead and positioning lug optional with manufacturer based on casting method used.\
NOTE 2—Positioning lug shall be omitted on 2 in. extensions.
NOTE 3—Double fittings shall have baffles.

ASA Code Group 022		Size, in.	Dimensions, in. (mm)^A								
Item No.	√		E	B	H	H Extended	D	E^E	F^B ±1⁄8 (3.2)	F Extended^B ±1⁄8 (3.2)	W
		Regular									
8100	4	3 by 2 RH	5 1⁄16 (129)	1 1⁄2 (38)	3 7⁄16 (87)	...	7 9⁄16 (192)	4 1⁄8 (105)	11 (279)	...	1 1⁄8 (29)
8102	0	3 by 2 LH	5 1⁄16 (129)	1 1⁄2 (38)	3 7⁄16 (87)	...	7 9⁄16 (192)	4 1⁄8 (105)	11 (279)	...	1 1⁄8 (29)
8108	7	3 by 2 DBL	5 1⁄16 (129)	1 1⁄2 (38)	3 7⁄16 (87)	...	7 9⁄16 (192)	4 1⁄8 (105)	11 (279)	...	1 1⁄8 (29)
8106	1	4 by 2 RH	6 1⁄2 (165)	1 1⁄2 (38)	4 (102)	...	9 (229)	4 1⁄2 (114)	13 (330)	...	1 1⁄8 (29)
8104	6	4 by 2 LH	6 1⁄2 (165)	1 1⁄2 (38)	4 (102)	...	9 (229)	4 1⁄2 (114)	13 (330)	...	1 1⁄8 (29)
		Extended									
8122	8	3 by 2 RH	5 1⁄16 (129)	1 1⁄2 (38)	...	9 7⁄16 (240)	7 9⁄16 (192)	4 1⁄8 (105)	...	17 (432)	1 1⁄8 (29)
8120	2	3 by 2 LH	5 1⁄16 (129)	1 1⁄2 (38)	...	9 7⁄16 (240)	7 9⁄16 (192)	4 1⁄8 (105)	...	17 (432)	1 1⁄8 (29)
8126	9	4 by 2 RH	6 1⁄2 (165)	1 1⁄2 (38)	...	8 (203)	9 (229)	4 1⁄2 (114)	...	17 (432)	1 1⁄8 (29)
8124	4	4 by 2 LH	6 1⁄2 (165)	1 1⁄2 (38)	...	8 (203)	9 (229)	4 1⁄2 (114)	...	17 (432)	1 1⁄8 (29)
8130	1	4 by 2 DBL	6 1⁄2 (165)	1 1⁄2 (38)	...	8 (203)	9 (229)	4 1⁄2 (114)	...	17 (432)	1 1⁄8 (29)

^A For details of barrel, spigot, and gasket positioning lug, see Fig. 1 and Fig. 2.
^B Dimensions F and F Extended are laying lengths.

FIG. 57 Regular or Extended Left or Right and Regular or Extended Double (corresponds to Table 82, Fig. 6 of CISPI Specification 301)

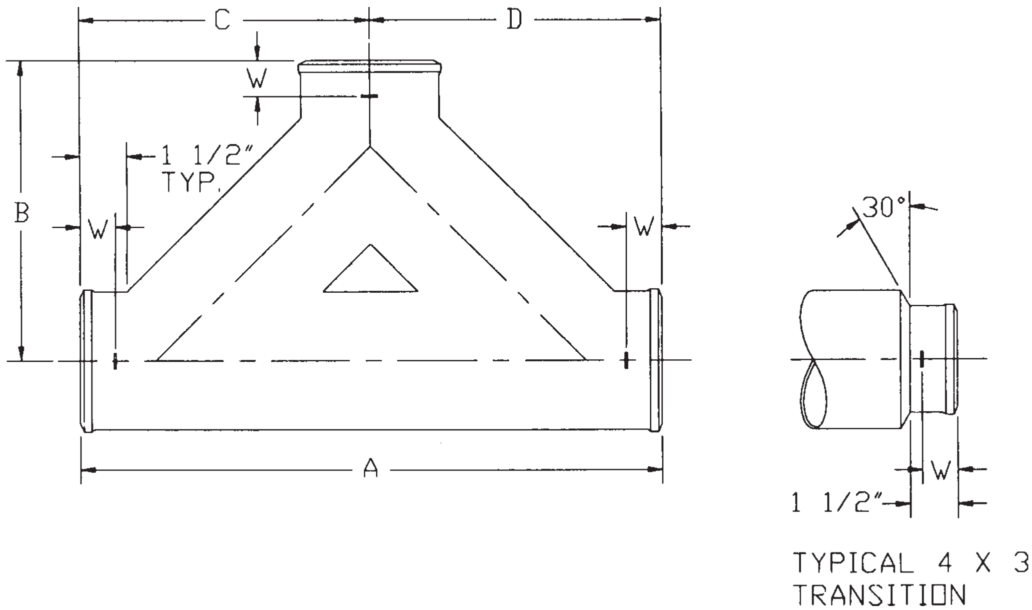


NOTE 1—On side opening, inclusion of spigot bead and positioning lug optional with manufacturer based on casting method used.
NOTE 2—Positioning lug to be omitted on 2 in. extensions.
NOTE 3—Double fittings shall have baffles.

ASA Code Group 022		Size, in.	Dimensions, in. (mm)[A]							
Item No.	√		E	B	H	H Extended	D	E[E]	F[B] ±1⁄8 (3.2)	W
		Regular								
8136	8	3 by 2 RH	5 1⁄16 (129)	1 1⁄2 (38)	3 7⁄16 (87)	...	7 9⁄16 (192)	4 1⁄8 (105)	11 (279)	1 1⁄8 (29)
8138	4	3 by 2 LH	5 1⁄16 (129)	1 1⁄2 (38)	3 7⁄16 (87)	...	7 9⁄16 (192)	4 1⁄8 (105)	11 (279)	1 1⁄8 (29)
8144	2	3 by 2 DBL	5 1⁄16 (129)	1 1⁄2 (38)	3 7⁄16 (87)	...	7 9⁄16 (192)	4 1⁄8 (105)	11 (279)	1 1⁄8 (29)
8140	0	4 by 2 RH	6 1⁄2 (165)	1 1⁄2 (38)	4 (102)	...	9 (229)	4 1⁄2 (114)	13 (330)	1 1⁄8 (29)
8142	6	4 by 2 LH	6 1⁄2 (165)	1 1⁄2 (38)	4 (102)	...	9 (229)	4 1⁄2 (114)	13 (330)	1 1⁄8 (29)
		Extended								
8156	6	3 by 2 RH	5 1⁄16 (129)	1 1⁄2 (38)	...	9 7⁄16 (240)	7 9⁄16 (192)	4 1⁄8 (105)	11 (279)	1 1⁄8 (29)
8158	2	3 by 2 LH	5 1⁄16 (129)	1 1⁄2 (38)	...	9 7⁄16 (240)	7 9⁄16 (192)	4 1⁄8 (105)	11 (279)	1 1⁄8 (29)
8160	8	4 by 2 RH	6 1⁄2 (165)	1 1⁄2 (38)	...	8 (203)	9 (229)	4 1⁄2 (114)	13 (330)	1 1⁄8 (29)
8162	4	4 by 2 LH	6 1⁄2 (165)	1 1⁄2 (38)	...	8 (203)	9 (229)	4 1⁄2 (114)	13 (330)	1 1⁄8 (29)
8166	5	4 by 2 DBL	6 1⁄2 (165)	1 1⁄2 (38)	...	8 (203)	9 (229)	4 1⁄2 (114)	13 (330)	1 1⁄8 (29)

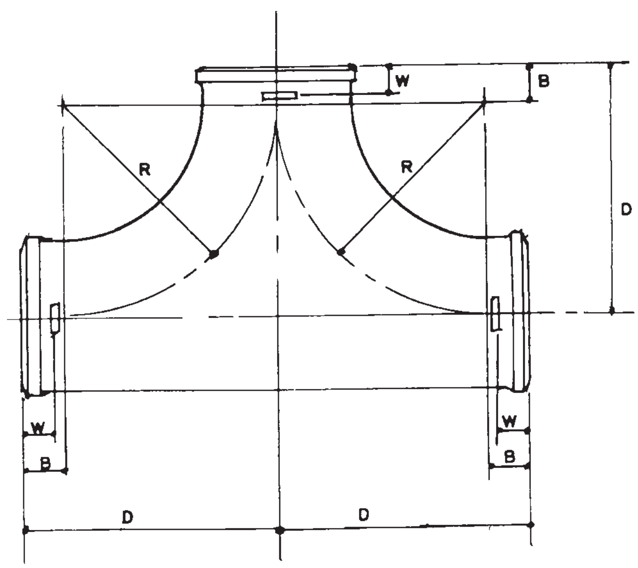
[A] For details of barrel, spigot, and gasket positioning lug, see Fig. 1 and Fig. 2.
[B] Dimensions F and F Extended are laying lengths.

FIG. 58 Regular or Extended Left or Right and Regular or Extended Double (corresponds to Table 83, Fig. 8 of CISPI Specification 301)



ASA Code Group 022		Size, in.	Dimensions, in. (mm)				
Item No.	√		A	B	C	D	W
8442	0	3 by 3 by 4	15 (381)	9 (229)	7½ (191)	7½ (91)	1⅛ (29)
8444	6	4 by 3 by 4	19½ (495)	9½ (241)	9 3/16 (233)	10¼ (260)	1⅛ (29)
8446	1	4 by 4 by 4	18⅜ (467)	9½ (241)	9 3/16 (233)	9 3/16 (233)	1⅛ (29)

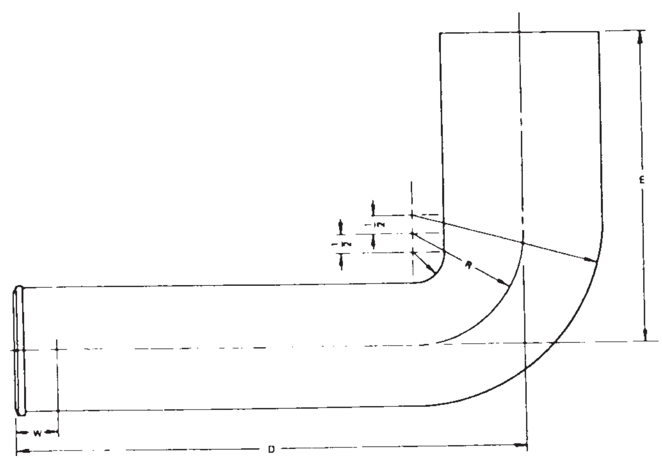
FIG. 59 Two-Way Cleanout (corresponds to Table 87 of CISPI Specification 301)



ASA Code Group 022		Size, in.	Dimensions, in. (mm)^A			
Item No.	√		D^B ±⅛ (3.2)	R	B	W
2990	2	4	7½ (191)	6 (152)	1½ (38)	1⅛ (29)

^{A} For details of barrel, spigot, and gasket positioning lug, see Fig. 1 and Fig. 2.
^{B} Dimension D is laying length.

FIG. 60 Twin Cleanout (corresponds to Table 88 of CISPI Specification 301)



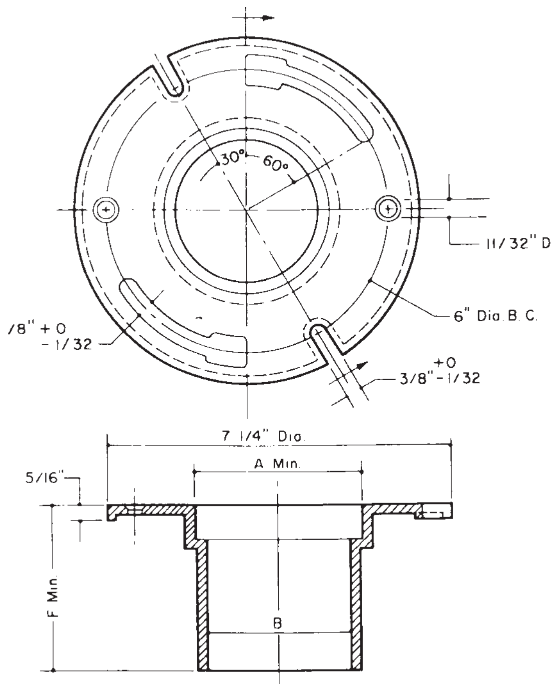
NOTE 1—Inclusion of spigot bead and positioning lug optional with manufacturer, based on casting method used.

NOTE 2—Inclusion of breaking rings on inlet end optional.

Size, in.	Dimensions, in. (mm)^A			
	D ±⅛ (3.2)	E ±⅛ (32)	R	W
3 by 4	Various	Various	3 (76)	1⅛ (29)
4 by 4	Various	Various	3 (76)	1⅛ (29)

^{A} For details of barrel, spigot, and gasket positioning lug, see Fig. 1 and Fig. 2.

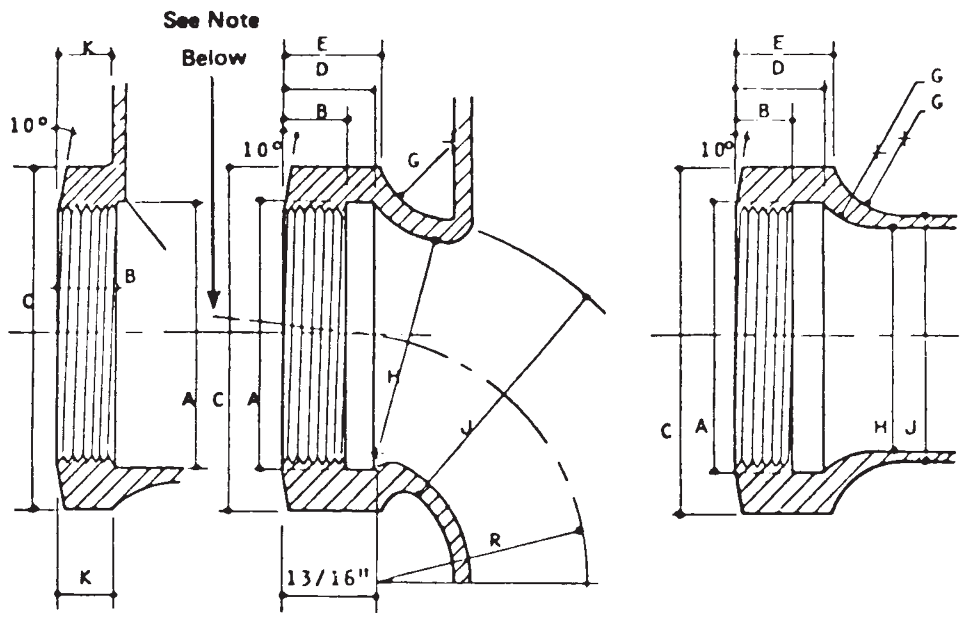
FIG. 61 Closet Bend (corresponds to Table 89 of CISPI Specification 301)



ASA Code Group 022		Size, in.	Dimensions, in. (mm)		
Item No.	√		A, Minimum	B	F, Minimum
2966	4	4 by 3 by 3½	4 (102)	3 (76)	3½ (89)
2968	0	4 by 3 by 5½	4 (102)	3 (76)	5½ (140)
2970	6	4 by 4 by 4	4 (102)	4 (102)	4 (102)

FIG. 62 Closet Flange Riser (corresponds to Table 90 of CISPI Specification 301)

DETAILS OF TAPPING BOSSES



For Fittings where Casting Opening is Larger than Tapped Opening

For Fittings Tapped on Sanitary Branch

For Fittings where Casting Opening is Smaller than Tapped Opening

NOTE 1—Horizontal inlet waste bosses to be tapped at an angle of ¼ in. (6 mm) per foot to provide flow.

Size, in.	Dimensions, in.[A]									
	A	B	C	D	E	G	H	J	K	R
1¼	1 15/16	7/16	2 11/16	¾	7/8	½	1½	1 13/16	½	1¾
1½	1 15/16	7/16	2 11/16	¾	7/8	½	1½	1 13/16	½	1¾
2	2 7/16	7/16	3¼	¾	15/16	5/8	2	2 5/16	½	2¼
2½	3	5/8	3 15/16	1	1 1/8	¾	2½	2 13/16	5/8	2¾
3	3 9/16	¾	4 5/8	1 3/16	1 5/16	1	3	3 5/16	¾	3
3½	4 1/16	¾	5 1/8	1¼	1 3/8	1	3½	3 13/16	¾	3
4	4 9/16	13/16	5¾	1¼	1 7/16	1 1/8	4	4½	1 3/16	3½
5	5 5/8	15/16	7 1/16						1 3/8	
6	6 11/16	1	8 5/16						1 7/16	
8	8 7/8	1	10¼						1 13/16	
10	11	1¼	12						1 15/16	

[A] 1 in. = 25.4 mm.

FIG. 63 Dimensions for Tapping Bosses (corresponds to Table 91 of CISPI Specification 301)

SUPPLEMENTARY REQUIREMENTS

The following supplementary requirements shall be applied only when specified by the purchaser. Details of the supplementary requirements shall be agreed upon by the manufacturer and the purchaser. The specified tests shall be performed by the manufacturer prior to shipment of the castings.

S1. Leak Tests on Pipe

S1.1 Sample lengths of pipe shall be checked for leaks by subjecting them to an internal hydrostatic pressure of 20 psi (138 kPa).

S1.2 Samples shall be taken at substantially regular intervals in the course of production so as to be representative of the material delivered and shall consist of at least 20 % of the lengths ordered in each size. For every sample that leaks, four or more additional samples shall be taken. Each additional sample shall be representative of the same material as that of the defective sample.

S1.3 Pipes that leak shall be rejected.

APPENDIXES

(Nonmandatory Information)

X1. ELECTRONIC DATA PROCESSING (EDP) NUMBERS

X1.1 Please take note that electronic data processing (EDP) numbers have been added. The EDP numbers indicated represent a new Uniform Industry Code adopted by the Cast Iron Soil Pipe Institute (CISPI) and the American Supply Association (ASA). A group designation prefix (022) is assigned to hubless products, followed by the four digit identification assigned to individual items and a check digit. This system has been instituted to facilitate EDP control through distribution channels, and should now be used universally in ordering and specifying product items.

X2. PROCEDURES FOR SOIL SURVEY TESTS AND OBSERVATIONS AND THEIR INTERPRETATION TO DETERMINE WHETHER CAST IRON PIPE FOR WASTE WATER OR OTHER LIQUIDS REQUIRES POLYETHYLENE ENCASEMENT

X2.1 Scope

X2.1.1 In the appraisal of soil and other conditions that affect the corrosion rate of cast iron pipe, a minimum number of factors must be considered. They are outlined in the following sections. A method of evaluating and interpreting each factor and a method of weighting each factor to determine whether polyethylene encasement should be used are subsequently described.

X2.2 Earth Resistivity

X2.2.1 There are three methods for determining earth resistivity: four-pin, single-probe, and soil-box. In the field, a four-pin determination should be made with pins spaced at approximate pipe depth. This method yields an average of resistivity from the surface to a depth equal to pin spacing. However, results are sometimes difficult to interpret where dry top soil is underlaid with wetter soils and where soil types vary with depth. The Wenner configuration is used in conjunction with a resistivity meter. For all-around use, a unit with a capacity of up to 10^4 ohms is suggested because of its versatility in permitting both field and laboratory testing in most soils.

X2.2.2 Because of the aforementioned difficulty in interpretation, the same unit may be used with a single probe that yields resistivity at the point of the probe. A boring is made into the subsoil so that the probe may be pushed into the soil at the desired depth.

X2.2.3 Inasmuch as the soil may not be typically wet, a sample should be removed for resistivity determination, which may be accomplished with any one of several laboratory units that permits the introduction of water to saturation, thus stimulating saturated field conditions. Each of these units is used in conjunction with a soil resistivity meter.

X2.2.4 Intepretation of resistivity results is extremely important. To base an opinion on a four-pin reading with dry top soil averaged with wetter subsoil would probably result in an inaccurate premise. Only by reading the resistivity in soil at pipe depth can an accurate interpretation be made. Also, every effort should be made to determine the local situation concerning ground-water table, presence of shallow ground water, and approximate percentage of time the soil is likely to be water-saturated.

X2.2.5 With cast iron pipe, corrosion protection provided by products of corrosion is enhanced if there are dry periods during each year. Such periods seem to permit hardening or toughening of the corrosion scale or products, which then become impervious and serve as better insulators.

X2.2.6 In making field determinations of resistivity, temperature is important. The result obtained increases as temperature decreases. As the water in the soil approaches freezing, resistivity increases greatly, and, therefore, is not reliable. Field determinations under frozen soil conditions should be avoided. Reliable results under such conditions can be obtained only by collection of suitable subsoil samples for analysis under laboratory conditions at suitable temperature.

X2.2.7 *Interpretation of Resistivity*—Because of the wide variance in results obtained under the methods described, it is difficult specifically to interpret any single reading without knowing which method was used. It is proposed that interpretation be based on the lowest reading obtained with consideration being given to other conditions, such as normal moisture content of the soil in question. Because of the lack of exact correlation between experiences and resistivity, it is necessary to assign ranges of resistivity rather specific numbers. In Table X2.1, points are assigned to various ranges of resistivity. These points, when considered along with points assigned to other soil characteristics, are meaningful.

X2.3 pH

X2.3.1 In the pH range from 0.0 to 4.0, the soil serves well as an electrolyte, and total acidity is important. In the pH range from 6.5 to 7.5, soil conditions are optimum for sulfate reduction. In the pH range from 8.5 to 14.0, soils are generally quite high in dissolved salts, yielding a low soil resistivity.

X2.3.2 In testing pH, glass and reference electrodes are pushed into the soil sample and a direct reading is made following suitable temperature setting on the instrument. Normal procedures are followed for standardization.

X2.4 Oxidation-Reduction (Redox) Potential

X2.4.1 The oxidation-reduction (redox) potential of a soil is significant because the most common sulfate-reducing bacteria can live only under anaerobic conditions. A redox potential greater than + 100 mV shows the soil to be sufficiently aerated

TABLE X2.1 Soil-Test Evaluation[A]

Soil Characteristics	Points
Resistivity, ohm-cm (based on single probe at pipe depth or water-saturated soil-box):	
<700	10
700–1000	8
1000–1200	5
1200–1500	2
1500–2000	1
>2000	0
pH:	
0–2	5
2–4	3
4–6.5	0
6.5–7.5	0[B]
7.5–8.5	0
>8.5	3
Redox potential:	
> + 100 mV	0
+ 50 tp + 100 mV	3.5
0 to + 50 mV	4
Negative	5
Sulfides:	
Positive	3.5
Trace	2
Negative	0
Moisture:	
Poor drainage, continuously wet	2
Fair drainage, generally moist	1
Good drainage, generally dry	0

[A] Ten points = corrosive to cast iron pipe; protection indicated.
[B] If sulfides are present and low or negative redox potential results are obtained, three points shall be given for this range.

so that it will not support sulfate reducers. Potentials of 0 to + 100 mV may or may not indicate anaerobic conditions under which sulfate reducers thrive. This test also is accomplished using a portable pH meter, with platinum and reference electrodes inserted into the soil sample, which permits a reading of potential between the two electrodes. It should be noted that soil samples removed from a boring or excavation can undergo a change in redox potential on exposure to air. Such samples should be tested immediately on removal from the excavation. Experience has shown that heavy clays, muck, and organic soils are often anaerobic, and these soils should be regarded as potentially corrosive.

X2.5 Sulfides

X2.5.1 The sulfide determination is recommended because of its field expediency. A positive sulfide reaction reveals a potential problem due to sulfate-reducing bacteria. The sodium azide-iodine qualitative test is used. In this determination, a solution of 3 % sodium azide in a 0.1 *N* iodine solution is introduced into a test tube containing a sample of the soil in question. Sulfides catalyze the reaction between sodium azide and iodine, with the resulting evolution of nitrogen. If strong bubbling or foaming results, sulfides are present, and the presence of sulfate-reducing bacteria is indicated. If very slight bubbling is noted, sulfides are probably present in small concentration, and the result is noted as a trace.

X2.6 Moisture Content

X2.6.1 Since prevailing moisture content is extremely important to all soil corrosion, every effort must be made to determine this condition. It is not proposed, however, to determine specific moisture content of a soil sample, because of the probability that content varies throughout the year, but to question local authorities who are able to observe the conditions many times during the year. (Although mentioned in X2.2, this variability factor is being reiterated to emphasize the importance of notation.)

X2.7 Soil Description

X2.7.1 In each investigation, soil types should be described completely. The description shoud include color and physical characteristics, such as particle size, plasticity, friability, and uniformity. Observation and testing will reveal whether the soil is high in organic content; this should be noted. Experience has shown that in a given area, corrosivity may often be reflected in certain types and colors of soil. This information is valuable for future investigations or for determining the most likely soils to suspect. Soil uniformity is important because of the possible development of local corrosion cells due to the difference in potential between unlike soil types, both of which are in contact with the pipe. The same is true for uniformity of aeration. If one segment of soil contains more oxygen than a neighboring segment, a corrosion cell can develop from the difference in potential. This cell is known as a differential aeration cell.

X2.7.2 There are several basic types of soil that should be noted: sand, loam, silt, clay, muck. Unusual soils, such as peat or soils high in foreign material, should also be noted and described.

X2.8 Potential Stray Direct Current

X2.8.1 Any soil survey should include consideration of possible stray direct current with which the cast iron pipe installation might interfere. The widespread use of rectifiers and ground beds for cathodic protection of underground structures has resulted in a considerable threat from this source. Proximity of such cathodic protection systems should be noted. Among other potential sources of stray direct current are electric railways, industrial equipment, including welding, and mine transportation equipment.

X2.9 Experience With Existing Installations

X2.9.1 The best information on corrosivity of soil with respect to cast iron pipe is the result of experience with these materials in the area in question. Every effort should be made to acquire such data by questioning local officials and, if possible, by actual observation of existing installations.

X2.10 Soil-Test Evaluation

X2.10.1 Using the soil-test procedures described herein, the following tests are considered in evaluating corrosivity of the soil: resistivity, pH, redox potential, sulfides, and moisture. For each of these tests, results are categorized according to their contribution to corrosivity. Points are assigned based on experience with gray and ductile cast iron pipe. When results of these five test observations are available, the assigned points are totaled. If the sum is equal to ten or more, the soil is corrosive to cast iron pipe and protection against exterior corrosion should be provided. This system is limited to soil corrosion and does not include consideration of stray direct current. Table X2.1 lists points assigned to the various test results.

X2.11 General

X2.11.1 These notes deal only with cast iron pipe, the soil environment in which they will serve, and methods of determining the need for polyethylene encasement. When it is determined that a soil environment is corrosive to cast iron the practice outlined in Appendix X3 should be used.

X3. POLYETHYLENE ENCASEMENT FOR CAST IRON PIPE FOR WASTE WATER

X3.1 Scope

X3.1.1 This practice covers materials and installation procedures for polyethylene encasement to be applied to underground installations of cast iron pipe. It is also used for polyethylene encasement of fittings, and other appurtenances to cast iron pipe systems.

X3.1.2 *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.*

X3.2 Referenced Documents

X3.2.1 *ASTM Standard*:

D 1248 Specification for Polyethylene Plastics Molding and Extrusion Materials[10]

X3.3 Terminology

X3.3.1 *Definitions*:

X3.3.1.1 *polyethylene encasement, n*—polyethylene material, in tube or sheet form, that is used to encase cast iron pipe.

X3.3.1.2 *securing overlap, n*—any one of various methods of holding polyethylene encasement in place at the point of overlap until backfilling operations are completed. This may be accomplished with adhesive tape, plastic string, or other suitable material.

X3.4 Requirements

X3.4.1 *Materials*:

X3.4.1.1 *Low-Density Polyethylene Film*—Low-density polyethylene film shall be manufactured of virgin polyethylene material conforming to the requirements of Table 2 in Specification D 1248.

(*1*) *Thickness*—Low-density Polyethylene film shall have a minimum nominal thickness of 0.008 in. (0.20 mm). The minus tolerance on thickness shall not exceed 10 % of the nominal thickness.

X3.4.1.2 *High-Density Cross-Laminated Polyethylene Film*—High-density cross-laminated polyethylene film shall be manufactured of virgin polyethylene material conforming to the requirements of Specification D 1248 as shown in Table X3.2.

(*1*) *Thickness*—High-density cross-laminated polyethylene film shall have a minimum nominal thickness of 0.004 in. (0.10 mm). The minus tolerance on thickness shall not exceed 10 % of the nominal thickness.

X3.4.2 *Tube Size*—The tube size for each pipe diameter shall be as listed in Table X2.2.

TABLE X3.1 Polyethylene Characteristics

Raw Material Used to Manufacture Polyethylene Encasement Material	
Type, class, grade, other characteristics in accordance with the latest revision of Specification D 1248:	
Type	I
Class	A—Natural color or C—Black
Grade	E1
Flow rate, g/10 min	0.4 max
Dielectric strength, volume resistivity	10^{15}·cm^3, min
Polyethylene Encasement Material	
Tensile strength	1200 psi (8 MPa), min
Elongation	300 %, min
Dielectric strength	800 V/mil (31.5 V/um) thickness, min

TABLE X3.2 Polyethylene Tube Sizes

Nominal Pipe Diameter, in.	Recommended Polyethylene Flat Tube Width, in. (cm)[A]
1½ , 2, 3	14 (35)
4	16 (41)
6	20 (51)
8	24 (61)
10	27 (69)
12	30 (76)
14	34 (86)
15	37 (94)

[A] For flat sheet polyethylene, see X3.5.2.3.

X3.5 Installation

X3.5.1 *General*:

X3.5.1.1 The polyethylene encasement shall prevent contact between the pipe and the surrounding backfill and bedding material but is not intended to be a completely airtight or watertight enclosure. All lumps of clay, mud, cinders, etc., that are on the pipe surface shall be removed prior to installation of the polyethylene encasement. During installation, care shall be exercised to prevent soil or embedment material from becoming entrapped between the pipe and the polyethylene.

X3.5.1.2 The polyethylene film shall be fitted to the contour of the pipe to effect a snug, but not tight, encasement with minimum space between the polyethylene and the pipe. Sufficient slack shall be provided in contouring to prevent stretching the polyethylene, bridging irregular surfaces such as hub-spigot interfaces, coupled joints, or fittings, and to prevent damage to the polyethylene due to backfilling operations. Overlaps and ends shall be secured by the use of adhesive tape,

[10] *Annual Book of ASTM Standards*, Vol 08.01.

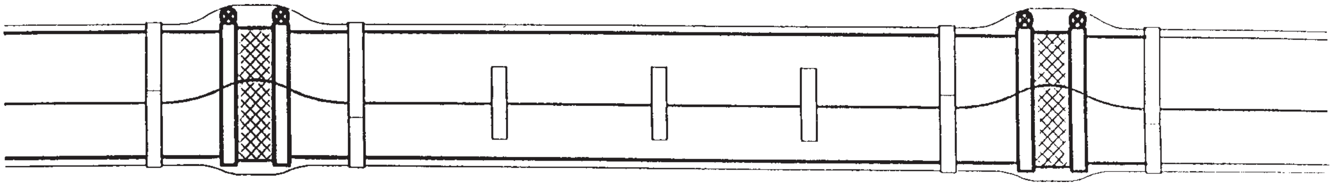


FIG. X3.1 Method A Hubless Pipe

string, plastic tie straps, or any other material capable of holding the polyethylene encasement in place until backfilling operations are completed.

X3.5.1.3 For installations below the water table or in areas subject to tidal actions, or both, it is recommended that tube-form polyethylene be used with both ends sealed as thoroughly as possible with adhesive tape or plastic tie straps at the joint overlap. It is also recommended that circumferential wraps of tape or plastic tie straps be placed at 2-ft (0.6-m) intervals along the barrel of the pipe to help minimize the space between the polyethylene and the pipe.

X3.5.2 *Pipe*—This practice includes three different methods for the installation of polyethylene encasement. Method A and B are for use with polyethylene tubes, and Method C is for use with polyethylene sheets.

X3.5.2.1 *Method A* (see Fig. X3.1):

(1) Cut the polyethylene tube to a length approximately 2 ft (0.6 m) longer than the length of the pipe section. Slip the tube around the pipe, centering it to provide a 1-ft (0.3-m) overlap on each adjacent pipe section, and bunching it accordion fashion lengthwise until it clears the pipe ends.

(2) Lower the pipe into the trench and make up the pipe joint with the preceding section of pipe. A shallow bell hole must be made at joints to facilitate installation of the polyethylene tube.

(3) After assembling the pipe joint, make the overlap of the polyethylene tube. Pull the bunched polyethylene from the preceding length of pipe, slip it over the end of the new length of pipe, and secure in place. Then slip the end of the polyethylene from the new pipe section over the end of the first wrap until it overlaps the joint at the end of the preceding length of pipe. Secure the overlap in place. Take up the slack width at the top of the pipe as shown in Fig. X3.2, to make a snug, but not tight, fit along the barrel of the pipe, securing the fold at quarter points.

(4) Repair any rips, punctures, or other damage to the polyethylene with adhesive tape or with a short length of polyethylene tube cut open, wrapped around the pipe, and secured in place. Proceed with installations of the next section of pipe in the same manner.

X3.5.2.2 Cut the polyethylene tube to a length approximately 1 ft (0.3 m) shorter than the length of the pipe section. Slip the tube around the pipe, centering it to provide 6 in. (150 mm) of bare pipe at each end. Make the polyethylene snug, but not tight, as shown in Fig. X3.2; secure ends as described in X3.5.2.1.

X3.5.2.3 Before making up a joint, slip a 3-ft (0.9-m) length of polyethylene tube over the end of the preceding pipe section, bunching it accordion fashion lengthwise. After completing the

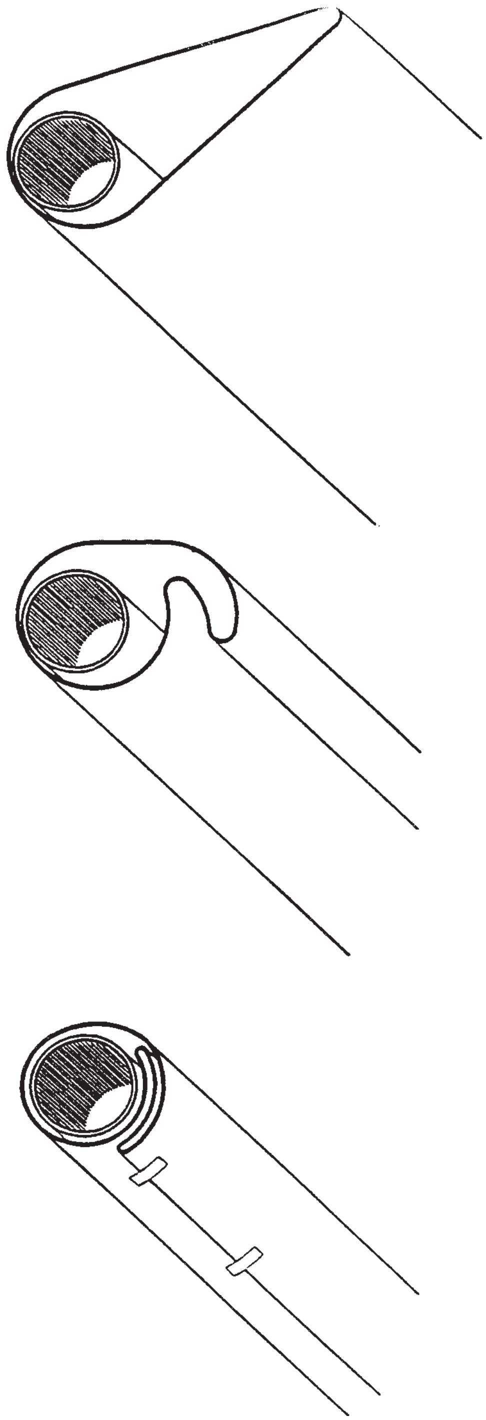


FIG. X3.2 Method A Slack Reduction Procedure joint, pull the 3-ft length of polyethylene previously installed on each adjacent section of pipe by at least 1 ft (0.3 m); make snug and secure each end as described in X3.5.2.1.

X3.5.2.4 Repair any rips, punctures, or other damage to the polyethylene as described in X3.5.2.1. Proceed with installation of the next section of pipe in the same manner.

X3.5.3 Flat sheet polyethylene shall have a minimum width twice the flat tube width shown in Table X3.3.

X3.5.3.1 Cut the polyethylene sheet to a length approximately 2 ft (0.6 m) longer than the length of pipe section. Center the cut length to provide a 1-ft (0.3-m) overlap on each adjacent pipe section, bunching it until it clears the pipe ends. Wrap the polyethylene around the pipe so that it overlaps circumferentially over the top quadrant of the pipe. Secure the cut edge of polyethylene sheet at approximately 3-ft (0.9-m) intervals along the pipe length.

X3.5.3.2 Lower the wrapped pipe into the trench and make up the pipe joint with the preceding section of pipe. A shallow hub hole must be made at joints to facilitate installation of the polyethylene. After completing the joint, make the overlap as described in X3.5.2.1.

X3.5.3.3 Repair any rips, punctures, or other damage to the polyethylene as described in X3.5.2.1. Proceed with installation of the next section of pipe in the same manner.

X3.5.4 *Pipe-Shaped Appurtenances*—Bends, reducers, offsets, and other pipe-shaped appurtenances shall be covered with polyethylene in the same manner as the pipe.

X3.5.5 *Odd-Shaped Appurtenances*—Wrap tees, crosses, and other odd-shaped pieces that cannot practically be wrapped in a tube, with a flat sheet or split length of polyethylene tube. Pass the sheet under the appurtenance and bring up around the body. Make seams by bringing the edges together, folding over twice, and taping down (see Fig. X3.3). Handle slack width and overlaps at joints as described in X3.5.2.1. Tape polyethylene securely in place.

X3.5.6 *Repairs*—Repair any cuts, tears, punctures, or damage to polyethylene with adhesive tape or with a short length of polyethylene tube cut open, wrapped around the pipe covering the damaged area, and secured in place.

TABLE X3.3 High-Density Cross-Laminated Polyethylene Characteristics

Raw Material Used to Manufacture Polyethylene Encasement Material	
Type, class, grade, other characteristics in accordance with the latest revision of Specification D 1248:	
Type	111
Class	A—Natural color, B—Colors, or C—Black
Grade	P33
Flow rate, g/10 min	0.4 to 0.5 g/10 min
Dielectric strength, volume resistivity	10^{15} ohm-cm·min
High-Density Cross-Laminated Polyethylene Encasement Material	
Tensile strength	5000 psi (34.6 MPa), min
Elongation	100 %, min
Dielectric strength	800 V/mil (31.5 V/um) thickness, min

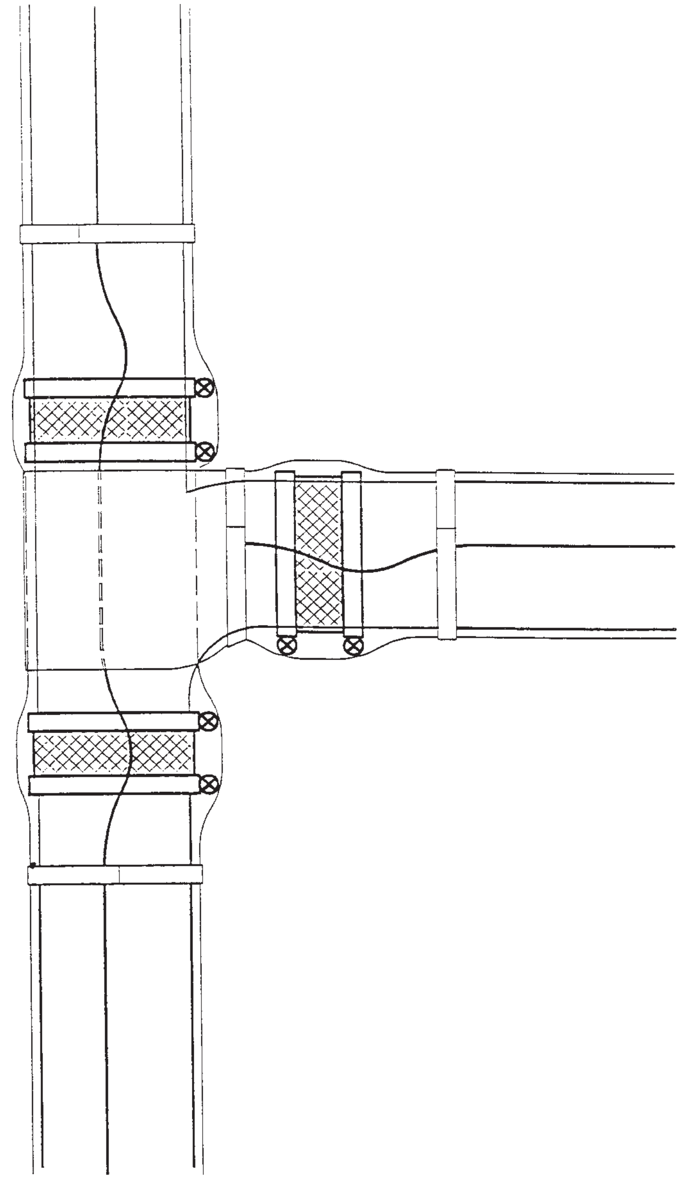


FIG. X3.3 Installation on Odd-Shaped Appurtenances Hubless Pipe

X3.5.7 *Junctions Between Wrapped and Unwrapped Pipe*—Where polyethylene-wrapped pipe joins a pipe that is not wrapped, extend the polyethylene tube to cover the unwrapped pipe a distance of at least 3 ft (0.9 m). Secure the end with circumferential turns of tape.

X3.5.8 *Backfill for Polyethylene-Wrapped Pipe*—Backfill material shall be the same as specified for pipe without polyethylene wrapping. Take special care to prevent damage to the polyethylene wrapping when placing backfill. Backfill material shall be free of cinders, refuse, boulders, rocks, stones, or other material that could damage polyethylene.

Designation: A 890/A 890M – 99 (Reapproved 2003)

Standard Specification for Castings, Iron-Chromium-Nickel-Molybdenum Corrosion-Resistant, Duplex (Austenitic/Ferritic) for General Application[1]

This standard is issued under the fixed designation A 890/A 890M; 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 a group of cast duplex stainless steels (austenitic/ferritic).

1.2 The duplex stainless steel alloys offer a combination of enhanced mechanical properties and corrosion resistance when properly balanced in composition and properly heat treated. Ferrite levels are not specified, but these alloys will develop a range of approximately 30 to 60 % ferrite with the balance austenite.

1.3 The values stated in either inch-pound units or metric (SI) units are to be regarded separately as standard. Within the text the metric (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 the specification.

2. Referenced Documents

2.1 *ASTM Standards:*

A 370 Test Methods and Definitions for Mechanical Testing of Steel Products[2]

A 732/A732M Specification for Castings, Investment, Carbon and Low-Alloy Steel for General Application, and Cobalt Alloy for High Strength at Elevated Temperatures[3]

A 781/A781M Specification for Castings, Steel and Alloy, Common Requirements, for General Industrial Use[3]

E 29 Practice for Using Significant Digits in Test Data to Determine Conformance With Specifications[4]

E 562 Practice for Determining Volume Fraction by Systematic Manual Point Count[5]

E 1245 Practice for Determining the Inclusion or Second-Phase Constituent Content of Metals by Automatic Image Analysis[5]

3. Ordering Information

3.1 Orders for material to this specification shall include the following, as required, to describe the material adequately:

3.1.1 Description of casting by pattern or drawing number (dimensional tolerance shall be included on the casting drawing),

3.1.2 Specification designation and grade including year of issue,

3.1.3 Options in the specification (See 9.1), and

3.1.4 Supplementary requirements desired, including the standards of acceptance.

4. Process

4.1 The steel shall be made by the electric furnace process with or without separate refining such as argon-oxygen-decarburization (AOD).

5. Heat Treatment

5.1 Castings shall be heat treated in accordance with the requirements in Table 1.

NOTE 1—Proper heat treatment of these alloys is usually necessary to enhance corrosion resistance and in some cases to meet mechanical

TABLE 1 Heat Treatment Requirements

Grade	Heat Treatment
1A, 1B, 1C	Heat to 1900°F [1040°C] minimum, hold for sufficient time to heat casting uniformly to temperature, quench in water or rapid cool by other means.
2A	Heat to 2050°F [1120°C] minimum, hold for sufficient time to heat casting uniformly to temperature, quench in water or rapid cool by other means.
3A	Heat to 1950°F [1070°C] minimum, hold for sufficient time to heat casting uniformly to temperature, quench in water or rapid cool by other means.
4A	Heat to 2050°F [1120°C] minimum for sufficient time to heat casting uniformly to temperature and water quench, or the casting may be furnace cooled to 1850°F [1010°C] minimum, hold for 15 min minimum and then water quench. A rapid cool by other means may be employed in lieu of water quench.
5A	Heat to 2050°F [1120°C] minimum, hold for sufficient time to heat casting to temperature, furnace cool to 1910°F [1045°C] minimum, quench in water or rapid cool by other means.
6A	Heat to 2010°F [1100°C] minimum, hold for sufficient time to heat casting uniformly to temperature, quench in water or cool rapidly by other means.

[1] This specification is under the jurisdiction of ASTM Committee A01 on Steel, Stainless Steel, and Related Alloys and is the direct responsibility of Subcommittee A01.18 on Castings.

Current edition approved Oct. 1, 2003. Published October 2003. Originally approved in 1988. Last previous edition approved in 1999 as A 890/A 890M – 99.

[2] *Annual Book of ASTM Standards*, Vol 01.03.

[3] *Annual Book of ASTM Standards*, Vol 01.02.

[4] *Annual Book of ASTM Standards*, Vol 14.02.

[5] *Annual Book of ASTM Standards*, Vol 03.01.

properties. Minimum heat-treat temperatures are specified; however, it is sometimes necessary to heat-treat at higher temperatures, hold for some minimum time at temperature and then rapidly cool the castings in order to enhance the corrosion resistance and meet mechanical properties.

6. Chemical Composition

6.1 The steel shall conform to the requirements as to chemical composition prescribed in Table 2.

7. General Requirements

7.1 Material furnished to this specification shall conform to the requirements of Specification A 781/A 781M, including any supplementary requirements that are indicated in the purchase order. Failure to comply with the general requirements of Specification A 781/A 781M constitutes nonconformance with this specification. In case of conflict between the requirements of this specification and Specification A 781/A 781M, this specification shall prevail.

8. Repair by Welding

8.1 The composition of the deposited weld metal may be similar to that of the casting or may be suitably alloyed to achieve the desired corrosion resistance and mechanical properties.

8.2 Weld repairs shall be subject to the same quality standards as are used to inspect the castings.

8.3 When post weld/heat treatment is believed necessary for adequate corrosion resistance or impact resistance, Supplementary Requirement S33 Post Weld/Heat Treatment shall be included in the purchase order.

9. Product Marking

9.1 Castings shall be marked for material identification with the specification designation and grade. In addition, the manufacturer's name or identification mark and the pattern number shall be cast or stamped using low-stress stamps on all castings. Small-size castings may be such that marking must be limited consistent with the available area. The marking of heat numbers on individual castings shall be agreed upon between the manufacturer and the purchaser. Marking shall be in such position as not to injure the usefulness of the casting.

10. Keywords

10.1 austenite; duplex stainless steel; ferrite; stainless steel; steel castings

TABLE 2 Chemical Requirements

Grade	1A	1B	1C[A]	2A
Type	25Cr-5Ni-Mo-Cu	25Cr-5Ni-M0-Cu-N	25Cr-6Ni-Mo-Cu-N	24Cr-10Ni-Mo-N
UNS	J93370	J93372	J93373	J93345
ACI	CD4MCu	CD4MCuN	CD3MCuN	CE8MN
Composition:				
Carbon, max	0.04	0.04	0.030	0.08
Manganese, max	1.00	1.0	1.20	1.00
Silicon, max	1.00	1.0	1.10	1.50
Phosphorus, max	0.040	0.04	0.030	0.04
Sulfur, max	0.040	0.04	0.030	0.04
Chromium	24.5–26.5	24.5–26.5	24.0-26.7	22.5–25.5
Nickel	4.75–6.00	4.7–6.0	5.6-6.7	8.0–11.0
Molybdenum	1.75–2.25	1.7–2.3	2.9-3.8	3.0–4.5
Copper	2.75–3.25	2.7–3.3	1.40-1.90	. . .
Tungsten	. . .	. . .	. . .	. . .
Nitrogen		0.10–0.25	0.22-0.33	0.10–0.30
Grade	3A	4A	5A[A]	6A[A]
Type	25Cr-5Ni-Mo-N	22Cr-5Ni-Mo-N	25Cr-7Ni-Mo-N	25Cr-7Ni-Mo-N
UNS	J93371	J92205	J93404	J93380
ACI	CD6MN	CD3MN	CE3MN	CD3MWCuN
Composition:				
Carbon, max	0.06	0.03	0.03	0.03
Manganese, max	1.00	1.50	1.50	1.00
Silicon, max	1.00	1.00	1.00	1.00
Phosphorus, max	0.040	0.04	0.04	0.030
Sulfur, max	0.040	0.020	0.04	0.025
Chromium	24.0–27.0	21.0–23.5	24.0–26.0	24.0–26.0
Nickel	4.0–6.0	4.5–6.5	6.0–8.0	6.5–8.5
Molybdenum	1.75–2.5	2.5–3.5	4.0–5.0	3.0–4.0
Copper	. . .	1.00, max	. . .	0.5–1.0
Tungsten	. . .	. . .	. . .	0.5–1.0
Nitrogen	0.15–0.25	0.10–0.30	0.10–0.30	0.20–0.30

[A] % Cr + 3.3 % Mo + 16 % N $\geq$ 40.

SUPPLEMENTARY REQUIREMENTS

The following supplementary requirements shall not apply unless specified in the purchase order. A list of standardized supplementary requirements for use at the option of the purchaser is included in Specification A 781/A 781M. Those that are ordinarily considered suitable for use with this specification are listed below by title only. Others enumerated in Specification A 781/A 781M may be used with this specification upon agreement between the manufacturer and purchaser.

S2. Radiographic Examination

S3. Liquid Penetrant Examination

S5. Examination of Weld Preparation

S6. Certification

S7. Prior Approval of Major Weld Repairs

S9. Charpy Impact Test

S10. Hardness Test

S12. Test Report

S13. Unspecified Elements

S31. Estimating Ferrite Content

S31.1 Ferrite contents shall be determined by point count (Practice E 562), by other quantitative metallographic methods such as image analysis (Practice E 1245), by measurement of magnetic response, or by other methods upon agreement between the manufacturer and the purchaser. Frequency of testing and location of tests shall be by agreement between the manufacturer and the purchaser.

S32. Tensile Requirements

S32.1 One tensile test shall be made from each heat and shall conform to the tensile requirements specified in Table S32.1. Test bars shall be poured in special blocks from the same heat as the castings represented. (See S32.4.)

S32.2 The bar from which the test specimen is removed shall be heat-treated in production furnaces to the same procedure as the castings it represents.

S32.3 Test specimens may be cut from heat-treated castings, at the producer's option, instead of from test bars.

S32.4 Test coupons may be cast integrally or as separate cast blocks in accordance with Figs. 1 and 2 of Specification A 781/A 781M. Tension coupons shall be machined to the form and dimensions of Fig. 4 of Test Methods and Definitions A 370, except when investment castings are ordered. When investment castings are ordered, the manufacturer may prepare

TABLE S32.1 Tensile Requirements

Grade	1A	2A	3A	4A
Type	25Cr-5Ni-Mo-Cu	24Cr-10Ni-Mo-N	25Cr-5Ni-Mo-N	22Cr-5Ni-Mo-N
Tensile strength, ksi [MPa], min	100 [690]	95 [655]	95 [655]	90 [620]
Yield strength (0.2 % offset), ksi [MPa], min	70 [485]	65 [450]	65 [450]	60 [415]
Elongation in 2 in. [50 mm], %, min[A]	16	25	25	25
Grade	5A	6A	1B	1C
Type	25Cr-7Ni-Mo-N	25Cr-7Ni-Mo-N	25Cr-5Ni-Mo-Cu-N	25Cr-6Ni-Mo-Cu-N
Tensile strength, ksi [MPa], min	100 [690]	100 [690]	100 [690]	100 [690]
Yield strength (0.2 % offset), ksi [MPa], min	75 [515]	65 [450]	70 [485]	65 [450]
Elongation in 2 in. [50 mm], %, min[A]	18	25	16	25

[A] When ICI test bars are used in tensile testing as provided for in this specification, the gage length to reduced section diameter ratio shall be 4:1.

test specimens in accordance with S3.2 of Specification A 732/A 732M. Testing shall be in accordance with Test Methods and Definitions A 370.

S32.5 If any specimen shows defective machining or develops flaws, it may be discarded and another substituted from the same heat.

S32.6 To determine conformance with the tension test requirements, an observed value or calculated value shall be rounded off in accordance with Practice E 29 to the nearest 500 psi [5 MPa] for yield and tensile strength and to the nearest 1 % for elongation and reduction of area.

S33. Post Weld/Heat Treatment

S33.1 Castings shall be heat-treated after major weld repairs, but heat treatment after minor weld repairs is not required except upon agreement between the manufacturer and the purchaser.

S33.2 Weld repairs shall be considered major in the case of a casting that has leaked on hydrostatic testing or when the depth of the cavity after preparation for repair exceeds 20 % of the actual wall thickness, or 1 in. [25 mm], whichever is smaller, or when the extent of the cavity exceeds approximately 10 in.^{2}[65 cm^2]. All other weld repairs shall be considered minor.

S33.3 Post weld heat treatment shall be in accordance with Table 1.

S34. Prior Approval of Weld Material

S34.1 The purchaser must give approval of all weld filler materials to be used prior to any weld repairs.

S35. Heat Treatment of Test Material

S35.1 Test material for each heat shall be heat-treated with the castings it represents.

Standard Specification for Austempered Ductile Iron Castings[1]

This standard is issued under the fixed designation A 897/A 897M; 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 ductile iron castings that are subsequently heat treated by an austempering process as defined in 10.1.

1.2 The application of the austempering heat treatment extends the range of properties achievable in ductile iron castings.

1.3 No precise quantitative relationship can be stated between the properties of the iron in various locations of the same casting or between the properties of castings and those of a test specimen cast from the same iron (see Appendix X1). However, austempering heat treatment will tend to diminish any differences in mechanical properties.

1.4 The production of castings, machining (if required), and the austempering heat treatments may be performed by different manufacturers, as covered in Section 15. The purchaser should establish by contract agreement, at the time of ordering, the responsibility of the various parties for meeting the specification requirements.

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 shall 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:* [2]

A 247 Test Method for Evaluating the Microstructure of Graphite in Iron Castings

A 370 Test Methods and Definitions for Mechanical Testing of Steel Products

A 732 Specification for Castings, Investment, Carbon and Low Alloy Steel for General Application, and Cobalt Alloy for High Strength at Elevated Temperatures

A 834 Specification for Common Requirements for Iron Castings for General Industrial Use

E 8 Test Methods for Tension Testing of Metallic Materials

E 10 Test Methods for Brinell Hardness of Metallic Materials

E 23 Test Methods for Notched Bar Impact Testing of Metallic Materials

2.2 *Military Standard:*

MIL-STD-129 Marking for Shipment and Storage[3]

3. Ordering Information

3.1 Orders for material to this specification shall include the following information:

3.1.1 ASTM designation, with year of issue,

3.1.2 Grade of austempered ductile iron required (see Table 1 and Sections 6 and 7),

3.1.3 Chemical composition requirements, if any (see Section 4),

3.1.4 Heat treated microstructure restrictions (see Section 10),

3.1.5 Test coupon criteria (see Section 12),

3.1.6 Lot size and tests per lot (see 12.6 and Section 15),

3.1.7 Special requirements, if desired, including hardness, radiographic soundness, magnetic particle inspection, pressure tightness, dimensions, or surface finish (see Section 9),

3.1.8 Certification, if required (see Section 16),

3.1.9 Special preparation for delivery, if required (see Section 17).

4. Chemical Composition

4.1 Although this specification has no specific chemical requirements, such requirements may be agreed upon between the manufacturer, heat treater, and the purchaser.

5. Microstructure

5.1 The graphite component of the microstructure shall consist of a minimum 80 % spheroidal graphite conforming to Types I and II per Test Method A 247.

[1] This specification is under the jurisdiction of ASTM Committee A04 on Iron Castings and is the direct responsibility of Subcommittee A04.02 on Malleable and Ductile Iron Castings.

Current edition approved Dec. 1, 2003. Published January 2004. Originally approved in 1990. Last previous edition approved in 2002 as A 897 - 02.

[2] 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.

[3] Available from Standardization Documents, Order Desk, Building 4, Section D, 700 Robbins Ave., Philadelphia, PA 19111-5098, Attn: NPODS.

TABLE 1 Mechanical Property Requirements of Grades

Inch-pound units	Grade 130/90/09	Grade 150/110/07	Grade 175/125/04	Grade 200/155/02	Grade 230/185/01
Tensile strength, min, ksi	130	150	175	200	230
Yield strength, min, ksi	90	110	125	155	185
Elongation in 2 in., min, %	9	7	4	2	1
Impact energy, ft-lb[A]	75	60	45	25	15
Typical hardness, HBW, kg/mm^2	269–341	302–375	341–444	388–477	402–512

[A] Unnotched charpy bars tested at 72 ± 7°F. The values in the table are a minimum for the average of the highest three test values of the four tested samples.

SI units	Grade 900/650/09	Grade 1050/750/07	Grade 1200/850/04	Grade 1400/1100/02	Grade 1600/1300/01
Tensile strength, min, MPa	900	1050	1200	1400	1600
Yield strength, min, MPa	650	750	850	1100	1300
Elongation in 50 mm, min, %	9	7	4	2	1
Impact energy, J[A]	100	80	60	35	20
Typical hardness, HBW, kg/mm^2	269–341	302–375	341–444	388–477	402–512

[A] Unnotched charpy bars tested at 22 ± 4°C. The values in the table are a minimum for the average of the highest three test values of the four tested samples.

5.2 The matrix microstructure shall substantially consist of ausferrite (acicular ferrite and high carbon, stable austenite).

5.3 The cooling rate within some sections may not be sufficient to avoid the formation of pearlite or other high temperature transformation products. In some cases, the maximum acceptable quantities of these microconstituents and the location(s) within the casting may be established by agreement between the manufacturer, heat treater, and the purchaser.

5.4 Martensite may be present in minor amounts in the microstructures of Grades 200/155/02 [1400/1100/02] and 230/185/01 [1600/1300/01]. Acceptable quantities of martensite may be established by agreement between the manufacturer, heat treater, and the purchaser.

5.5 The microstructure shall be substantially free of undesirable microconstituents, the details of which shall be agreed upon by the manufacturer, heat treater, and the purchaser.

5.6 The manufacturer, heat treater, and the purchaser may agree upon special chemical compositions or processing requirements to limit the microconstituents described in 5.3, 5.4, and 5.5.

6. Mechanical Properties

6.1 Tensile property requirements include tensile strength, yield strength, and elongation and apply only after austempering heat treatment.

6.2 The iron represented by the test specimens shall conform to the requirements as presented in Table 1.

6.3 The yield strength shall be determined by the 0.2 % offset method (see Test Methods E 8).

7. Impact Requirements

7.1 The iron represented by the test specimens shall conform to the impact properties presented in Table 1.

7.2 Impact energy requirements apply only after test material has been austempered. The impact test specimens must be finish ground to required dimensions after heat treatment.

8. Hardness

8.1 The area or areas on the castings where hardness is to be checked shall be established by agreement between the manufacturer and purchaser, or the manufacturer and the end user.

8.2 Brinell hardness shall be determined according to Test Method E 10 after sufficient material has been removed from the casting surface to insure representative hardness readings. The 10 mm ball and 3000 kg load shall be used unless otherwise specified and agreed upon.

9. Special Requirements

9.1 When specified in the contract or purchase order, castings shall meet special requirements as to hardness, chemical composition, microstructure, pressure tightness, radiographic soundness, magnetic particle inspection, dimensions, and surface finish. Refer to Specification A 834 for a list of common requirements for iron castings not specifically referenced elsewhere in this specification.

9.2 When specified in the contract or purchase order, castings shall meet special requirements prior to the austempering heat treatment operation.

10. Heat Treatment

10.1 Castings produced in accordance with this specification shall be heat treated by an austempering process consisting of heating the castings to a fully austenitic, homogeneous condition, cooling (at a rate usually sufficient to avoid the formation of pearlite) to a temperature above the martensite start temperature, and isothermally transforming the matrix structure for a time sufficient to produce the desired properties. This process shall produce a microstructure that is substantially ausferrite.

10.2 Upon agreement between the manufacturer and the purchaser, tension test specimens described in Section 13 may be machined prior to the austempering heat treatment. In this case, heat treatment shall be performed in an inert or carbon controlled environment so as to prevent carburization, decarburization, or scaling. Handling and fixturing must be such as to prevent test bar distortion (see X1.4).

10.3 Re-austempering of castings or any deviation from the established heat treating process is only permissable with the approval of the casting purchaser.

11. Workmanship, Finish, and Appearance

11.1 The surfaces of castings shall be clean and free of adhering molding material, heat treatment oils or salts, cracks, hot tears, or other injurious defects such as slag and surface porosity. Dimensions shall conform to drawings or patterns supplied by the purchaser.

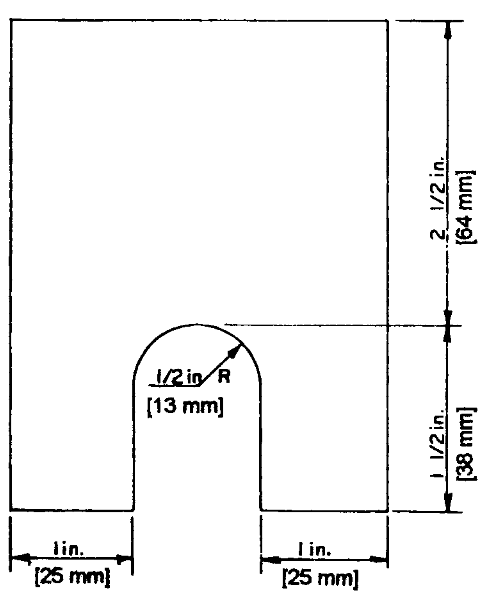
11.2 Castings shall not have chilled corners or center chill in areas to be machined.

11.3 Welding repair is not acceptable on austempered castings.

12. Test Coupons

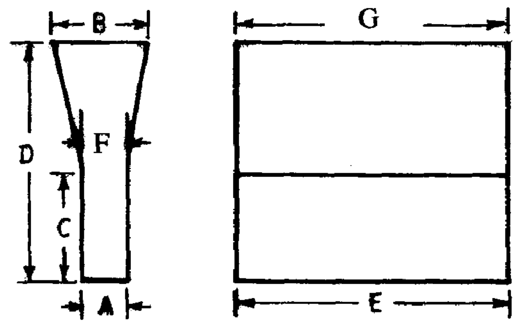
12.1 Separately cast test coupons from which the tension test and Charpy test specimens are machined shall be cast to the size and shape shown in Fig. 1 or Fig. 2. A modified keel block cast from the mold shown in Fig. 3 may be substituted for the 1-in. [25-mm] Y-block or the 1-in. [25-mm] keel block. The test coupons shall be cast in open molds made of suitable core sand having a minimum wall thickness of 1½ in. [38-mm] for the ½-in. [13-mm] and 1-in. [25-mm] sizes and 3 in. [76-mm] for the 3-in. [76-mm] size. The coupons shall be left in the mold until they have cooled to a black color (900°F [480°C] or less). The size and type of coupon cast to represent the casting shall be at the option of the purchaser. In case no option is expressed, the manufacturer shall make the choice.

12.2 When investment castings are made in accordance with this specification, the manufacturer may use cast-to-size test specimens that are either incorporated in the mold with the castings or separately cast using the same type of mold and the same thermal conditions that are used to produce the castings. The test specimens shall be made to the dimensions shown in Fig. 1 of Specification A 732 or Fig. 5 of Test Methods and Definitions A 370. The exact procedure to be used for producing test specimens shall be agreed upon by the manufacturer and the purchaser.



NOTE—The length of the keel block shall be 6 in. [150 mm].

FIG. 1 Keel Block for Test Coupons



Dimensions	"Y" Block Size: For Castings of Thickness Less Than ½ in. [13 mm]	For Castings of Thickness ½ to 1½ in. [13 to 38 mm]	For Castings of Thickness of 1½ in. [38 mm] and Over
	in. [mm]	in. [mm]	in. [mm]
A	½	1 [25]	3 [75]
B	1⅝	2⅛	5 [125]
C	2 [50]	3 [75]	4 [100]
D	4 [100]	6 [150]	8 [200]
E	7 [175] approx	7 [175] approx	7 [175] approx
F	9⁄16 [14]	1 1⁄16 [27]	3 1⁄16 [78]
G	7 1⁄8 [180] approx	7 1⁄8 [180] approx	7 1⁄8 [180] approx

FIG. 2 Y-Blocks for Test Coupons

12.3 When castings made in accordance with this specification are produced by nodularization directly in the mold, the manufacturer may use either separately cast test coupons or test specimens cut from castings. If test bars are to be cut from castings, test bar location shall be agreed upon by the purchaser and the manufacturer and indicated on the casting drawing. When separately cast test coupons are used, selection shall be as outlined in 12.1 and shown in Figs. 1-6. Appendix X2 provides guidelines for selection of coupons with mold cooling rates representative of various casting sections.

12.4 Test coupons shall be poured from the same ladle or heat as the castings they represent and, unless otherwise agreed upon by the manufacturer and the purchaser, shall be subject to the same post inoculation and alloying practice.

12.5 Test coupons shall be heat treated with the castings they represent.

12.6 The number of test coupons and the number of tests required per order or lot size shall be established at the time of ordering. This agreement should include a definition of lot size. Lot size can be defined to include the entire order, a specified portion of that order, a specified manufacturing production period, or a specified quantity of parts shipped to the purchaser.

12.7 If any test specimen shows obvious defects, another may be cut from the same test block or from another test block representing the same metal. Positions other than "A" or "B" in Fig. 4 shall not be used. In those cases where removal of test bars from actual castings has been agreed upon (see 12.2 and 12.3), a second test bar may be obtained from an alternate location of equivalent section or from a second casting processed in the same lot.

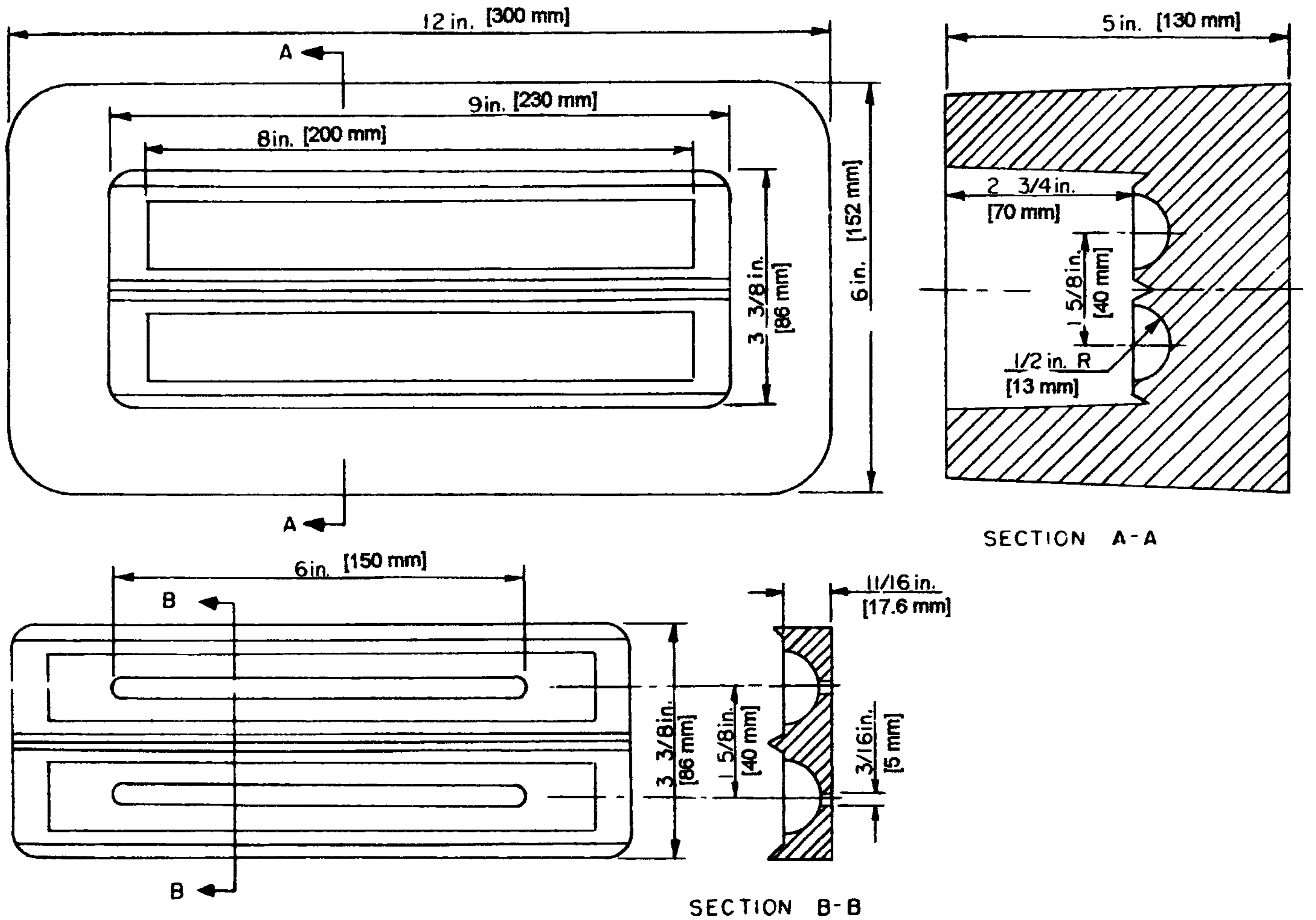


FIG. 3 Mold for Modified Keel Block

13. Tension Test Specimens

13.1 The standard round tension test specimen with a 2-in. [50-mm] gage length shown in Fig. 5 shall be used, except when the ½-in. [13-mm] Y-block coupon is used. In this case, either of the test specimens shown in Fig. 6 shall be satisfactory. Tension test specimens shall be machined only from Positions A (preferred) or B in Fig. 4. The test bars may be machined before or after heat treatment in accordance with 10.2.

14. Impact Test Specimens

14.1 The unnotched Charpy impact strength shall be determined according to Test Methods E 23 with the following variations: Specimens are to be prepared unnotched to dimensions in Fig. 9 of Test Methods E 23. Blanks from which test specimens are machined shall be cut only from Positions A or B in Fig. 4. Test temperature shall be 72 ± 7°F [22 ± 4°C]. Four specimens shall be tested, with the lowest impact energy value discarded and the remaining three values averaged. The average impact energy shall meet the requirement of Table 1.

15. Responsibility for Quality and Inspection

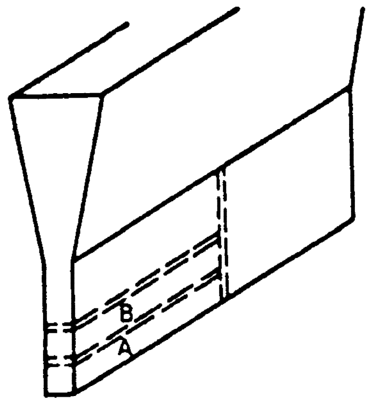
15.1 At the time of an order, the purchaser should establish an agreement for quality and inspection requirements with the manufacturers. The form of this agreement depends upon which of the conditions in 15.2 or 15.3 are determined to exist.

15.2 If all manufacturing operations are performed by a single manufacturer, that manufacturer is responsible for performance of all quality and inspection requirements covered herein.

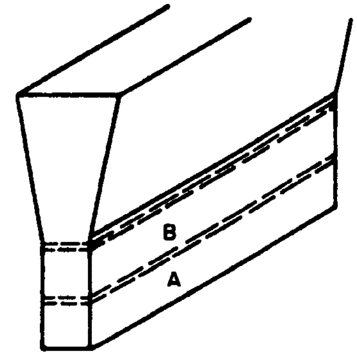
15.3 If, at the time of ordering, the purchaser determines that more than one manufacturer will contribute to the casting, machining, and heat treatment operations, in any sequential fashion, an agreement should be negotiated that defines and assigns individual responsibility for each specific quality and inspection requirement. This does not prevent an agreement wherein any one manufacturer in the chain of sequential operations can agree to assume full responsibility for all quality and inspection requirements.

15.4 To avoid future disputes, the purchaser can require that all companies in the manufacturing chain be identified. Changes shall not be made without approval of the purchaser. The manufacturer(s) may require the purchaser to provide written agreement for any changes mutually agreed upon.

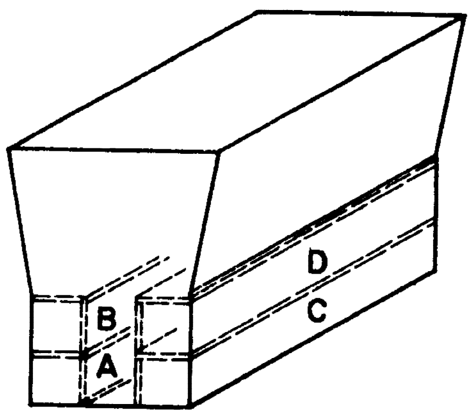
15.5 Unless specified to the contrary by the purchaser, any of the manufacturers in the chain may use his or her own or any other facilities for performance of the inspection requirements. Responsibility for meeting the specified properties remains



(a) ½-in. [13-mm] Y-Block—Two blanks for 0.252-in. [6.5-mm] diameter tension test specimens.



(b) 1-in. [25-mm] Y-Block—Two blanks for 0.50-in. [13-mm] diameter tension test specimens.



(c) 3-in. [75-mm] Y-Block—Two blanks for 0.50-in. [13-mm] diameter tension test specimens.

FIG. 4 Sectioning Procedure for Y-Blocks

NOTE—The gage length and fillets shall be as shown but the ends may be of any shape to fit the holders of the testing machine in such a way that the load shall be axial. The reduced section shall have a gradual taper from the ends toward the center, with the ends 0.003 to 0.005 in. [0.08 to 0.13 mm] larger in diameter in the center.

FIG. 5 Standard Round Tension Test Specimen with 2-in. [50-mm] Gage Length

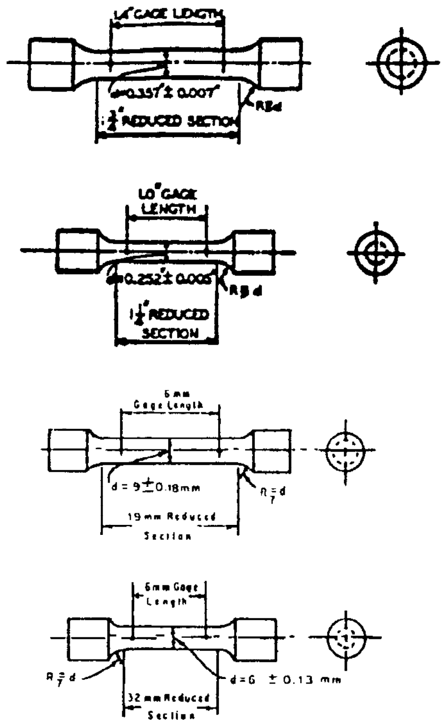
with the parties defined in 15.2 or 15.3. This shall not prevent the purchaser from also performing any or all of the quality and inspection requirements.

16. Certification

16.1 Where required by contract, the manufacturer's certification shall be furnished to the purchaser stating that the material was manufactured, sampled, tested, and inspected in accordance with the material specification and was found to meet the requirements. The certification shall include the results of all tests performed.

17. Preparation for Delivery

17.1 Unless otherwise specified in the contract or purchase order, cleaning, drying, preservation, and packaging of castings shall be in accordance with the manufacturer's commercial practice. Packaging and marking shall be adequate to ensure safe delivery by the carrier.



NOTE—If desired, the length of the reduced section may be increased to accommodate an extensometer.

FIG. 6 Examples of Small-Size Specimens Proportional to Standard ½-in. [13-mm] Round Specimen

17.2 *Government Procurement*—When specified in the contract or purchase order, marking for shipment shall be in accordance with the requirements of MIL-STD-129.

APPENDIXES

(Nonmandatory Information)

X1. MECHANICAL PROPERTIES OF CASTINGS

X1.1 In order to achieve the required mechanical properties in castings, or test coupons, the iron must have a chemical composition that provides sufficient hardenability to fully respond in the austempering heat treatment cycle. The response to heat treatment is affected by the effective section size, graphite nodule count, and chemical composition. It also depends on the capabilities of the specific heat treater's equipment. The heavier the effective section size and the more massive the casting, the slower will be the cooling or quenching rate in the austempering cycle. This quenching rate must exceed some critical value to attain the correct microstructure (high carbon austenite plus acicular ferrite).

X1.2 Published literature and commercial heat treaters as well as many foundries can provide information on required alloy additions needed for specific parts, casting section sizes, or masses. Austempered Ductile Iron can be successfully produced from ductile iron castings with a wide range of chemical compositions and configurations. There is no optimum recipe; however those produced to the following parameters have been shown to yield excellent results.

X1.2.1 The castings should be free of non-metallic inclusions, carbides, shrink and dross. Proper purchasing, storage and use of charge materials will minimize the occurrence of carbides and gas defects. Proper molding control will minimize surface defects and other sub-surface discontinuities. The castings should be properly gated and poured using consistent and effective treatment and inoculation techniques to yield shrink free castings. Any of the aforementioned non-conforming conditions will reduce the toughness of an ADI component, even if adequate for conventional ductile iron. The following should be met as a minimum: Nodule Count 100/mm2 and Nodularity 80%.

X1.2.2 The carbon equivalent (CE) can be approximated by the relationship: CE = %C + 1/3 (%Si). It should be controlled as follows in Table X1.1.

X1.3 Alloying elements such as Molybdenum, Copper, Nickel and additional Manganese above the base metal level should be added only when additional hardenability is required for heavy sections. Increased hardenability is only required to avoid the formation of pearlite during quenching. The amount of alloying required (if any) will be a function of the alloy

TABLE X1.1 Suggested Carbon Equivalent Ranges for Various Section Sizes

Section Size	CE Range
0 to ½ in. (0 to 13 mm)	4.4 to 4.6
½ to 2 in. (13 to 51 mm)	4.3 to 4.6
Over 2 in. (51 mm)	4.3 to 4.5

content in the base metal, the part configuration and the austempering process used. The proper alloy composition should be determined jointly by the foundry and the heat treating source. Addition of alloying elements when not required does not enchance the properties of ADI and merely adds to the cost of the iron. Composition guidelines are recommended in Table X1.2 and Table X1.3.

X1.3.1 Other nodulizing elements like beryllium, calcium, strontium, barium, yttrium, lanthanum and cerium should be present only to the extent that they are used to replace Mg in treatment. The amount of residual Mg plus the amounts of these elements should not exceed 0.06%. Carbide forming elements (like Cr, Ti , V) tend to be additive in effect with Mn and/or Mo; thus, one should take note of this in alloy design to avoid the formation of carbides in the casting.

X1.3.2 The preceding guidelines are intended to be useful parameters for production. Good ADI can, and is, being produced from ductile iron not meeting these criteria, however,

TABLE X1.2 Suggested Targets and Control Ranges for Intentionally Added Elements

Element	Recommended Range
Carbon Carbon should be controlled within the recommended range except when deviations are required to produce a defect-free casting. If too high levels of carbon are present, carbon flotation can occur and reduce the apparent strength levels of ADI.	3.60 % ± 0.20 %
Silicon Silicon is one of the most important elements in ADI because it promotes graphite formation, decreases the solubility of carbon in austenite, increases the eutectoid temperature and inhibits the formation of bainitic carbide. Excessively high levels of Si can suppress ausferrite in localized areas by stabilizing ferrite.	2.50 % ± 0.20 %
Magnesium Magnesium is added to create the conditions for graphite nodules to form. Excessively high levels will promote carbide formation while low levels promote nonspheroidal graphite.	(% S x 0.76) + 0.025 % ± 0.005 %
Manganese Manganese additions above that of the base metal composition are not recommended because Mn segregates to the last to freeze regions of the casting and will retard the formation of ausferrite if the nodule count is not sufficiently high to break up the Mn segregated region. In section sizes up to ½ in. or 13 mm, Mn targets as high as 0.60 % have been used due to high nodule counts. In section sizes over ½ in. (13 mm) or in the presence of Mo other carbide formers, the Mn target should be reduced to 0.35 % or less to minimize the formation of cell boundary carbides which may negatively affect component machinability or ductility, or both.	0.35% ± 0.05 %
Copper Copper may be added to ADI to increase hardenability in additions up to 0.80 %. Above this level, Cu creates a diffusion barrier around the graphite nodules, thus inhibiting carbon mobility during austenitizing.	0.80 % maximum, only as needed ± 0.05 %
Nickel Nickel may be used to increase the hardenability of ductile iron in additions up to 2.0 %. Because of the costs associated with the use of Ni, larger additions may be cost prohibitive.	2.0 % maximum, only as needed ± 0.10 %
Molybdenum Molybdenum is the most potent hardenability agent in ADI and may be necessary in heavy section castings to prevent the formation of pearlite. Both tensile strength and ductility decrease as the Mo content increases beyond that required for hardenability. This deterioration in properties is likely caused by the segregation of Mo to cell boundaries and the formation of carbides. The level of Mo should be restricted to not more than 0.30 % in heavy section castings.	0.30 % maximum (only as needed) ± 0.03 %

TABLE X1.3 Suggested Targets and Control Ranges for Trace or Tramp Elements

Trace or Tramp Elements	Suggested Target (or maximum)	Typical Control Range
Sn Tin	0.02% maximum	± 0.003 %
Sb Antimony	0.002% maximum	± 0.0003 %
P Phosphorus	0.04% maximum	
S Sulfur	0.02% maximum	
O Oxygen	50 ppm maximum	
Cr Chromium	0.10% maximum	
Ti Titanium	0.040 % maximum	
V Vanadium	0.10% maximum	
Al Aluminium	0.050% maximum	
As Arsenic	0.020% maximum	
Bi Bismuth	0.002% maximum	
B Boron	0.0004% maximum	
Cd Cadmium	0.005% maximum	
Pb Lead	0.002% maximum	
Se Selenium	0.030% maximum	
Te Tellurium	0.003% maximum	

these criteria represent sound, commercial practices known to produce good results. They do not constitute a guarantee of final properties.

X1.4 Machining of tension test specimens after austempering may be difficult, particularly for the higher strength grades. For this reason, some manufacturers prefer to machine the test bars to size or near net size (with some final grinding allowances) before the austempering operation. (**Warning—** Achieving the required mechanical properties and austempered microstructure in the smaller cross sections of a premachined test bar does not ensure the correct response in the heavier sections of actual parts, as explained in X1.1. When premachined test bars are to be used, it is recommended that adequate austempering be verified. This can be done by sectioning a casting, examining the microstructure in that section, and then comparing the results with that of a premachined test bar that has been austempered in the same furnace load. When inadequate austempering response is identified, increased alloying as discussed in X1.3 may be required.)

X2. Y-BLOCK SELECTION

X2.1 Table X2.1 provides guidelines for the selection of Y-blocks that have cooling rates that are representative of equivalent shapes having the dimensions shown.

TABLE X2.1 Equivalent Geometric Shapes Corresponding to Y-Blocks[A]

Y-Block Size, in. [mm]	Infinite Plate Thickness, in. [mm]	Round Diameter, in. [mm]	Cube Edge, in. [mm]
0.5 [13]	0.5 [13]	1.2 [30]	1.8 [46]
1.0 [25]	0.9 [22]	1.8 [46]	2.8 [72]
3.0 [76]	1.6 [40]	3.1 [80]	4.8 [120]

[A] For castings with cross sections that would require a Y-block greater than 3 in. [76mm], alloy requirements must be based upon experimental trials with test castings or previous experience with similar parts. Test coupons should be selected upon agreement between the producer and the purchaser.

Designation: A 903/A 903M – 99 (Reapproved 2003)

Standard Specification for Steel Castings, Surface Acceptance Standards, Magnetic Particle and Liquid Penetrant Inspection[1]

This standard is issued under the fixed designation A 903/A 903M; 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 acceptance criteria for the surface inspection of steel castings when nondestructively examined by magnetic particle or liquid penetrant inspection.

1.2 This specification is to be used wherever the inquiry, contract, order, or specification states that the acceptance standards for magnetic particle or liquid penetrant inspection shall be in accordance with Specification A 903/A 903M.

1.3 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 must be used independently of the other. Combining values from the two systems may result in a nonconformance with this specification.

2. Referenced Documents

2.1 *ASTM Standards:*

E 165 Test Method for Liquid Penetrant Examination[2]

E 709 Guide for Magnetic Particle Examination[2]

3. Terminology

3.1 *Definitions:*

3.1.1 *linear indications*—an indication whose length is equal to or greater than three times its width shall be classified as a linear indication.

3.1.2 *nonlinear indications*—an indication whose length is less than three times its width shall be classified as nonlinear.

3.1.3 *relevant indications*—relevant indications are indications which result from mechanical discontinuities. Only indications whose major dimension exceeds 1⁄16 in. [1.6 mm] shall be considered relevant.

4. Ordering Information

4.1 The inquiry and order should indicate the following information:

4.1.1 *Nondestructive Practice*—Practice E 165 for liquid penetrant inspection or Guide E 709 for magnetic particle inspection. Unless a specific technique within a practice is specified, the choice shall be the option of the manufacturer.

4.1.2 *Personnel Qualifications*.

4.1.3 *Extent of Inspection*—The number of castings and the extent of casting surfaces to be examined.

4.1.4 *Acceptance Level*—If more than one acceptance level is specified for different locations, a nondestructive test drawing identifying acceptance levels and locations should accompany the inquiry and order.

4.1.5 *Supplementary Requirements*, if any.

5. Personnel Qualifications

5.1 Personnel performing examination shall be qualified in accordance with an acceptable written procedure as agreed upon between the purchaser and manufacturer.

6. Evaluation of Indications

6.1 All relevant indications shall be evaluated in terms of the acceptance criteria.

6.2 Mechanical discontinuities are indicated by bleed-out of the penetrant or retention of the magnetic particle examination medium. However, false indications may be produced by localized surface irregularities, metallurgical discontinuities, or magnetic permeability variations. Any indication in excess of the acceptance criteria which is believed to be false may be reexamined. Surface conditioning may precede reexamination. When agreed upon between the manufacturer and purchaser, the liquid penetrant method may be used to verify the presence of surface discontinuities which had been previously indicated by the magnetic particle method.

6.3 Broad areas of fluorescence, pigmentation, or particle accumulation which may mask indications of discontinuities are unacceptable, and such areas will be cleaned and reexamined.

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[1] This specification is under the jurisdiction of ASTM Committee A01 on Steel, Stainless Steel, and Related Alloys and is the direct responsibility of Subcommittee A01.18 on Castings.

Current edition approved Oct. 1, 2003. Published October 2003. Originally approved in 1991. Last previous edition approved in 1999 as A 903/A 903M-99.

[2] *Annual Book of ASTM Standards*, Vol 03.03.

7. Acceptance Criteria

7.1 Individual relevant linear and nonlinear indications exceeding the specified acceptance levels in Table 1 are unacceptable.

7.2 Ten or more relevant indications, although individually acceptable, are collectively unacceptable when they occur in any 6 in. ^{2}[38.7 cm.^{2}] of casting surface, with the major dimension of this area not to exceed 6 in. [152 mm] taken in the most unfavorable orientation relative to the indications being evaluated.

7.3 When the casting surface is being inspected to Acceptance Levels I, II, or III the following relevant indications, although individually acceptable are collectively unacceptable when they are grouped as described in 7.3.1 and 7.3.2.

TABLE 1 Surface Inspection Acceptance Criteria Indication Size, in. [mm]

Type	Level I	Level II	Level III	Level IV	Level V
Linear	1⁄16 [1.6]	1⁄8 [3.2]	3⁄16 [4.8]	1⁄4 [6.4]	3⁄8 [9.5]
Nonlinear	1⁄8 [3.2]	3⁄16 [4.8]	3⁄16 [4.8]	1⁄4 [6.4]	3⁄8 [9.5]

7.3.1 Four or more in a line, separated by 1⁄16 in. [1.6 mm] or less edge-to-edge.

7.3.2 Four or more that are clustered and individually separated from the nearest adjoining indication by 1⁄16 in. [1.6 mm] or less edge-to-edge.

7.4 When the casting surface is being inspected to Acceptance Levels IV or V, individually acceptable relevant indications grouped as described in 7.3.1 and 7.3.2 shall be considered a single relevant linear and nonlinear indication respectively, and be evaluated in accordance with 7.1.

8. Certification

8.1 The manufacturer shall certify that inspection was performed in accordance with the appropriate practice (Practice E 165 for liquid penetrant inspection or Guide E 709 for magnetic particle inspection) and that the parts were found to meet the requirements of the specified inspection level of Specification A 903/A 903M (including year-date).

8.2 When certified test reports are required by the purchaser, Supplementary Requirement S1 shall be specified.

SUPPLEMENTARY REQUIREMENTS

The following supplementary requirements shall apply only when specified by the purchaser in the contract or order.

S1. Certified Test Reports

S1.1 A certified test report shall be furnished by the manufacturer, listing the following as a minimum:

S1.1.1 Customer name,
S1.1.2 Purchase order number,
S1.1.3 Material,
S1.1.4 Description of part,
S1.1.5 Vendor name,
S1.1.6 NDE procedure,
S1.1.7 Acceptance criteria,
S1.1.8 Vendor control number,
S1.1.9 Name of inspector, and
S1.1.10 Inspector qualification level.

Designation: A 915/A 915M – 93 (Reapproved 2003)

Standard Specification for Steel Castings, Carbon, and Alloy, Chemical Requirements Similar to Standard Wrought Grades[1]

This standard is issued under the fixed designation A 915/A 915M; 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 carbon and low alloy steel castings having chemical analyses similar to that of the standard wrought grades.

1.2 Several grades are covered and are designated by chemical composition shown in Table 1.

1.3 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 must be used independently of the other. Combining values from the two systems may result in nonconformance with the specification. Inch-pound units are applicable for material ordered to Specification A 915 and SI units for material ordered to Specification A 915M.

2. Referenced Documents

2.1 *ASTM Standards:*

A 370 Test Methods and Definitions for Mechanical Testing of Steel Products[2]

A 781/A 781M Specification for Castings, Steel and Alloy, Common Requirements, for General Industrial Use[3]

3. Ordering Information

3.1 Orders for material under this specification should include the following information:

3.1.1 Quantity,

3.1.2 Specification, including year, date, and grade,

3.1.3 Description of the casting by pattern number or drawing. Dimensional tolerances shall be included on the casting drawing,

3.1.4 Options in the specification, and

3.1.5 Supplementary requirements desired, including standards of acceptance.

4. Heat Treatment

4.1 Grades SC 1020 and SC 1025 may be supplied unheat treated or heat treated as described in 4.2.

4.2 Castings shall be heat treated either by full annealing, normalizing, normalizing and tempering, or quenching and tempering. Unless otherwise specified in the inquiry, contract, or order, the castings may be heat treated by any of these heat treatments or combination of these heat treatments at the option of the manufacturer.

4.3 Heat treatment shall be performed after the castings have been allowed to cool below the transformation range.

4.4 The furnace temperature for heat treating shall be effectively controlled by the use of recording-type pyrometers.

5. Chemical Composition

5.1 The steel shall conform to the requirements of chemical composition as prescribed in Table 1.

5.2 The product analysis tolerances given in Specification A 781/A 781M shall apply to all product analysis performed on castings supplied to this specification.

6. General Conditions for Delivery

6.1 Material furnished to this specification shall conform to the applicable requirements of Specification A 781/A 781M, including the supplementary requirements indicated on the purchaser's order.

7. Repair by Welding

7.1 Weld repairs shall be inspected to the same quality standards used to inspect the castings. When castings are produced with Supplementary Requirement S1 specified, weld repairs shall be inspected by magnetic particle examination to the same standards used to inspect the castings. When castings are produced with Supplementary Requirement S2specified, weld repairs in which the depth of the cavity prepared for repair welding exceeds 20 % of the wall thickness or 1 in. [25 mm], whichever is smaller, or in which the cavity prepared for welding is greater than approximately 10 in.^{2} [65 cm^2], shall be radiographed to the same standards used to inspect the castings.

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[1] This specification is under the jurisdiction of ASTM Committee A01 on Steel, Stainless Steel, and Related Alloys and is the direct responsibility of Subcommittee A01.18 on Castings.

Current edition approved April 10, 2003. Published April 2003. Originally approved in 1993. Last previous edition approved in 1998 as A 915/A 915M – 93 (1998).

[2] *Annual Book of ASTM Standards*, Vol 01.03.

[3] *Annual Book of ASTM Standards*, Vol 01.02.

TABLE 1 Chemical Composition (weight, percent)

Grade	C	Mn	P, max	S, max	Si	Ni	Cr	Mo
SC 1020 (J02003)	0.18/0.23	0.40/0.80	0.040	0.040	0.30/0.60	. . .	. . .	. . .
SC 1025 (J02508)	0.22/0.28	0.40/0.80	0.040	0.040	0.30/0.60	. . .	. . .	. . .
SC 1030 (J03012)	0.28/0.34	0.50/0.90	0.040	0.040	0.30/0.60	. . .	. . .	. . .
SC 1040 (J04003)	0.37/0.44	0.50/0.90	0.040	0.040	0.30/0.60	. . .	. . .	. . .
SC 1045 (J04502)	0.43/0.50	0.50/0.90	0.040	0.040	0.30/0.60	. . .	. . .	. . .
SC 4130 (J13502)	0.28/0.33	0.40/0.80	0.035	0.040	0.30/0.60	. . .	0.80/1.10	0.15/0.25
SC 4140 (J14045)	0.38/0.43	0.70/1.10	0.035	0.040	0.30/0.60	. . .	0.80/1.10	0.15/0.25
SC 4330 (J23259)	0.28/0.33	0.60/0.90	0.035	0.040	0.30/0.60	1.65/2.00	0.70/0.90	0.20/0.30
SC 4340 (J24053)	0.38/0.43	0.60/0.90	0.035	0.040	0.30/0.60	1.65/2.00	0.70/0.90	0.20/0.30
SC 8620 (J12095)	0.18/0.23	0.60/1.00	0.035	0.040	0.30/0.60	0.40/0.70	0.40/0.60	0.15/0.25
SC 8625 (J12595)	0.23/0.28	0.60/1.00	0.035	0.040	0.30/0.60	0.40/0.70	0.40/0.60	0.15/0.25
SC 8630 (J13095)	0.28/0.33	0.60/1.00	0.035	0.040	0.30/0.60	0.40/0.70	0.40/0.60	0.15/0.25

7.2 Weld repairs shall be considered major when the depth of the cavity prepared for welding exceeds 20 % of the wall thickness or 1 in. [25 mm], whichever is smaller, or when the extent of the cavity exceeds 10 in.^{2} [65 cm^2]. Castings produced from Grades SC 1020, SC 1025, or SC 1030 which contain major weld repairs shall receive a postweld heat treatment. Castings produced from any of the other grades shall receive a postweld heat treatment regardless of weld repair size. Postweld heat treatment shall consist of a thermal stress relief or a complete reheat treatment. The postweld heat treatment shall be in accordance with the qualified weld procedure used.

8. Rejection and Rehearing

8.1 Subsequent to acceptance at the manufacturer's works, material which is found to be unacceptable as determined by requirements specified in the order may be rejected by the purchaser. The manufacturer should be notified of such rejection. If the manufacturer is dissatisfied with the results of any tests performed by the purchaser, he may make claim for a rehearing.

9. Keywords

9.1 alloy steel; carbon steel; steel castings

SUPPLEMENTARY REQUIREMENTS

The following supplementary requirements shall not apply unless specified in the purchase order. A list of standardized supplementary requirements for use at the option of the purchaser is included in Specification A 781/A 781M. Those which are ordinarily considered suitable for use with this specification are given below together with additional supplementary requirements that are applicable only to this specification. Other supplementary requirements enumerated in Specification A 781/A 781M may be used with this specification upon agreement between the manufacturer and purchaser.

S1. Magnetic particle examination.

S2. Radiographic examination.

S3. Liquid penetrant examination.

S4. Ultrasonic examination.

S5. Examination of weld preparation.

S6. Certification.

S7. Prior approval of major weld repairs.

S8. Marking.

S9. Charpy impact test.

S10. Hardness test.

S12. Test report.

S13. Unspecified elements.

S14. Tension test from casting.

S15. Alternate tension test coupons.

S50. Tension test.

S50.1 Tensile properties shall be determined from material representing each heat. The bar from which the test specimen is taken shall be heat treated in production furnaces to the same procedure as the castings it represents. The results shall conform to requirements agreed upon between the manufacturer and purchaser.

S50.2 Test bars shall be poured in separately cast keel blocks similar to Fig. 1 in Specification A 781/A 781M.

S50.3 Tension test specimens may be cut from heat treated castings, or from as-cast castings if no heat treatment is specified for the castings, instead of from test bars, when agreed upon between the manufacturer and the purchaser.

S50.4 Test specimens shall be machined to the form and dimensions of the standard round 2-in. [50-mm] gage length specimen shown in Fig. 6 of Test Methods and Definitions A 370, and shall be tested in accordance with Test Methods and Definitions A 370.

S50.5 If the results of the mechanical tests for any heat, lot, or casting do not conform to the requirements agreed upon, retests are permitted as outlined in Test Methods and Definitions A 370. At the manufacturer's option, castings may be reheat-treated and retested. When castings are reheat-treated, they may not be reaustenitized more than three times without the approval of the purchaser. Testing after reheat treatment shall consist of the full number of specimens taken from locations complying with the specification or order.

S50.6 If any test specimen shows defective machining or develops flaws, it may be discarded and another specimen substituted from the same heat.

Standard Specification for Silicon Metal[1]

This standard is issued under the fixed designation A 922; 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 three regular grades of silicon metal designated as Grades A, B, and C.

1.2 The values stated in inch-pound units are to be regarded as the standard. The SI equivalents of inch-pound units given may be approximate.

2. Referenced Documents

2.1 *ASTM Standards:*

E 11 Specification for Wire-Cloth Sieves for Testing Purposes[2]

E 29 Practices for Using Significant Digits in Test Data to Determine Conformance with Specifications [2]

E 32 Practices for Sampling Ferroalloys and Steel Additives for Determination of Chemical Composition[3]

E 50 Practices for Apparatus, Reagents, and Safety Precautions for Chemical Analysis of Metals [3]

E 60 Practice for Photometric and Spectrophotometric Methods for Chemical Analysis of Metals [3]

E 360 Test Methods for Chemical Analysis of Silicon and Ferrosilicon[4]

3. Ordering Information

3.1 Orders for material under this specification shall include the following information:

3.1.1 Quantity,

3.1.2 Name of material,

3.1.3 ASTM designation and year of issue,

3.1.4 Grade,

3.1.5 Size, and

3.1.6 Requirements for packaging, analysis reports, etc. as appropriate.

3.2 Although silicon metal is purchased by total net weight, the customary basis of payment is per pound of contained silicon.

4. Chemical Composition

4.1 The grades shall conform to the requirements as to the chemical composition prescribed in Table 1.

4.2 The manufacturer shall furnish an analysis of each shipment showing the silicon content and any other required element.

4.3 Upon request of the purchaser, the manufacturer shall furnish an analysis of any trace elements on a schedule mutually agreed upon between the manufacturer (including their agents) and the purchaser.

5. Size

5.1 The grades of silicon metal are available in sizes listed in Table 2.

5.2 The sizes listed in Table 2 are typical as shipped from the manufacturer's plant. The various grades can exhibit different degrees of friability; therefore some attrition may be expected in transit, storage, and handling. A quantitative test is not available for rating relative friability of silicon metal. A code system has been developed, therefore, for this purpose, and a number rating for each product type is shown in Table 3. Definitions applicable to these code numbers are given in Table 3.

6. Sampling

6.1 The material shall be sampled in accordance with Practices E 32.

6.2 Other methods of sampling mutually agreed upon between the manufacturer and the purchaser may be used; however, in case of discrepancy, Practices E 32 shall be used for referee.

7. Chemical Analysis

7.1 The chemical analysis of the material shall be made in accordance with the procedure for silicon metal as described in Methods E 360 or alternative methods that will yield equivalent results.

7.2 If alternative methods of analysis are used, in case of discrepancy, Methods E 360 shall be used for referee.

7.3 Where no method is given in Methods E 360 for the analysis for a particular element, the analysis shall be made in accordance with a procedure agreed upon between the manufacturer and the purchaser.

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[1] This specification is under the jurisdiction of ASTM Committee A-1 on Steel, Stainless Steel, and Related Alloys and is the direct responsibility of Subcommittee A01.18 on Castings.

Current edition approved Dec. 15, 1993. Published March 1994.

[2] *Annual Book of ASTM Standards*, Vol 14.02.

[3] *Annual Book of ASTM Standards*, Vol 03.05.

[4] *Annual Book of ASTM Standards*, Vol 03.06.

TABLE 1 Chemical Requirements

Element	Composition %		
	Grade A	Grade B	Grade C
Silicon	>98.00	89.00 to 97.99	80.00 to 88.99
Iron	. . .	4.00 max	4.00 max

TABLE 2 Standard Sizes and Tolerances[A]

Standard Sizes	Tolerances	
8 by 2 in. (200 by 50 mm)	60 lb. (27.2 kg) lump, max	10 % max, passing 2 in. (50 mm) sieve
6 in. (150 mm) by down	10 % max, retained on 6 in. (150 mm) sieve	12 % max, passing 8 M sieve
4 in. (100 mm) by down	10 % max, retained on 4 in. (100 mm) sieve	12 % max, passing 8 M sieve
4 by ½ in. (100 by 12.5 mm)	10 % max, retained on 4 in. (100 mm) sieve	10 % max, passing ½in. (12.5 mm) sieve
4 by 1 in. (100 by 25 mm)	10 % max, retained on 4 in. (100 mm) sieve	10 % max, passing 1 in. (25 mm) sieve
3 by ½ in. (75 by 12.5 mm)	12 % max, retained on 3 in. (75 mm) sieve	15 % max, passing ½in. (12.5 mm) sieve
3 by 1 in. (75 by 25 mm)	12 % max, retained on 3 in. (75 mm) sieve	15 % max, passing 1 in. (25 mm) sieve
2 by ½ in. (50 by 12.5 mm)	12 % max, retained on 3 in. (75 mm) sieve	15 % max, passing ½in. (12.5 mm) sieve
1 in. (25 mm) by No. 8	10 % max, retained on 1 in. (25 mm) sieve	10 % max, passing No. 8.
1 in. (25 mm) by down	12 % max, retained on 1 in. (25 mm) sieve	20 % max, passing No. 8.
No. 8 by down	10 % max, retained on No. 8 sieve	. . .
No. 20 by down	10 % max, retained on No. 20 sieve	. . .

[A]Tolerances and sieve sizes defined by Specification E 11.

NOTE 1—For further information, see Practices E 29, E 50, and E 60.

8. Inspection

8.1 The manufacturer shall afford the inspector representing the purchaser all reasonable facilities, without charge, to satisfy the inspector that the material is being furnished in accordance with this specification.

TABLE 3 Friability and Friability Ratings

Product Grade	Proposed Friability Rating
A	5
B	5
C	5

Friability Ratings

Code	Definition
1	Very tough materials that are susceptible to little, if any breakage during shipment or handling. (Example: low carbon ferrochrome.)
2	Some breakage of large pieces probable in shipping and handling. No appreciable fines produced from either lump or crushed sizes. (Example: chrome metal.)
3	Appreciable reduction in size of large pieces possible in shipping and handling. No appreciable production of fines in handling of crushed sizes. (Example: ferrovanadium.)
4	Appreciable reduction in size of large pieces upon repeated handling. Some fines produced upon repeated handling of crushed sizes. (Example: standard ferromanganese.)
5	Appreciable reduction in size in repeated handling of large pieces. Appreciable fines may be produced in the handling of crushed sizes. (Example: 50 % ferrosilicon.)
6	This category represents the most friable alloys. (Example: calcium silicon.)

9. Rejection

9.1 Any claims or rejections shall be made to the manufacturer within 45 days from receipt of material by the purchaser.

10. Packaging

10.1 The material shall be packaged in sound containers, or shipped in bulk, in such a manner that none of the product is lost or contaminated in shipment.

Standard Specification for Centrifugally Cast White Iron/Gray Iron Dual Metal Abrasion-Resistant Roll Shells[1]

This standard is issued under the fixed designation A 942; 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 double pour, centrifugally cast, abrasion-resistant roll shells for general application. The outer layer is white iron and the inner layer is gray iron. There shall be no gradient of mottled iron between the white iron and the gray iron.

1.2 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 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 48 Specification for Gray Iron Castings[2]

E 8 Test Methods for Tension Testing of Metallic Materials[3]

E 10 Test Method for Brinell Hardness of Metallic Materials[3]

3. Classification

3.1 The white iron portion of the casting shall be classified by type based upon Brinell Hardness.

3.2 The gray iron portion of the casting shall be classified by class based upon tensile strength.

4. Ordering Information

4.1 Orders for material to this specification shall include the following:

4.1.1 Specification title, designation, and year of issue,

4.1.2 Quantity of castings required,

4.1.3 Required dimensions and thickness of white iron layer (8.1),

4.1.4 Surface condition—as cast or machined,

4.1.5 Type of white iron required for the outer layer of the casting (7.1),

4.1.6 Class of gray iron required for the inner layer (7.2),

4.1.7 Certification, if required (Section 13), and

4.1.8 Special position of marking information, if required (Section 14).

4.2 Additional requirements may be agreed upon between the manufacturer and the purchaser.

5. Materials and Manufacture

5.1 Both the white and the gray irons may be melted by any suitable melting process.

5.2 The white iron portion of the casting shall be produced by chemistry rather than chilling.

6. Chemical Composition

6.1 A chemical analysis shall be performed by the manufacturer on both the white and gray irons. The chemical compositions shall be controlled to obtain the required mechanical properties.

7. Mechanical Properties

7.1 The white iron shall conform to the following requirements:

Type I — 450 to 500 HB
Type II — 500 to 550 HB
Type III — 550 to 600 HB
Type IV — 600 to 650 HB

7.2 The gray iron shall conform to the following requirements:

Class	Tensile Strength min, ksi	Tensile Strength min, (MPa)
No. 20	20	(138)
No. 25	25	(172)
No. 30	30	(207)
No. 35	35	(241)

8. Other Requirements

8.1 The thickness of the white iron layer shall be a minimum of ½ in.

8.1.1 The thickness of the white iron layer shall be measured on the roll face at each end and shall conform to the specified thickness.

9. Finish and Appearance

9.1 All exterior surfaces shall be machined or ground prior to the rolls being placed into service.

9.2 The manufacturer shall be responsible for providing castings with adequate stock for final machining.

[1] This specification is under the jurisdiction of ASTM Committee A04 on Iron Castings and is the direct responsibility of Subcommittee A04.01 on Gray and White Iron Castings.

Current edition approved Oct. 10, 1995. Published December 1995.

[2] *Annual Book of ASTM Standards*, Vol 01.02.

[3] *Annual Book of ASTM Standards*, Vol 03.01.

9.3 Surfaces and corners of the machined castings shall be free from burrs and extremely sharp edges.

9.4 Machined surfaces of the castings may be protected by the application of a rust and corrosion preventive coating.

10. Sampling

10.1 Each casting shall be tested for chemical composition, hardness, and tensile strength.

10.2 The white iron hardness shall be determined on crop ends removed from the casting.

10.3 The tension test of the gray iron shall be performed on specimens obtained from separately cast test bars poured in accordance with Specification A 48. Standard test bar B shall be the size of the test bar poured.

10.4 Chemical analysis shall be performed on samples obtained during pouring of the iron.

11. Test Methods

11.1 The hardness test shall be performed in accordance with Test Method E 10, using a 10-mm tungsten carbide ball and 3000 kgf load. Test results shall be considered accurate up to 700 HB.

11.2 The tension test shall be performed in accordance with Test Methods E 8.

12. Inspection

12.1 All tests and inspections required by this specification shall be performed by the manufacturer or other reliable source whose services have been contracted by the manufacturer. Complete records of all tests and inspections shall be maintained by the manufacturer, and shall be available for review by the purchaser.

13. Certification

13.1 When specified by the purchaser, the manufacturer's certification shall be furnished to the purchaser stating that the material was manufactured, sampled, tested, and inspected in accordance with this specification. This certification shall include the results of all tests required by this specification and give the thickness of the white iron supplied.

14. Packaging and Package Marking

14.1 When specified by the purchaser, the manufacturer's name or identifying mark shall be stamped at one end in the gray iron portion of the casting. When further specified, the casting identification number shall be stamped at the casting end.

14.2 Unless otherwise specified by the contract or purchase order, castings shall be packed in accordance with the manufacturer's commercial practice to ensure acceptance and safe delivery by the carrier.

15. Keywords

15.1 abrasion-resistant; cast iron; centrifugal casting; dual metal; gray cast iron; roll shell; white cast iron

Designation: A 957 – 03

Standard Specification for Investment Castings, Steel and Alloy, Common Requirements, for General Industrial Use[1]

This standard is issued under the fixed designation A 957; 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 a group of requirements that are mandatory for castings produced by the investment casting process to meet the metallurgical requirements of the following steel casting specifications issued by ASTM.

ASTM Designation	Title of Specification
A 27/A 27M	Steel Castings, Carbon, for General Application
A 148/A 148M	Steel Castings, High-Strength, for Structural Purposes
A 297/A 297M	Steel Castings, Iron-Chromium and Iron-Chromium-Nickel, Heat-Resistant, for General Application
A 447/A 447M	Steel Castings, Chromium-Nickel-Iron Alloy (25-12 Class), for High-Temperature Service
A 494/A 494M	Castings, Nickel and Nickel Alloy
A 560/A 560M	Castings, Chromium-Nickel Alloy
A 732/A 732M	Castings, Investment, Carbon and Low Alloy Steel for General Application, and Cobalt Alloy for High Strength at Elevated Temperatures
A 743/A 743M	Castings, Iron-Chromium, Iron-Chromium-Nickel, Corrosion-Resistant, for General Application
A 744/A 744M	Castings, Iron-Chromium-Nickel, Corrosion Resistant, for Severe Service
A 747/A 747M	Steel Castings, Stainless, Precipitation Hardening
A 890/A 890M	Castings, Iron-Chromium-Nickel-Molybdenum Corrosion-Resistant, Duplex (Austenitic/Ferritic) for General Application
A 915/A 915M	Steel Castings, Carbon and Alloy, Chemical Requirements Similar to Standard Wrought Grades

1.2 This specification also covers a group of supplementary requirements that may be applied to the above specifications as indicated therein. These are provided for use when additional testing or inspection is desired and apply only when specified individually by the purchaser in the order.

1.3 When investment castings are ordered, the requirements stated herein form an integral part of the material specification. In cases of conflict, the requirements of this specification shall take precedence over the individual material specification requirements.

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. Combining values from the two systems may result in nonconformance with the specification. Inch-pound units are applicable for material ordered to Specification A 957 and SI units for material ordered to Specification A 957M.

2. Referenced Documents

2.1 *ASTM Standards:*

A 27/A 27M Specification for Steel Castings, Carbon, for General Application[2]

A 148/A 148M Specification for Steel Castings, High Strength, for Structural Purposes[2]

A 297/A 297M Specification for Steel Castings, Iron-Chromium and Iron-Chromium-Nickel, Heat Resistant, for General Application[2]

A 370 Test Methods and Definitions for Mechanical Testing of Steel Products[3]

A 447/A 447M Specification for Steel Castings, Chromium-Nickel-Iron Alloy (25-12 Class), for High-Temperature Service[4]

A 488/A 488M Practice for Steel Castings, Welding, Qualifications of Procedures and Personnel[2]

A 494/A 494M Specification for Castings, Nickel and Nickel Alloy[2]

A 560/A 560M Specification for Castings, Chromium-Nickel Alloy[2]

[1] This specification is under the jurisdiction of ASTM Committee A01 on Steel, Stainless Steel and Related Alloys and is the direct responsibility of Subcommittee A01.18 on Castings.

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[2] *Annual Book of ASTM Standards*, Vol 01.02.

[3] *Annual Book of ASTM Standards*, Vol 01.03.

[4] Discontinued. See 2002 *Annual Book of ASTM Standards*, Vol 01.02.

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

A 609/A 609M Practice for Castings, Carbon, Low-Alloy, and Martensitic Stainless Steel, Ultrasonic Examination Thereof[2]
A 732/A 732M Specification for Castings, Investment, Carbon and Low Alloy Steel for General Application, and Cobalt Alloy for High Strength at Elevated Temperatures[2]
A 743/A 743M Specification for Castings, Iron-Chromium, Iron-Chromium-Nickel, Corrosion Resistant, for General Application[2]
A 744/A 744M Specification for Castings, Iron-Chromium-Nickel, Corrosion Resistant, for Severe Service[2]
A 747/A 747M Specification for Steel Castings, Stainless, Precipitation Hardening[2]
A 751 Test Methods, Practices, and Terminology for Chemical Analysis of Steel Products[3]
A 800/A 800M Practice for Steel Casting, Austenitic Alloy, Estimating Ferrite Content Thereof[2]
A 890/A 890M Specification for Castings, Iron-Chromium-Nickel-Molybdenum Corrosion-Resistant, Duplex (Austenitic/Ferritic) for General Application[2]
A 903 Specification for Steel Castings, Surface Acceptance Standards, Magnetic Particle and Liquid Penetrant Inspection[2]
A 915/A 915M Specification for Steel Castings, Carbon and Alloy, Chemical Requirements Similar to Standard Wrought Grades[2]
A 941 Terminology Relating to Steel, Stainless Steel, Related Alloys, and Ferroalloys[5]
A 991/A 991M Test Method for Conducting Temperature Uniformity Surveys of Furnaces Used to Heat Treat Steel Products[3]
E 29 Practice for Using Significant Digits in Test Data to Determine Conformance with Specifications[6]
E 94 Guide for Radiographic Examination[7]
E 125 Reference Photographs for Magnetic Particle Indications on Ferrous Castings[7]
E 165 Test Method for Liquid Penetrant Examination[7]
E 186 Reference Radiographs for Heavy-Walled (2 to 4½–in. (51 to 114-mm)) Steel Castings[7]
E 192 Reference Radiographs for Investment Steel Castings of Aerospace Applications[7]
E 280 Reference Radiographs for Heavy-Walled (4½ to 12-in. (114 to 305-mm)) Steel Castings[7]
E 353 Test Methods for Chemical Analysis of Stainless, Heat-Resisting, Maraging, and Other Similar Chromium-Nickel-Iron Alloys[8]
E 354 Test Methods for Chemical Analysis of High-Temperature, Electrical, Magnetic, and Other Similar Iron, Nickel, and Cobalt Alloys[8]
E 446 Reference Radiographs for Steel Castings Up to 2 in. (51 mm) in Thickness[7]
E 709 Guide for Magnetic Particle Examination[7]

2.2 *SAE Aerospace Recommended Practice:*.

ARP 1341 Determining Decarburization and Carburization in Finished Parts of Carbon and Low-Alloy Steel[9]

3. Terminology

3.1 *Definitions*—The definitions in Test Methods and Definitions A 370, Test Methods, Practices, and Terminology A 751, and Terminology A 941 are applicable to this specification and to those listed in 1.1.

3.2 *Definitions of Terms Specific to This Standard:*

3.2.1 *investment casting*, *n*—a metal casting that is produced in a mold obtained by investing (surrounding) an expendable pattern with a ceramic slurry that is allowed to solidify. The expendable pattern may consist of wax, plastic, or other material and is removed prior to filling the mold with liquid metal.

3.2.2 *master heat*, *n*—a quantity of metal processed in a single furnace or refining vessel at one time in such a manner as to produce the desired composition and properties.

3.2.3 *sub-heat*, *n*—a portion of a master heat remelted without additional processing for pouring into castings. Synonyms: melt, production heat.

4. Materials and Manufacture

4.1 *Melting Process*—Master heats shall be made by the electric furnace process with or without separate refining such as argon-oxygen-decarburization (AOD), vacuum-oxygen-degassing (VOD), vacuum-induction-melting (VIM), and so forth, unless otherwise specified in the individual specification or agreed upon between the customer and producer. Master heats may be used directly for producing castings or converted into ingot, bar, shot, or other suitable form, not including gates and risers from casting production, for later remelting as a sub-heat.

4.2 *Re-melting Process*—Sub-heats shall be produced from master heat metal in suitable batch sizes by electric induction furnace with or without atmosphere protection such as vacuum or inert gas unless otherwise specified in the individual specification or agreed upon between the customer and producer. Revert (gates, sprues, risers, and rejected castings) shall not be re-melted except in master heats.

4.3 *Sampling*:

4.3.1 If castings are poured directly from one or more master heats, then the samples for chemical and other required testing shall also be poured directly from each of the master heats.

4.3.2 If castings are poured from a sub-heat, then the samples for chemical and other required testing shall also be poured from a sub-heat of that same master heat, but not necessarily from the same sub-heat as the castings. The sub-heat used for the test samples shall be produced using the same practices and additions as used for the castings.

4.3.3 Unless otherwise specified by the purchaser, test specimens may be taken from castings or from coupons cast integrally with the castings, in the same molds as the castings, or in separate molds.

[5] *Annual Book of ASTM Standards*, Vol 01.01.
[6] *Annual Book of ASTM Standards*, Vol 14.02.
[7] *Annual Book of ASTM Standards*, Vol 03.03.
[8] *Annual Book of ASTM Standards*, Vol 03.05.

[9] Available from Society of Automotive Engineers, Inc., 400 Commonwealth Dr., Warrendale, PA 15096-0001.

4.4 *Heat Treatment*

4.4.1 Castings shall be heat treated in the working zone of a furnace that has been surveyed in accordance with Test Method A 991/A 991M.

4.4.2 When castings are heat treated at temperatures above 2000°F (1100°C), then the working zone shall have been established by a survey performed at not more than 25°F (15°C) below nor more than 200°F (110°C) above the minimum heat treatment temperature specified for the grade. If a minimum heat treatment temperature is not specified for the grade, then the survey temperature shall be not more than 50°F (30°C) below nor more than 175°F (100°C) above the furnace set point used.

4.4.3 The maximum variation in measured temperature as determined by the difference between the highest temperature and the lowest temperature shall be as agreed between the purchaser and producer except that during production heat treatment no portion of the furnace shall be below the minimum specified temperature nor above the maximum specified temperature for the grade being processed.

5. Chemical Composition

5.1 *Chemical Analysis*—Chemical analysis of materials covered by this specification shall be in accordance with Test Methods, Practices, and Terminology A 751.

5.2 *Heat Analysis*—An analysis of samples obtained in accordance with 4.3 or Supplementary Requirement S17 as appropriate, shall be made by the manufacturer to determine the percentages of the elements specified in the individual specification for the grade being poured. When drillings are used, they shall be taken not less than 1⁄16 in. [1.6 mm] beneath the surface. The chemical composition thus determined shall conform to the requirements in the individual specification for the grade being poured.

5.3 *Product Analysis*—A product analysis may be made by the purchaser from material representing each master heat, sub-heat, lot, or casting. The analysis shall be made on representative material. Samples for carbon analysis of carbon and alloy steel shall be taken no closer than 1⁄16 in. [1.6 mm] to a cast surface, except that castings too thin for this shall be analyzed on representative material. The chemical composition thus determined shall meet the requirements specified in the applicable specification for the grade involved, or shall be subject to rejection by the purchaser, except that the chemical composition determined for carbon and low alloy steel castings may vary from the specified limits by the amounts shown in Table 1. The product analysis tolerances of Table 1 are not applicable as acceptance criteria for heat analysis by the casting manufacturer. When comparing product and heat analysis for other than carbon and low alloy steels, the reproducibility Data R2, in Test Methods E 353 or E 354, as applicable, shall be taken into consideration.

5.4 *Unspecified Elements*—When chemical analysis for elements not specified for the grade ordered is desired, Supplementary Requirement S13 may be specified.

NOTE 1—All commercial metals contain small amounts of various elements in addition to those that are specified. It is neither practical nor necessary to specify limits for every unspecified element that might be present, despite the fact that the presence of many of these elements is often routinely determined by the producer.

TABLE 1 Product Analysis Tolerances

Element	Range, %[A]	Tolerances[B,C] Over Maximum or Under Minimum Limit, %
C	up to 0.65	$0.03 \times \%\ C_L + 0.02$
	above 0.65	0.04
Mn	up to 1	$0.08 \times \%\ Mn_L + 0.01$
	above 1	0.09
Si	up to 0.60	$0.22 \times \%\ Si_L - 0.01$
	above 0.60	0.15
P	all	$0.13 \times \%\ P_L + 0.005$
S	all	$0.36 \times \%\ S_L + 0.001$
Ni	up to 2	$0.10 \times \%\ Ni_L + 0.03$
	above 2	0.25
Cr	up to 2	$0.07 \times \%\ Cr_L + 0.04$
	above 2	0.18
Mo	up to 0.6	$0.04 \times \%\ Mo_L + 0.03$
	above 0.6	0.06
V	up to 0.25	$0.23 \times \%\ V_L + 0.004$
	above 0.25	0.06
W	up to 0.10	$0.08 \times \%\ W_L + 0.02$
	above 0.10	0.02
Cu	up to 0.15	$0.18 \times \%\ Cu_L + 0.02$
	above 0.15	0.05
Al	up to 0.10	$0.08 \times \%\ Al_L + 0.02$
	above 0.10	0.03

[A] The range denotes the composition limits up to which tolerances are computed by the equation, and above which the tolerances are given by a constant.

[B] The subscript L for the elements in each equation indicates that the limits of the element specified by the applicable specification are to be inserted into the equation to calculate the tolerance for the upper limit and the lower limit (if applicable), respectively. Examples of computing tolerances are presented in footnote C.

[C] To illustrate the computation of the tolerance, consider the manganese maximum of 0.70 for an 0.30 carbon grade 65-35 in Specification A 27/A 27M. The maximum permissible deviation is ($0.08 \times 0.70 + 0.01$) = 0.066. Therefore, the highest acceptable product analysis is 0.766. Similarly, for an 0.20 carbon grade 70-40 in Specification A 27/A 27M, the maximum manganese content is 1.40; thus, the highest acceptable product analysis is (1.40 + 0.09) = 1.49.

5.5 The substitution of a grade or composition different from that specified by the purchaser is prohibited.

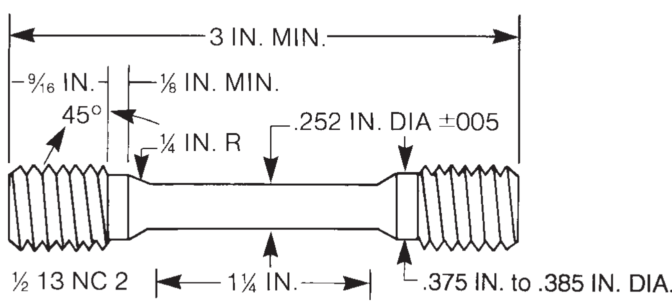


FIG. 1 Design and Dimensions of the ICI Test Bar

6. Tensile Requirements

6.1 The individual product specifications vary as to whether tension tests are required; for this reason, and to determine specific test requirements, the individual product specification should be reviewed. If tension testing is required by the product specification, sampling shall be in accordance with 4.3 or with Supplementary Requirement S18 as appropriate.

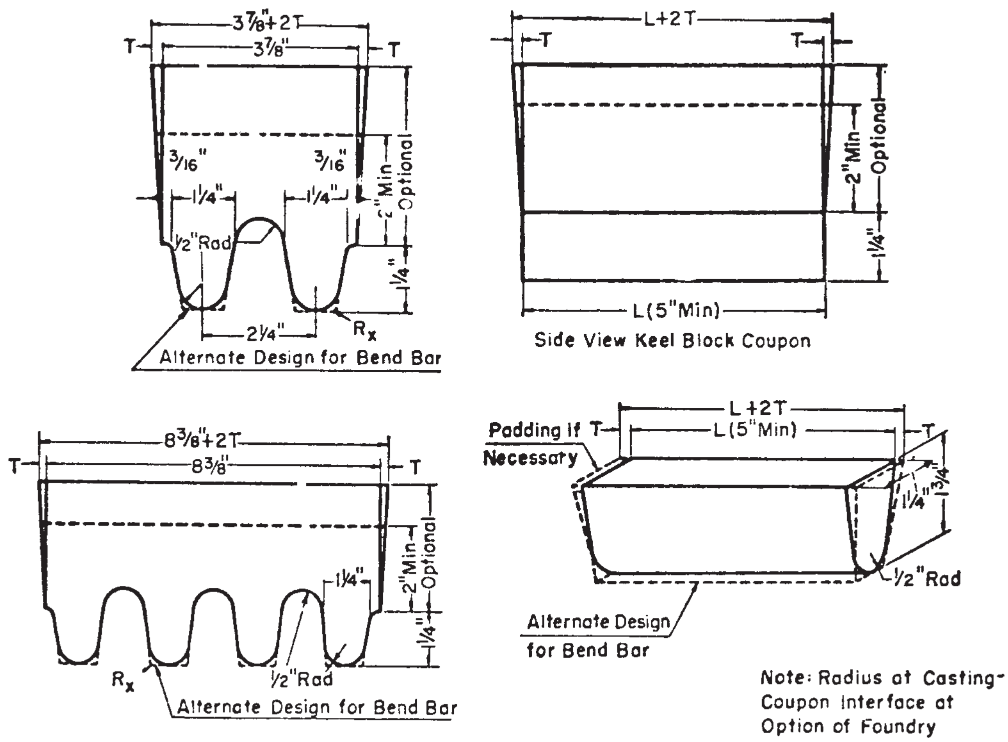
6.2 Unless otherwise specified by the purchaser, when mechanical properties are required by the product specification, test coupons may be taken from castings, may be cast integrally with the castings, or may be cast in separate molds of the same type and material as those used for the castings, in accordance with Fig. 1, Fig. 2, Fig. 3, or Fig. 4, except when Supplementary Requirement S15 is specified. The test coupon in Fig. 4 shall be employed only for austenitic alloy castings with cross sections less than 2½ in.[10]

6.3 The coupon from which the test specimen is taken shall be heat treated in production furnaces to the same procedure as the castings it represents.

6.4 The specimens may be cast to shape or machined from coupons to dimensions in accordance with Test Methods and Definitions A 370 or the ICI bar shown in Fig. 1.

6.5 If any specimen shows defective machining or develops flaws, it may be discarded and another substituted from the same master heat.

6.6 To determine conformance with the tension test requirements, an observed value or calculated value shall be rounded off in accordance with Practice E 29 to the nearest 500 psi [5 MPa] for yield and tensile strength and to the nearest 1 % for elongation and reduction of area.



NOTE 1—*Test Coupons for Large and Heavy Steel Castings*—The test coupons in Fig. 2 are to be used for large and heavy steel castings. However, at the option of the foundry the cross-sectional area and length of the standard coupon may be increased as desired.

NOTE 2—*Bend Bar*—If a bend bar is required, an alternate design (as shown by dotted lines in Fig. 2) is indicated.

FIG. 2 Test Coupons for Castings with Details of Design

7. Workmanship, Finish, and Appearance

7.1 All castings shall be made in a workmanlike manner and shall conform to the dimensions on drawings furnished by the purchaser before manufacture is started. If the pattern is supplied by the purchaser or is produced using a die supplied by the purchaser, the dimensions of the casting shall be as predicated by the pattern or die.

8. Quality

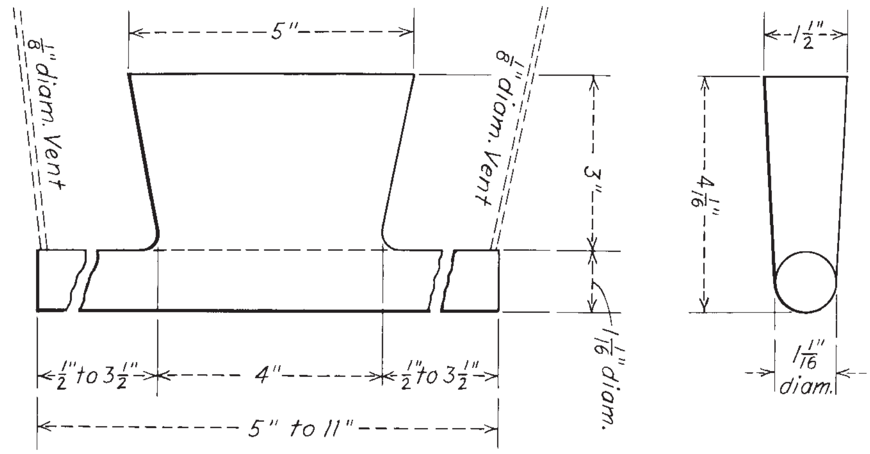
8.1 The surface of the casting shall be free of adhering ceramic, scale, cracks, and hot tears as determined by visual examination. Other surface discontinuities shall meet the visual acceptance standards specified in the order. Unacceptable visual surface discontinuities shall be removed and their removal verified by visual examination of the resultant cavities.

8.2 When additional inspection is desired, Supplementary Requirements S1, S2, S3, S4, or S5 may be specified.

9. Repair

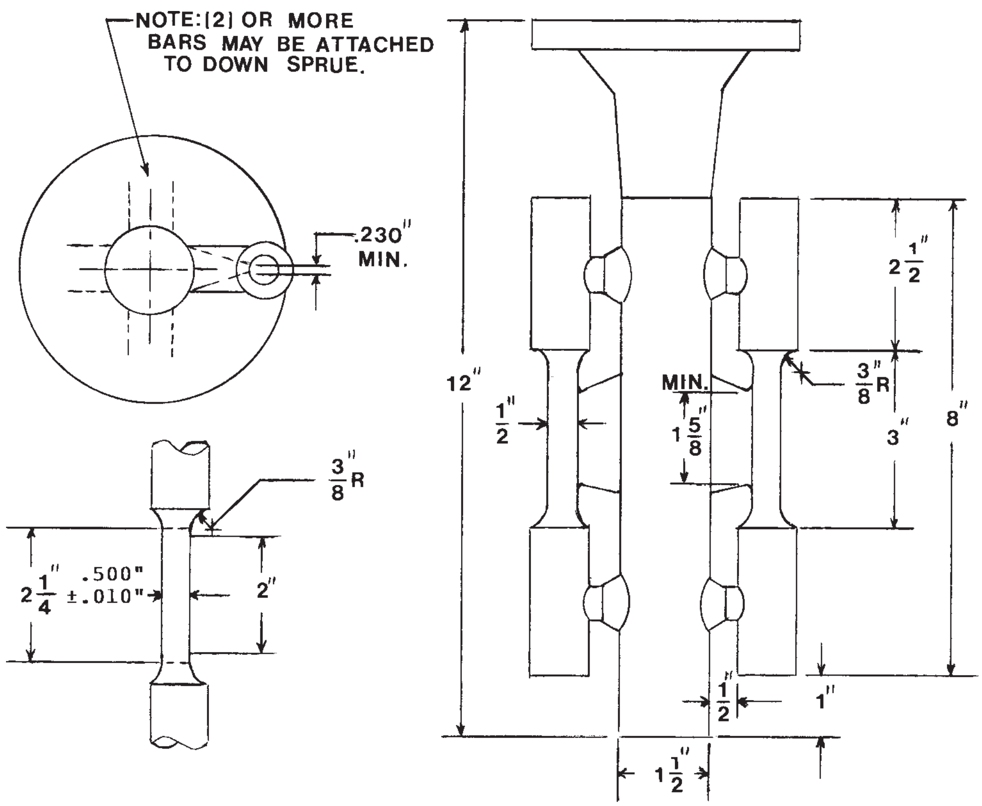
9.1 Repair by welding shall be in accordance with the requirements of the individual specification using procedures and welders qualified in accordance with Practice A 488/A 488M.

[10] Information on the relationship of mechanical properties determined on test coupons obtained as specified in 6.2 with those obtained from the casting may be found in "The Steel Casting Handbook," Fifth Edition, Steel Founders' Society of America, 1980, pp. 15–35 through 15–43.



NOTE—Pour through head; cover molten head with powdered charcoal, coke dust, and so forth, immediately after pouring, in order to keep head fluid as long as possible.

FIG. 3 Test Block for Tension Test Specimen



NOTE—Coupons produced in this manner are suitable for austenitic alloys only. The mold may be preheated for pouring to produce a sound coupon.

FIG. 4 Cast-To-Shape Test Coupon for Tension Specimen

10. Inspection

10.1 The manufacturer shall afford the purchaser's inspector all reasonable facilities necessary to satisfy that the material is being produced and furnished in accordance with the applicable specification. Foundry inspection by the purchaser shall not interfere unnecessarily with the manufacturer's operations. All tests and inspections, with the exception of product analysis (5.3), are the responsibility of the manufacturer.

11. Rejection

11.1 Subsequent to acceptance at the manufacturer's works, material that is found to be unacceptable as determined by requirements specified in the order may be rejected by the purchaser. The manufacturer should be notified of such rejection. If the manufacturer is dissatisfied with the results of any tests performed by the purchaser, he may make claim for a rehearing.

12. Keywords

12.1 casting; investment casting; master heat; sub-heat

SUPPLEMENTARY REQUIREMENTS

Supplementary requirements shall be applied only when specified by the purchaser. Details of the supplementary requirements shall be agreed upon between the manufacturer and purchaser. The specified tests shall be performed by the manufacturer prior to shipment of the castings.

S1. Magnetic Particle Examination

S1.1 Castings shall be examined for surface and near surface discontinuities by magnetic particle examination. The examination shall be in accordance with Practice E 709. The extent of examination and the basis for acceptance shall be agreed upon between the manufacturer and the purchaser. Specification A 903 may be used as a basis for such agreement.

S2. Radiographic Examination

S2.1 Castings shall be examined for internal defects by means of X-rays or gamma rays. The procedure shall be in accordance with Guide E 94, and types and degrees of discontinuities considered shall be judged by Reference Radiographs E 186, E 192, E 280, or E 446. Extent of examination and basis for examination shall be agreed upon between the manufacturer and purchaser.

S3. Liquid Penetrant Examination

S3.1 Castings shall be examined for surface discontinuities by means of liquid penetrant examination. The examination shall be in accordance with Practice E 165. Areas to be inspected, methods and types of liquid penetrants to be used, developing procedure, and basis for acceptance shall be agreed upon between the manufacturer and purchaser. Specification A 903 may be used as a basis for such agreement.

S4. Ultrasonic Examination

S4.1 Castings shall be examined for internal defects by means of ultrasonic examination. The examination procedure shall be in accordance with Practice A 609/A 609M. Extent of examination, methods of testing, and basis for acceptance shall be agreed upon between the manufacturer and purchaser.

S5. Examination of Weld Preparation

S5.1 Magnetic particle or liquid penetrant examination of cavities prepared for welding shall be performed to verify removal of those discontinuities found unacceptable by the examination method specified for the casting. Unless other degrees of shrinkage or types of discontinuities found in the cavities are specified, Type II, Internal Shrinkage, of Reference Photographs E 125, of Degree 2 in sections up to 2 in. [50.8 mm] thick and of Degree 3 in sections over 2 in. thick shall be acceptable.

S6. Certification

S6.1 The manufacturer's certification shall be furnished to the purchaser stating that the material was manufactured, sampled, tested, and inspected in accordance with the material specification (including year date) and was found to meet the requirements.

S7. Prior Approval of Major Weld Repairs

S7.1 Major weld repairs as defined and agreed upon between the manufacturer and purchaser shall be subject to the prior approval of the purchaser.

S8. Marking

S8.1 The castings shall be marked for identification or traceability, or both. The content of the marking and the method of marking, including size, location, and style, shall be as agreed upon between the purchaser and the producer.

S9. Charpy Impact Test

S9.1 Charpy impact test properties shall be determined from a set of three Charpy V-notch specimens made from a test coupon in accordance with Test Methods and Definitions A 370, and tested at a test temperature agreed upon between the manufacturer and the purchaser. The sampling requirements shall be agreed upon between the manufacturer and purchaser (see 4.3). The acceptance requirements shall be energy absorbed, lateral expansion, or percent shear area, or any combination thereof, and shall be that agreed upon between the manufacturer and purchaser. Test specimens shall be prepared as Type A and tested in accordance with Test Methods and Definitions A 370.

S9.2 *Absorbed Energy*—Average energy value of three specimens shall be not less than specified, with not more than one value permitted to fall below the minimum specified and no value permitted below the minimum specified for a single specimen.

S9.3 *Lateral Expansion*—Lateral expansion value shall be agreed upon between the manufacturer and purchaser.

S9.4 *Percent Shear Area*—Percent shear area shall be agreed upon between the manufacturer and purchaser.

S10. Hardness Test

S10.1 Hardness measurements at specified locations of the castings shall be made in accordance with Test Methods and Definitions A 370 and reported.

S11. Specified Ferrite Range

S11.1 The chemical composition of the heat shall be controlled such that the ferrite content, as determined by the chemical composition procedure of Practice A 800/A 800M shall be in conformance with the specified ferrite content range.

S11.2 The specified ferrite content shall be as agreed upon between the manufacturer and the purchaser. If both minimum and maximum ferrite contents are specified, the minimum specified ferrite content range shall be 10 %. The minimum specified ferrite content shall be no lower than the percent necessary to achieve the minimum mechanical properties required for the alloy.

S11.3 Should the purchaser wish to have the ferrite content determined by either the magnetic response or metallographic methods, the purchaser should impose Supplementary Requirement S1 or S2 of Practice A 800/A 800M.

S12. Test Report

S12.1 The manufacturer shall supply a test report to the purchaser giving the results of all tests required to be performed, including chemical analysis.

S13. Unspecified Elements

S13.1 Chemical analysis and limits for elements not specified for the grade ordered shall be as agreed upon between the manufacturer and purchaser.

S14. Tension Test from Castings

S14.1 In addition to the tension test required by the material specification, test material shall be cut from the casting. The mechanical properties and location for the test material shall be agreed upon between the manufacturer and purchaser.

S15. Alternate Tension Test Coupons and Specimen Locations for Castings (in lieu of Test Bars Poured from Special Coupons)

S15.1 Test coupons may be cast integrally with the mold in which the castings are produced or in separate molds. Test coupons shall be heat treated together with the castings they represent.

S15.2 The dimensions of the test coupon, the number and locations of the specimens, and the limits for the mechanical properties shall be agreed upon between the manufacturer and purchaser.

S16. Weld Repair Charts

S16.1 Weld repairs made to correct leakage on hydrostatic testing, or weld repairs for which the depth of the cavity required for welding exceeds 20 % of the actual wall thickness or 1 in. [25 mm], whichever is smaller, or weld repairs for which the area of the cavity required for welding exceeds approximately 10 in.^{2} [65 mm^2] shall be documented.

S16.2 Weld repairs requiring documentation shall be documented on sketches or photographs, or both. The sketches or photographs shall show the location and major dimensions of cavities prepared for weld repair. The weld repair documentation shall be submitted to the purchaser at the completion of the order.

S17. Increased Testing Frequency—Chemical Analysis

S17.1 Frequency of chemical analysis shall be as agreed upon between the purchaser and manufacturer.

S18. Increased Testing Frequency—Tensile Testing

S18.1 Frequency of tension tests shall be as agreed upon between the purchaser and manufacturer.

S19. Decarburization

S19.1 A representative casting or coupon shall be evaluated for total or complete decarburization, or both, in accordance with ARP 1341.

S19.2 The basis for acceptance shall be agreed upon between the purchaser and manufacturer. An example of an acceptance specification is: zero total decarburization and no more than 0.020 in. partial decarburization.

S20. Metallurgical Cleanliness

S20.1 After polishing, each casting shall be visually inspected for nonmetallic inclusions and porosity.

S20.2 The details of the method for inspection and the basis for acceptance shall be agreed upon between the purchaser and manufacturer.

S20.3 It is realized that the foundry may be unable to perform the inspection for metallurgical cleanliness prior to shipment, or that the purchaser may wish to defer inspection until after additional work or machining has been performed on the casting. However, the foundry is responsible for the satisfactory performance of the castings under the final inspection required in S20.1.

SUMMARY OF CHANGES

Committee A01 has identified the location of selected changes to this standard since the last issue (A 957–01a) that may impact the use of this standard.

(1) Added 4.4 to include requirements for performing temperature uniformity surveys of heat treatment furnaces.

Designation: A 958 – 00

Standard Specification for Steel Castings, Carbon and Alloy, with Tensile Requirements, Chemical Requirements Similar to Standard Wrought Grades[1]

This standard is issued under the fixed designation A 958; 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 carbon and low-alloy steel castings having chemical analyses similar to that of the standard wrought grades.

1.2 Several classes are covered and are designated by chemical composition as shown in Table 1.

1.3 Options for tensile properties are shown in Tables 2 and 3.

1.4 *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 must be used independently of the other. Combining values from the two systems may result in nonconformance with the specification. Inch-pound units are applicable for material ordered to Specification A 958 and SI units for material ordered to Specification A 958.*

2. Referenced Documents

2.1 *ASTM Standards:*

A 370 Test Methods and Definitions for Mechanical Testing of Steel Products[2]

A 488/A 488M Practice for Steel Castings, Welding, Qualification of Procedures and Personnel[2]

A 781/A 781M Specification for Castings, Steel and Alloy, Common Requirements, for General Industrial Use[2]

E 29 Practice for Using Significant Digits in Test Data to Determine Conformance with Specifications[3]

3. General Conditions for Delivery

3.1 Material furnished to this specification shall conform to the requirements of Specification A 781/A 781M, including any supplementary requirements that are indicated in the purchase order. Failure to comply with the general requirements of Specification A 781/A 781M constitutes nonconformance with this specification. In case of conflict between the requirements of this specification and Specification A 781/A 781M, this specification shall prevail.

4. Ordering Information

4.1 Orders for material under this specification should include the following information.

4.1.1 Quantity,

4.1.2 Specification, including year and date of issue,

4.1.3 Grade and class of steel,

4.1.4 Description of the casting by pattern number or drawing (Dimensional tolerances should be included on the casting drawing.),

4.1.5 Options in the specification, and

4.1.6 Supplementary requirements desired, including standards of acceptance.

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[1] This specification is under the jurisdiction of ASTM Committee A01 on Ferrous Metals and is the direct responsibility of Subcommittee A01.18 on Castings.

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[2] *Annual Book of ASTM Standards*, Vol 01.02.

[3] *Annual Book of ASTM Standards*, Vol 14.02.

TABLE 1 Chemical Composition, Weight Percent

NOTE 1—Values are maximum unless a range is given.

Grade	C	Mn	P	S	Si	Ni	Cr	Mo
SC 1020	0.18/0.23	0.40/0.80	0.040	0.040	0.30/0.60	-	-	-
SC 1025	0.22/0.28	0.40/0.80	0.040	0.040	0.30/0.60	-	-	-
SC 1030	0.28/0.34	0.50/0.90	0.040	0.040	0.30/0.60	-	-	-
SC 1040	0.37/0.44	0.50/0.90	0.040	0.040	0.30/0.60	-	-	-
SC 1045	0.43/0.50	0.50/0.90	0.040	0.040	0.30/0.60	-	-	-
SC 4130	0.28/0.33	0.40/0.80	0.035	0.040	0.30/0.60	-	0.80/1.10	0.15/0.25
SC 4140	0.38/0.43	0.70/1.10	0.035	0.040	0.30/0.60	-	0.80/1.10	0.15/0.25
SC 4330	0.28/0.33	0.60/0.90	0.035	0.040	0.30/0.60	1.65/2.00	0.70/0.90	0.20/0.30
SC 4340	0.38/0.43	0.60/0.90	0.035	0.040	0.30/0.60	1.65/2.00	0.70/0.90	0.20/0.30
SC 8620	0.18/0.23	0.60/1.00	0.035	0.040	0.30/0.60	0.40/0.70	0.40/0.60	0.15/0.25
SC 8625	0.23/0.28	0.60/1.00	0.035	0.040	0.30/0.60	0.40/0.70	0.40/0.60	0.15/0.25
SC 8630	0.28/0.33	0.60/1.00	0.035	0.040	0.30/0.60	0.40/0.70	0.40/0.60	0.15/0.25

TABLE 2 Tensile Requirements

Class	65/35	70/36	80/40	80/50	90/60	105/85	115/95	130/115	135/125	150/135	160/145	165/150	210/180
Tensile, ksi	65	70	80	80	90	105	115	130	135	150	160	165	210
Tensile, (MPa)	(450)	(485)	(550)	(550)	(620)	(725)	(795)	(895)	(930)	(1035)	(1105)	(1140)	(1450)
Yield, ksi	35	36	40	50	60	85	95	115	125	135	145	150	180
Yield, (MPa)	(240)	(250)	(275)	(345)	(415)	(585)	(655)	(795)	(860)	(930)	(1000)	(1035)	(1240)
Elongation in 2 in. or 50 mm, min, %	24	22	18	22	18	17	14	11	9	7	6	5	4
Reduction of Area, %	35	30	30	35	35	35	30	25	22	18	12	10	8

TABLE 3 Tensile Requirements/Grade Suitability

Class	65/35	70/36	80/40	80/50	90/60	105/85	115/95	130/115	135/125	150/135	160/145	165/150	210/180
Grade													
SC 1020	X[A]	X											
SC 1025	X	X											
SC 1030	X	X	X	X									
SC 1040	X[B]	X	X	X	X								
SC 1045	X[B]	X[B]	X	X	X	X	X						
SC 4130	X[B]	X[B]	X	X	X	X	X	X	X	X			
SC 4140	X[B]	X[B]	X[B]	X[B]	X	X	X	X	X	X	X	X	
SC 4330	X[B]	X[B]	X[B]	X[B]	X	X	X	X	X	X	X	X	X
SC 4340	X[B]	X[B]	X[B]	X[B]	X[B]	X	X	X	X	X	X	X	X
SC 8620	X[B]	X[B]	X	X	X	X	X						
SC 8625	X[B]	X[B]	X	X	X	X	X	X	X				
SC 8630	X[B]	X[B]	X	X	X	X	X	X	X	X			

[A] "X" denotes that the properties may be achieved by at least one of the heat treatments referenced in 5. The effect of section thickness should be considered in making grade selections. The heat treatment requirements do not imply that all section thicknesses will be through hardened.

[B] These grades are likely to significantly exceed the minimum strength levels, therefore, problems may be experienced when trying to produce castings to low hardness values.

5. Heat Treatment

5.1 All castings shall receive a heat treatment indicated in Table 4. Preliminary heat treatment prior to final heat treatment as well as multiple tempering is permitted.

TABLE 4 Heat Treatment

NOTE 1—The effect of section thickness should be considered in making grade selections. The heat treatment requirements do not imply that all section thicknesses will be through hardened.

NOTE 2—Post-weld heat treatment must be at or below the final tempering temperature.

NOTE 3—Following quenching the castings must be cooled below 500°F (260°C) prior to tempering.

Grade	Class	Austenitizing Temperature, min, °F (°C)	Media	Tempering Temperature, min,° F (°C)
SC1020	65/35	1700 (925)	A[A]	–
	70/36	1700 (925)	A	–
SC1025	65/35	1700 (925)	A	–
	70/36	1700 (925)	A	–
SC1030	65/35	1650 (900)	A	–
	70/36	1650 (900)	A	1100 (595)
	80/40	1650 (900)	L[A]	1100 (595)
	80/50	1650 (900)	L	1100 (595)
SC1040	65/35[B]	1650 (900)	A	1150 (621)
	70/36	1650 (900)	A	1150 (621)
	80/40	1650 (900)	A	1150 (621)
	80/50	1650 (900)	A	1100 (595)
	90/60	1650 (900)	A	1100 (595)
SC1045	65/35[B]	1600 (870)	A	1150 (621)
	70/36[B]	1600 (870)	A	1150 (621)
	80/40	1600 (870)	A	1150 (621)
	80/50	1600 (870)	A	1150 (621)
	90/60	1600 (870)	A	1100 (595)
	105/85	1600 (870)	A	1100 (595)
	115/95	1600 (870)	A	1050 (565)
SC4130	65/35[B]	1650 (900)	A	1200 (650)
	70/36[B]	1650 (900)	A	1200 (650)
	80/40	1650 (900)	A	1200 (650)
	80/50	1650 (900)	A	1200 (650)
	90/60	1650 (900)	A or L	1150 (621)
	105/85	1650 (900)	L	1100 (595)
	115/95	1650 (900)	L	1100 (595)
	130/115	1650 (900)	L	1000 (538)
	135/125	1650 (900)	L	1000 (538)
	150/135	1650 (900)	L	1000 (538)
SC4140	65/35[B]	1600 (870)	A	1200 (650)
	70/36[B]	1600 (870)	A	1200 (650)
	80/40[B]	1600 (870)	A	1200 (650)
	80/50[B]	1600 (870)	A	1150 (621)
	90/60	1600 (870)	A	1150 (621)
	105/85	1600 (870)	A or L	1150 (621)
	115/95	1600 (870)	L	1050 (566)
	130/115	1600 (870)	L	1000 (538)
	135/125	1600 (870)	L	1000 (535)
	150/135	1600 (870)	L	950 (510)
	160/145	1600 (870)	L	950 (510)
	165/150	1600 (870)	L	950 (510)
SC4330	65/35[B]	1650 (870)	A	1200 (650)
	70/36[B]	1650 (870)	A	1200 (650)
	80/40[B]	1650 (870)	A	1200 (650)
	80/50[B]	1650 (870)	A	1200 (650)
	90/60	1650 (870)	A or L	1150 (620)
	105/85	1650 (870)	L	1100 (595)
	115/95	1650 (870)	L	1100 (595)
	130/115	1650 (870)	L	1000 (535)
	135/125	1650 (870)	L	1000 (535)
	150/135	1650 (870)	L	1000 (535)
	160/145	1650 (870)	L	950 (510)
	165/150	1650 (870)	L	950 (510)
	210/180	1650 (870)	L	900 (482)

TABLE 4 *Continued*

Grade	Class	Austenitizing Temperature, min, °F (°C)	Media	Tempering Temperature, min,° F (°C)
SC4340	65/35[B]	1600 (870)	A	1200 (650)
	70/36[B]	1600 (870)	A	1200 (650)
	80/40[B]	1600 (870)	A	1200 (650)
	80/50[B]	1600 (870)	A	1150 (620)
	90/60[B]	1600 (870)	A	1150 (620)
	105/85	1600 (870)	A	1150 (620)
	115/95	1600 (870)	A or L	1050 (565)
	130/115	1600 (870)	L	1000 (535)
	135/125	1600 (870)	L	1000 (535)
	150/135	1600 (870)	L	950 (510)
	160/145	1600 (870)	L	950 (510)
	165/150	1600 (870)	L	950 (510)
	210/180	1600 (870)	L	900 (480)
SC8620	65/35[B]	1700 (925)	A	1200 (650)
	70/36[B]	1700 (925)	A	1200 (650)
	80/40	1700 (925)	A	1150 (620)
	80/50	1700 (925)	A or L	1150 (620)
	90/60	1700 (925)	L	1150 (620)
	105/85	1700 (925)	L	1100 (595)
	115/95	1700 (925)	L	1050 (565)
SC8625	65/35[B]	1700 (925)	A	1200 (650)
	70/36[B]	1700 (925)	A	1200 (650)
	80/40	1700 (925)	A or L	1150 (620)
	80/50	1700 (925)	A or L	1150 (620)
	90/60	1700 (925)	A or L	1150 (620)
	105/85	1700 (925)	L	1100 (595)
	115/95	1700 (925)	L	1100 (595)
	130/115	1700 (925)	L	1100 (595)
	135/125	1700 (925)	L	1050 (565)
SC8630	65/35[B]	1650 (900)	A	1200 (650)
	70/36[B]	1650 (900)	A	1200 (650)
	80/40	1650 (900)	A	1150 (620)
	80/50	1650 (900)	A	1150 (620)
	90/60	1650 (900)	A or L	1150 (620)
	105/85	1650 (900)	L	1100 (595)
	115/95	1650 (900)	L	1100 (595)
	130/115	1650 (900)	L	1100 (595)
	135/125	1650 (900)	L	1050 (565)
	150/135	1650 (900)	L	1050 (565)

[A] A = air cool (normalize).
L = Liquid quench. (Steels with carbon levels of 0.33 % and higher may exhibit cracks when quenched in water).
[B] These grades are likely to significantly exceed the minimum strength levels, therefore, problems may be experienced when trying to produce castings to low hardness values.

5.2 Heat treatment shall be performed after the castings have been allowed to cool below the transformation range.

5.3 The furnace temperature for heat treating shall be effectively controlled by the use of recording-type pyrometers.

6. Chemical Composition

6.1 The steel shall conform to the requirements of chemical composition as prescribed in Table 1.

6.2 The product analysis tolerances given in Specification A 781/A 781M shall apply to all product analyses performed on castings supplied to this specification.

7. Tensile Requirements

7.1 One tension test shall be made from each heat and shall conform to the tensile requirements specified for the grade selected in Tables 2 and 3.

7.2 Tension test coupons shall be machined in accordance with Paragraph 9 of Test Methods and Definitions A 370 and tested in accordance with those methods.

7.3 To determine conformance with the tension test requirements, an observed value or calculated value shall be rounded in accordance with Practice E 29 to the nearest 500 psi [5 MPa] for yield point and tensile strength and to the nearest 1 % for elongation and reduction of area.

8. Repair by Welding

8.1 Repairs shall be made using procedures and welders qualified in accordance with Practice A 488/A 488M.

8.2 Repair welds shall be inspected to the same quality standards that are used to inspect the castings. When castings are produced with Supplementary Requirement S1 specified, weld repairs shall be inspected by magnetic particle examination to the same standards that are used to inspect the castings. When castings are produced with Supplementary S2 or S4, or both, as specified, weld repairs in which the depth of the cavity prepared for weld repair exceeds 20 % of the wall thickness or 1 in. (25 mm), whichever is smaller, or in which the cavity prepared for welding is greater than approximately 10 in.^{2} (65 cm^2, shall be radiographed or ultrasonically tested, or both, to the same standards that are used to inspect the castings.

8.3 For all classes of Grades SC1020, SC1025, and SC1030, welds exceeding 20 % of the wall thickness or 1 in. (25 mm), whichever is smaller, or exceeding approximately 10 in.^{2} (65 cm^2) in area, shall be thermally stress-relieved or completely reheat-treated. All other grades and classes shall be thermally stress-relieved or completely reheat-treated following any repair welds.

9. Test Coupons and Specimens

9.1 Test bars shall be poured from the same heat as the castings represented. Test coupons may be cast integrally with the castings or as separate blocks similar to those shown in Fig. 1 of Specification A 781/A 781M.

9.2 The bar from which the test piece is taken shall be heat-treated in production furnaces to the same procedure as the castings it represents.

When the bar from which the test piece is taken is not heat-treated as part of the same heat-treatment load as the casting(s) it qualifies, the austenitizing temperatures for the bar shall be within 25°F of those for the casting(s). The tempering temperature for the bar shall be no higher than 25°F above that of the casting(s) and no higher than that permitted by the heat-treatment procedure for the material. The cycle time at each temperature shall not exceed that for the casting(s).

9.3 Test specimens may be cut from heat-treated castings at the producer's option, instead of from test bars.

9.4 If any specimen shows defective machining or exhibits flaws, it may be discarded and another substituted from the same heat.

9.5 If the results of the mechanical tests for any heat or lot or casting do not conform to the requirements agreed upon, retests are permitted in accordance with Test Methods and Definitions A 370. At the manufacturer's option, castings may be reheat-treated and retested. Testing after reheat-treatment shall consist of the full number of specimens taken from locations complying with the specification or order.

SUPPLEMENTARY REQUIREMENTS

The following supplementary requirements shall not apply unless specified in the purchase order. A list of standardized supplementary requirements for use at the option of the purchaser is included in Specification A 781/A 781M. Those which are ordinarily considered suitable for use with this specification are given as follows together with additional supplementary requirements that are applicable only to this specification. Other supplementary requirements enumerated in Specification A 781/A 781M may be used with this specification upon agreement between the manufacturer and the purchaser.

S1. Magnetic Particle Examination
S2. Radiographic Examination
S4. Ultrasonic Examination
S5. Examination of Weld Preparation
S6. Certification
S7. Prior Approval of Major Weld Repairs
S8. Marking
S9. Charpy Impact Test
S10. Hardness Test
S12. Test Report
S13. Unspecified Elements
S14. Tension Test from Casting
S15. Alternate Tension Test Coupons

Designation: A 985/A 985M – 0~~3~~4

Standard Specification for Steel Investment Castings General Requirements, for Pressure-Containing Parts[1]

This standard is issued under the fixed designation A 985/A 985M; 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 a group of common requirements, which are mandatory for steel castings produced by the investment casting process for pressure-containing parts under each of the following ASTM Specifications:

Title of Specification	ASTM Designation
Steel Castings, Carbon, Suitable for Fusion Welding for High-Temperature Service	A 216/A 216M
Steel Castings, Martensitic Stainless and Alloy, for Pressure-Containing Parts Suitable for High-Temperature Service	A 217/A 217M
Castings, Austenitic, Austenitic-Ferritic (Duplex), for Pressure-Containing Parts	A 351/A 351M
Steel Castings, Ferritic and Martensitic, for Pressure-Containing Parts Suitable for Low-Temperature Service	A 352/A 352M
Steel Castings, Alloy, Specially Heat-Treated, for Pressure-Containing Parts, Suitable for High-Temperature Service	A 389/A 389M
Steel Castings Suitable for Pressure Service	A 487/A 487M

1.2 This specification also covers a group of supplementary requirements, which may be applied to the above specifications as indicated therein. These requirements are provided for use when additional testing or inspection is desired and apply only when specified individually by the purchaser in the order.

1.3 When investment casting are ordered, the requirements of this specification shall take precedence over the individual material specification requirements.

1.4 The values stated in either inch-pound or SI units are to be regarded separately as the standard. Within the text, the SI units are shown in brackets. The values in each system are not exact equivalent; therefore, each system must be used independently of the other. Combining values from the two systems may result in nonconformance with this specification. Inch-pound units are applicable for material ordered to Specification A 985 and SI units for material ordered to Specification A 985M.

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.*

[1] This practice is under the jurisdiction of ASTM Committee A01 on Steel, Stainless Steel and Related Alloys and is the direct responsibility of Subcommittee A01.18 on Castings.

Current edition approved April 1~~0~~, 200~~3~~4. Published May 200~~3~~4. Originally approved in 1998. Last previous edition approved in 200~~1~~3 as A 985 ~~– 01a^ε1.~~ 03.

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

2. Referenced Documents

2.1 *ASTM Standards:* [2]

A 216/A 216M Specification for Steel Castings, Carbon, Suitable for Fusion Welding, for High-Temperature Service

A 217/A 217M Specification for Steel Castings, Martensitic Stainless and Alloy, for Pressure-Containing Parts, Suitable for High-Temperature Service

A 351/A 351M Specification for Castings, Austenitic, Austenitic-Ferritic (Duplex), for Pressure-Containing Parts

A 352/A 352M Specification for Steel Castings, Ferritic and Martensitic, for Pressure-Containing Parts Suitable for Low-Temperature Service

A 370 Test Methods and Definitions for Mechanical Testing of Steel Products

A 389/A 389M Specification for Steel Castings, Alloy, Specially Heat-Treated, for Pressure-Containing Parts, Suitable for High-Temperature Service

A 487/A 487M Specification for Steel Castings Suitable for Pressure Service

A 488/A 488M Practice for Steel Castings, Welding, Qualification of Procedures and Personnel

A 609/A 609M Practice for Castings, Carbon, Low-Alloy, and Martensitic Stainless Steel, Ultrasonic Examination Thereof

A 751 Test Methods, Practices, and Terminology for Chemical Analysis of Steel Products

A 800/A 800M Practice for Steel Casting, Austentic Alloy, Estimating Ferrite Content Thereof

A 903/A 903M Specification for Steel Castings, Surface Acceptance Standards, Magnetic Particle and Liquid Penetrant Inspection

A 941 Terminology Relating to Steel, Stainless Steel, Related Alloys, and Ferroalloys

A 991/A 991M Test Method for Conducting Temperature Uniformity Surveys of Furnaces Used to Heat Treat Steel Products

E 29 Practice for Using Significant Digits in Test Data to Determine Conformance with Specifications

E 94 Guide for Radiographic Examination

E 125 Reference Photographs for Magnetic Particle Indications on Ferrous Castings

E 165 Test Method for Liquid Penetrant Examination

E 186 Reference Radiographs for Heavy-Walled (2 to 4½-in. (51 to 114-mm)) Steel Castings

E 192 Reference Radiographs for Investment Steel Castings of Aerospace Applications

E 208 Test Method for Conducting Drop-Weight Test to Determine Nil-Ductility Transition Temperature of Ferritic Steels

E 280 Reference Radiographs for Heavy-Walled (4½ to 12-in. (114 to 305-mm)) Steel Castings

E 340 Test Method for Macroetching Metals and Alloys

E 353 Test Methods for Chemical Analysis of Stainless, Heat-Resisting, Maraging, and Other Similar Chromium-Nickel-Iron Alloys

E 354 Test Methods for Chemical Analysis of High-Temperature, Electrical, Magnetic, and Other Similar Iron, Nickel, and Cobalt Alloys

E 446 Reference Radiographs for Steel Castings Up to 2 in. (51 mm) in Thickness

E 709 Guide for Magnetic Particle Examination

2.2 *ANSI Standard:*[3]

B16.5 Steel Pipe Flanges and Flanged Fittings

2.3 *ASME Standard:*[4]

ASME Boiler and Pressure Vessel Code, Section III, NB-2546

2.4 *Standards of the Manufacturer's Standardization Society of the Valve and Fitting Industry:*[5]

MSS SP 53 Quality Standard for Steel Castings for Valves, Flanges and Fittings, and Other Piping Components (Dry Magnetic Particle Inspection Method)

MSS SP 54 Quality Standard for Steel Castings for Valves, Flanges and Fittings, and Other Piping Components (Radiographic Inspection Method)

2.5 *SAE Aerospace Recommended Practice:*[6]

ARP 1341 Determining Decarburization and Carburization in Finished Parts of Carbon and Low-Alloy Steel

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[2] 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*~~,~~ ~~Vol 01.02.~~ volume information, refer to the standard's Document Summary page on the ASTM website.

~~*Annual Book of ASTM*~~

[3] Available from American National Standards~~, Vol 01.03.~~ Institute, 25 W. 43rd St., 4th Floor, New York, NY 10036.

~~*Annual Book*~~

[4] Available from American Society of~~ ASTM Standards, Vol 01.01.~~ Mechanical Engineers, Three Park Ave., New York, NY 10016-5990

~~*Annual Book*~~

[5] Available from the Manufacturer's Standardization Society of~~ ASTM Standards, Vol 14.02.~~ the Valve and Fitting Industry, 127 Park St., NE, Vienna, VA 22180-4602.

~~*Annual Book*~~

[6] Available from the Society of~~ ASTM Standards, Vol 03.03.~~ Automotive Engineers, Inc., 400 Commonwealth Dr., Warranted, PA 15096-0001.

3. Terminology

3.1 *Definitions*— The definitions in Test Methods and Definitions A 370 and Terminology A 941 are applicable to this specification and those listed in 1.1.

3.2 *Definitions of Terms Specific to This Standard:*

3.2.1 *heat*, *n*—all the molten metal poured from a single furnace or all of the molten metal from two or more furnaces poured into a single ladle or casting prior to the replenishing of the furnace(s).

3.2.2 *investment casting*, *n*—a metal casting that is produced in a mold obtained by investing (surrounding) an expendable pattern with a ceramic slurry which is allowed to solidify. The expendable pattern may consist of wax, plastic, or other material and is removed prior to filling the mold with liquid metal.

3.2.3 *master heat*, *n*—a single furnace charge of alloy that may be either poured directly into castings or into remelt alloy for individual melts.

3.2.4 *subheat*, *n*—a portion of master heat remelted with only minor additions for deoxidation for pouring into castings. Syn. melt, production heat.

4. Materials and Manufacture

4.1 *Melting Process*— Master heats shall be made by the electric furnace process with or without separate refining such as argon-oxygen-decarburization (AOD), vacuum-oxygen-degassing (VOD), vacuum-induction-melting (VIM), and so forth, unless otherwise specified in the individual specification or agreed upon between the customer and producer. Master heats may be used directly for producing castings or converted into ingot, bar, shot, or other suitable form, not including gates and risers from casting production, for later remelting as a subheat.

TABLE 1 Product Analysis Tolerances for Carbon and Low-Alloy Steels

Element	Range[A]	Tolerances[BC] over max or under min, Limit, %
Carbon (C)	up to 0.65 %	$0.03 \times \% C_L + 0.02$
	above 0.65 %	0.04 %
Manganese (Mn)	up to 1 %	$0.08 \times \% Mn_L + 0.01$
	above 1 %	0.09
Silicon (Si)	up to 0.60 %	$0.22 \times \% Si_L - 0.01$
	above 0.60 %	0.15 %
Phosphorus (P)	all	$0.13 \times \% P_L + 0.005$
Sulfur (S)	all	$0.36 \times \% S_L + 0.001$
Nickel (Ni)	up to 2 %	$0.10 \times \% Ni_L + 0.003$
	above 2 %	0.25 %
Chromium (Cr)	up to 2 %	$0.07 \times \% Cr_L + 0.04$
	above 2 %	0.18 %
Molybdenum (Mo)	up to 0.6 %	$0.04 \times \% Mo_L + 0.03$
	above 0.6 %	0.06 %
Vanadium (V)	up to 0.25 %	$0.23 \times \% V_L + 0.004$
	above 0.25 %	0.06 %
Tungsten (W)	up to 0.10 %	$0.08 \times \% W_L + 0.02$
	above 0.10 %	0.02 %
Copper (Cu)	up to 0.15 %	$0.18 \times \% Cu_L + 0.02$
	above 0.15 %	0.05 %
Aluminum (Al)	up to 0.10 %	$0.08 \times \% Al_L + 0.02$
	above 0.10 %	0.03 %

[A] The range denotes the composition limits up to which the tolerances are computed by the equation, and above which the tolerances are given by a constant.

[B] The subscript $_L$ for the elements in each equation indicates that the limits of the element specified by the applicable specification are to be inserted into the equation to calculate the tolerance for the upper limit and the lower limit, if applicable, respectively. Examples of computing tolerances are presented in the footnote C.

[C] To compute the tolerances, consider the manganese limits 0.50 - 80 % of Grade WC4 of Specification A 217/A 217M. According to Table 1, the maximum permissible deviation of a product analysis below the lower limit 0.50 is 0.05 % = ($0.08 \times 0.50 + 0.01$). The lowest acceptable product analysis of Grade WC4, therefore, is 0.45 %. Similarly, the maximum permissible deviation above the upper limit of 0.80 % is 0.074 % = ($0.08 \times 0.08 + 0.01$). The highest acceptable product analysis of Grade WC4, therefore is 0.874. For Grade WCC of Specification A 216/A 216M, the maximum manganese content is 1.20 % if the carbon content is 0.20 %. In this case, the highest acceptable product analysis is 1.29 = (1.20 + 0.09).

4.2 *Re-melting Process*—Subheats shall be produced from master heat metal in suitable batch sizes by electric induction furnace, with or without atmosphere protection, such as vacuum or inert gas unless otherwise agreed upon between the customer and producer. Revert (gates, sprues, risers, and rejected) castings shall not be remelted except in master heats.

4.3 *Heat Treatment*

4.3.1 Ferritic and martensitic steel shall be cooled after pouring to provide substantially complete transformation of austenite prior to heat treatment to enhance mechanical properties.

4.3.2 Castings shall be heat treated in the working zone of a furnace that has been surveyed in accordance with Test Method A 991/A 991M.

4.3.2.1 When castings are heat treated at temperatures above 2000°F [1100°C], then the working zone shall have been established by a survey performed at not more than 25°F [15°C] below nor more than 200°F [110°C] above the minimum heat treatment temperature specified for the grade. If a minimum heat treatment temperature is not specified for the grade, then the survey temperature shall be not more than 50°F [30°C] below nor more than 175°F [100°C] above the furnace set point used.

4.3.2.2 The maximum variation in measured temperature as determined by the difference between the highest temperature and the lowest temperature shall be as agreed between the purchaser and producer except that during production heat treatment no portion of the furnace shall be below the minimum specified temperature nor above the maximum specified temperature for the grade being processed.

4.4 *Sampling*:

4.4.1 If castings are poured directly from one or more master heats, then the samples for chemical and other required testing also shall be poured directly from each of the master heats.

4.4.2 If castings are poured from a subheat, then the samples for chemical and other required testing also shall be poured from a subheat of that same master heat, but not necessarily from the same sub-heat as the castings. The subheat used for the test samples shall be produced using the same practices and additions as used for the castings.

4.4.3 Test specimens may be taken from castings or from coupons cast either integrally with the castings, in the same molds as the castings, or in separate molds.

4.4.4 Separately cast specimens for tension testing shall be cast in molds of the same type and material as those used for the castings, as shown in Figs. 1-4, and Table 2, except when Supplementary Requirement S26 is specified. The test coupon in Fig. 4 shall be employed only for austenitic alloy castings with cross sections less than 2½ in.[7]

5. Chemical Composition

5.1 *Chemical Analysis*—Chemical analysis of materials covered by this specification shall be in accordance with Test Methods, Practices, and Terminology A 751.

5.2 *Heat Analysis*— An analysis of samples obtained according to 4.4 or Supplementary Requirement S27 as appropriate, shall be made by the manufacturer to determine the percentages of the elements specified for the grade being poured. When drillings are used, they shall be taken not less than 1⁄16 in. [1.6 mm] beneath the surface. The chemical composition thus determined shall be reported to the purchaser, or his representative; and shall conform to the requirements in the individual specification for the grade being poured.

5.3 *Product Analysis*— A product analysis may be made by the purchaser from material representing each master heat, subheat, lot, or casting. The analysis shall be made on representative material. Samples for carbon analysis shall be taken no closer than 1⁄16 in. [1.6 mm] to a cast surface except that castings too thin for this shall be analyzed on representative material. The chemical composition thus determined shall meet the requirements specified in the applicable specification for the grade involved, or shall be subject to rejection by the purchaser, except that the chemical composition determined for carbon and low-alloy steel castings

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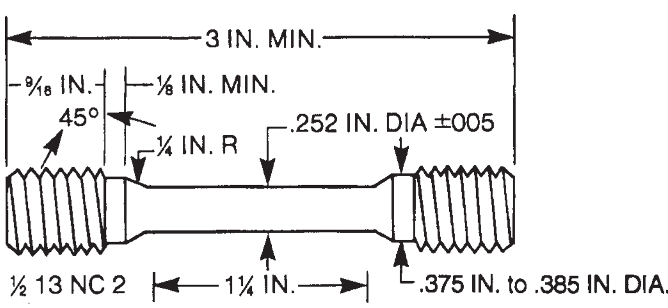
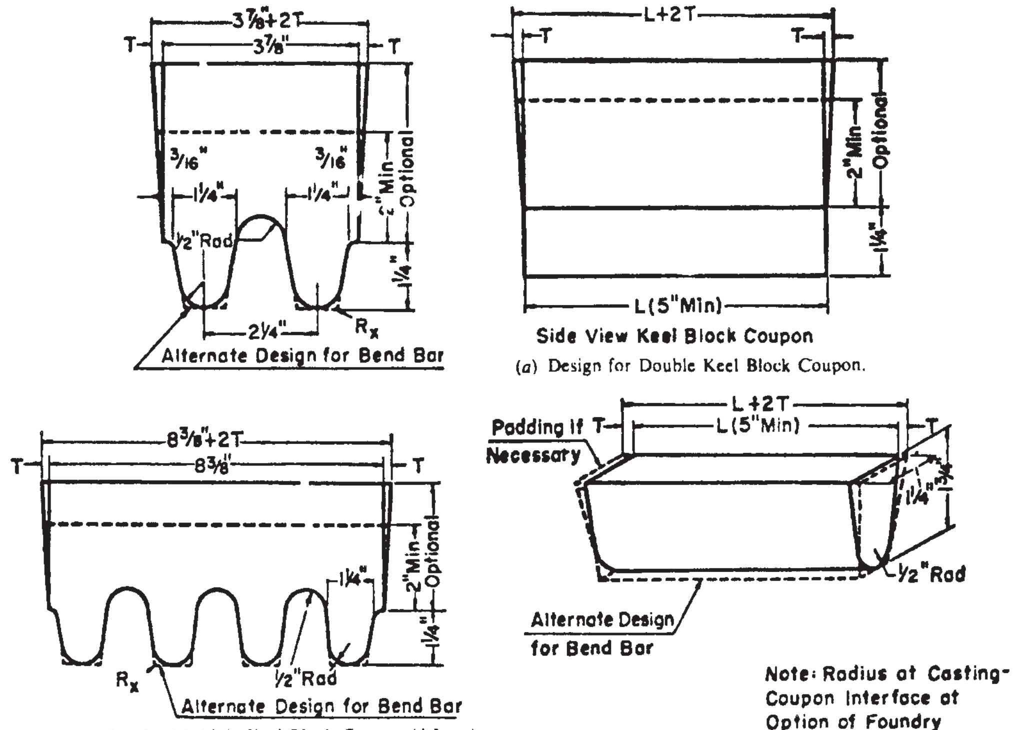
[7] Information on the relationship of ~~ASTM Standards, Vol 03.01.~~ mechanical properties determined on test coupons obtained as specified in 4.4.4 with those obtained from the casting may be found in "The Steel Castings Handbook," Fifth Edition, Steel Founders' Society of America, 1980, pp. 15-35 through 15-43.



Metric Equivalents

in.	0.005	1⁄8	0.252	0.375	0.385	9⁄16	1¼	3
[mm]	[0.15]	[3]	[6.40]	[9.50]	[9.75]	[15]	[30]	[75]

FIG. 1 Design and Dimensions of the ICI Test Bar



(*a*) Design for Double Keel Block Coupon.

(*b*) Design for Multiple Keel Block Coupon (4 Legs).

(*c*) Design for "Attached" Coupon.

Metric Equivalents

In.	3⁄16	½	1¼	1¾	2	2½	3⅞	5	8⅛
mm	4.8	13	32	45	51	57	98	127	213

FIG. 2 Test Coupons for Castings (see Table 2 for Details of Design)

may vary from the specified limits by the amounts shown in Table 1. The product analysis tolerances of Table 1 are not applicable as acceptance criteria for heat analysis by the casting manufacturer. When comparing product and heat analysis for other than carbon and low alloy steels, the reproducibility data R2, in Test Methods E 353 or E 354, as applicable, shall be taken into consideration.

5.4 *Unspecified Elements*—When chemical analysis for elements not specified for the grade ordered is desired, Supplementary Requirement S1 may be specified.

NOTE 1—All commercial metals contain small amounts of various elements in addition to those which are specified. It is neither practical nor necessary to specify limits for every unspecified element that might be present, despite the fact that the presence of many of these elements often is determined routinely by the producer.

5.5 The substitution of a grade or composition different from that specified by the purchaser is prohibited.

6. Mechanical Test Methods

6.1 All mechanical tests shall be conducted in accordance with Test Methods and Definitions A 370.

7. Tensile Requirements

7.1 Sampling for tension testing shall be in accordance with 4.4 or with Supplementary Requirement S28 as appropriate.

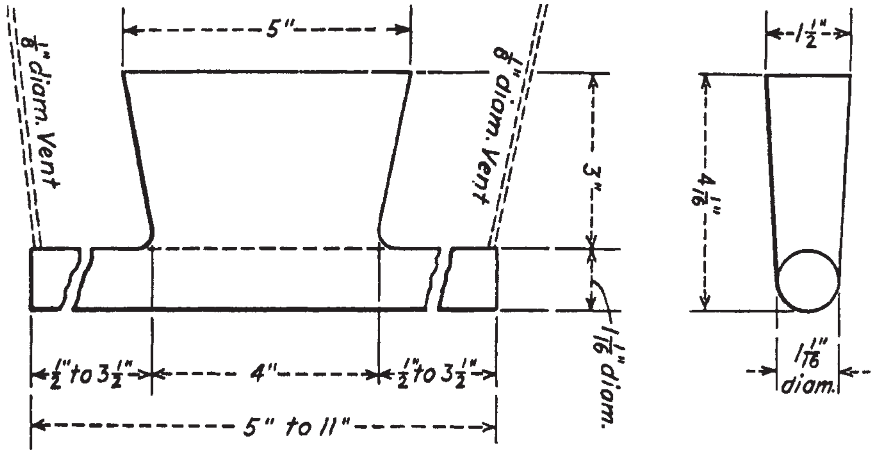
7.2 The coupon from which the test specimen is taken shall be heat-treated in production furnaces to the same procedure as the castings it represents.

7.3 If any specimen shows defective machining or develops flaws, it may be discarded and another substituted from the same heat.

7.4 To determine conformance with the tension test requirements, an observed value or calculated value shall be rounded off in accordance with Practice E 29 to the nearest 500 psi [51 MPa] for yield and tensile strength and to the nearest 1 % for elongation and reduction of area.

8. Repair by Welding

8.1 Repair by welding shall be in accordance with the requirements of individual specifications using procedures and welders qualified in accordance with Practice A 488/A 488M.



NOTE—Pour through head; cover molten head with powered charcoal, coke dust, etc., immediately after pouring, in order to keep head fluid as long as possible.

Metric Equivalents

in.	mm	in.	mm
1⁄8	3.2	3 1⁄2	88.9
1⁄2	12.7	4	101.6
1 1⁄16	27.0	4 1⁄16	103.2
1 1⁄2	38.1	5	127.0
3	76.2	11	279.4

FIG. 3 Test Block for Tension Test Specimen

9. Flanges

9.1 When a flange from a flanged casting is removed to make a weld-end castings, discontinuities may be observed that would not have been detrimental in a flanged castings. The disposition of the casting shall be subject to agreement between the purchaser and manufacturer.

10. Quality

10.1 The surface of the casting shall be free of adhering ceramic, scale, cracks, and hot tears as determined by visual examination. Other surface discontinuities shall meet the visual acceptance standards specified in the order. Unacceptable visual surface discontinuities shall be removed and their removal verified by visual examination of the resultant cavities.

10.2 The castings shall not be peened, plugged, or impregnated to stop leaks.

10.3 When additional inspection is desired, Supplementary Requirements S4, S5, S7, or S10 may be specified.

11. Hydrostatic Tests

11.1 Each casting shall be tested after machining to the hydrostatic shell test pressures prescribed in ANSI B16.5 for the applicable steel rating for which the casting is designed. The casting shall not show any leaks. Castings ordered for working pressures other than those in the standard ANSI ratings, or those listed for which test pressures are not specified by ANSI B16.5, shall be tested at a pressure agreed upon between manufacturer and the purchaser.

11.2 It is realized that the foundry may be unable to perform the hydrostatic test prior to shipment, or that the purchaser may wish to defer testing until additional work or machining has been performed on the casting. Castings ordered in the rough state for final machining by the purchaser may be tested hydrostatically prior to shipment by the manufacturer at pressures to be agreed upon with the purchaser. The foundry, however, is responsible for the satisfactory performance of the casting under the final test required in 11.1.

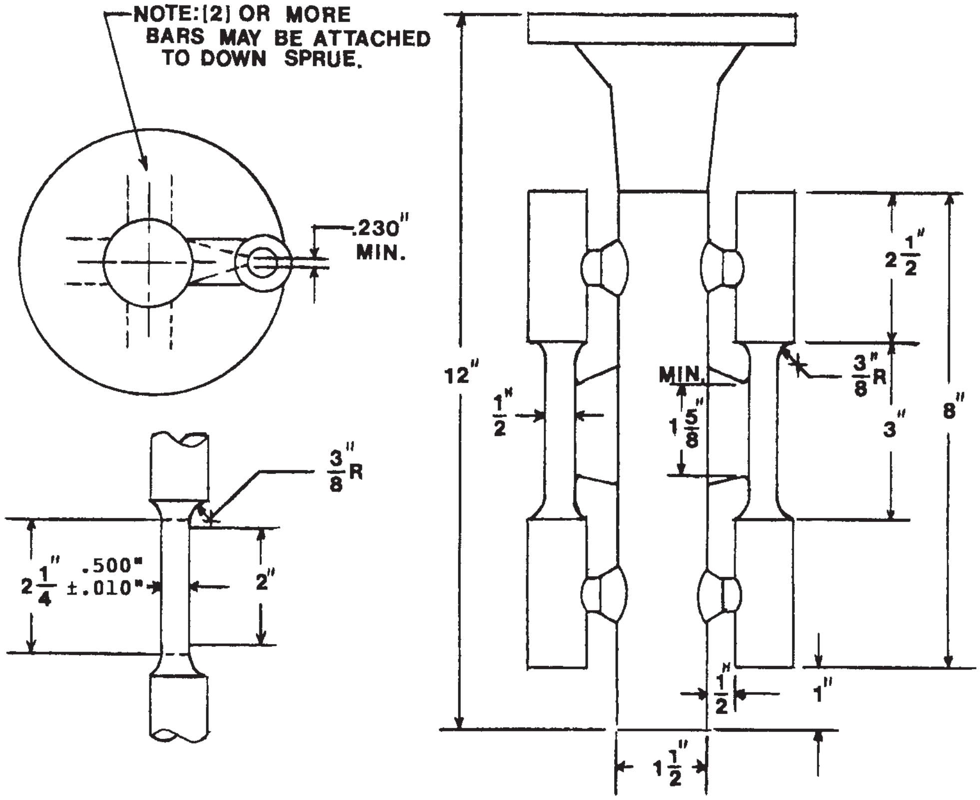
12. Workmanship, Finish, and Appearance

12.1 All castings shall be made in a workmanlike manner and shall conform to the dimensions on drawings furnished by the purchaser. When the pattern is supplied by the purchaser or is produced using a die supplied by the purchaser, the dimensions of the casting shall be as predicated by the pattern or die unless otherwise agreed upon.

12.2 Machined welding ends shall be suitably protected against damage during shipping.

13. Retests

13.1 If the results of the mechanical tests do not conform to the requirements specified, retests are permitted as outlined in Test Methods and Definitions A 370. At the manufacturer's option, castings may be reheat-treated and retested. Testing after reheat treatment shall consist of the full number of specimens taken from locations complying with the specification or order.



NOTE—Coupons produced in this manner are suitable for austenitic alloys only. The mold may be preheated for pouring to produce a sound coupon.

Metric Equivalents

in.	mm	in.	mm
0.010	0.254	1⅝	41.275
0.0230	5.842	2¼	57.15
⅜	9.525	2½	63.5
½	12.7	3	76.2
1	25.4	8	203.2
1½	38.1	12	304.8

FIG. 4 Cast-To-Shape Test Coupon for Tension Test Specimen

14. Inspection

14.1 The manufacturer shall afford the purchaser's inspector all reasonable facilities necessary to satisfy that the material is being produced and furnished in accordance with the applicable specification. Foundry inspection by the purchaser shall not interfere unnecessarily with the manufacturer's operations. All tests and inspections, with the exception of product analysis (5.2), are the responsibility of the manufacturer.

15. Rejection and Rehearing

15.1 Any rejection based on test reports shall be reported to the manufacturer within 30 days from the receipt of the test reports by the purchaser.

15.2 Material that shows unacceptable discontinuities as determined by the acceptance standards specified in the order subsequent to its acceptance at the manufacturer's works will be rejected, and the manufacturer shall be notified within 30 days after discovery of the rejectable condition.

15.3 Samples that represent rejected material shall be preserved for two weeks from the date of transmission of the test report. In case of dissatisfaction with the results of the tests, the manufacturer may make claim for a rehearing with that time.

16. Certification

16.1 The manufacturer's certification shall be furnished to the purchaser stating that the material was manufactured, sampled, tested, and inspected in accordance with the material specification (including year of issue) and was found to meet the requirements.

16.2 As applicable, the certification also shall include:

16.2.1 Material specification and grade.

TABLE 2 Details of Test Coupon Design for Casting (See Fig. 2)

NOTE 1—*Test Coupons for Large and Heavy Steel Castings:* The test coupons in Fig. 2 are to be used for large and heavy steel castings. However, at the option of the foundry the cross-sectional area and length of the standard coupon may be increased as desired.

NOTE 2—*Bend Bar:* If a bend bar is required, an alternate design (as shown by dotted lines in Fig. 2) is indicated.

Leg Design (125 mm)		Riser Design	
1. *L* (length)	A 5 in. [125 mm] minimum length will be used. This length may be increased at the option of the foundry to accommodate additional test bars (see Note 1).	1. *L* (length)	The length of the riser at the base will be the same as the top length of the leg. The length of the riser at the top therefore depends on the amount of taper added to the riser.
2. End taper	Use of and size of end taper is at the option of the foundry.	2. Width	The width of the riser at the base of a multiple-leg coupon shall be *n*, 2 ¼ [57 mm] − ⅝ [16 mm] where *n* equals the number of legs attached to the coupon. The width of the riser at the top is therefore dependent on the amount of taper added to the riser.
3. Height	1 ¼ in. [32 mm]		
4. Width (at top)	1 ¼ in. [32 mm] (see Note 1).		
5. Radius (at bottom)	½ in. [13 mm], max		
6. Spacing between legs	A ½-in. [13-mm] radius will be used between the legs.		
7. Location of test bars	The tensile, bend, and impact bars will be taken from the lower portion of the leg (see Note 1).	3. *T* (riser taper)	Use of and size is at the option of the foundry.
		Height	The minimum height of the riser shall be 2 in. [51 mm]. The maximum height is at the option of the foundry for the following reasons: (*a*) Many risers are cast open, (*b*) different compositions may require variation in risering for soundness, (*c*) different pouring temperatures may require variation in risering for soundness.
8. Number of legs	The number of legs attached to the coupon is at the option of the foundry providing they are equispaced according to Item 6.		
9. R_s	Radius from 0 to approximately 1/16 in. [2mm].		

16.2.2 Pattern or part number.

16.2.3 Master heat number or serial number traceable to the master heat number.

16.2.4 Chemical analysis results required by the specification and supplementary requirements specified in the purchase order.

16.2.5 Mechanical property results required by the specification and supplementary requirements specified in the purchase order.

16.2.6 Statement of satisfactory inspection, visual, and nondestructive testing specified in the purchase order.

16.2.7 Manufacturer's name, and

16.2.8 Additional purchase order requirements.

16.3 A signature is not required on the certification; however, the document shall identify clearly the organization submitting the certification. Notwithstanding the absence of a signature, the organization submitting the certification is responsible for its content.

17. Product Marking

17.1 Castings shall be marked for material identification with the grade symbols (WCB, WC9, CF8M, etc.). In addition, master heat numbers, or serial numbers that are traceable to master heat numbers, shall be marked on all pressure-containing casting individually weighing 50 lb [25 kg] or more. Pressure-containing castings weighing less than 50 lb [25 kg] shall be marked with either the master heat number or a lot number that will identify the casting as to the month in which it was poured. Marking shall be in such position as not to injure the usefulness of the casting.

17.2 On casting for which impact property requirements are specified, stamped markings using low-stress stamps shall be on a raised pad when such pad can be made a part of the castings.

17.3 Castings shall be marked with the manufacturer's identification or symbols except when other provisions have been made between the manufacturer and purchaser.

18. Keywords

18.1 casting; investment casting; master heat; pressure containing; steel casting; subheat

SUPPLEMENTARY REQUIREMENTS

The following standardized supplementary requirements are for use when desired by the purchaser and when allowed by and listed in the individual specifications. They shall not apply unless specified in the order, in which event the specified tests shall be made by the manufacturer before shipment of the castings.

S1. Unspecified Elements

S1.1 Limits may be established for elements not specified for the grade ordered by agreement between the manufacturer and purchaser. The results of the analysis for the agreed upon elements shall be reported.

S2. Destruction Tests

S2.1 Purchaser may select representative castings from each heat and cut up and etch, or otherwise prepare, the sections for examination for internal defects. Should injurious defects be found that evidence unsound steel or faulty foundry technique, all of the castings made from that particular pattern, heat, and heat treatment charge may be rejected. All other rejected castings, including those cut up, shall be replaced by the manufacturer without charge.

S3. Bend Test

S3.1 One bend test shall be made from a test coupon from each master heat in accordance with Test Methods and Definitions A 370, and shall be machined to 1 by ½ in. [25 by 13 mm] section with corners rounded to a radius not over 1⁄16 in. [1.6 mm].

S3.2 The specimen shall withstand being bent longitudinally at room temperature through an angle of 90° about a pin the diameter of which shall be the specimen thickness for carbon steels, and 1 in. [25 mm] for other steels. The specimen shall show no cracks on the outside of the bent portion of the specimen.

S3.3 Bend test specimens may be cut from heat-treated castings instead of from test bars when agreed upon between manufacturer and purchaser.

S3.4 If any test specimen shows defective machining or develops flaws, it may be discarded and another specimen substituted from the same heat.

S4. Magnetic Particle Inspection

S4.1 Castings shall be examined for surface and near surface discontinuities by magnetic particle inspection. The examination shall be in accordance with Guide E 709, and types and degrees of discontinuities considered, shall be judged by the Reference Photographs E 125. Extent of examination, time of examination, and basis for acceptance shall be agreed upon between the manufacturer, and purchaser. Specification, which may be used as a basis for such agreement, are Specifications A 903/A 903M and MSS SP 53.

S4.2 Personnel performing the examination shall be qualified in accordance with an acceptable written practice.

S5. Radiographic Inspection

S5.1 Castings shall be examined for internal defects by means of X-rays or gamma rays. The procedure shall be in accordance with Guide E 94 and types and degrees of discontinuities considered shall be judged by Reference Radiographs E 186, E 192, E 280, or E 446. Extent of examination and basis for acceptance shall be agreed upon between the manufacturer and purchaser. A specification that may be used as a basis for such agreement is MSS SP 54.

S5.2 Radiographic examination of castings may be performed before or after any heat treatment.

S5.3 Personnel performing the examination shall be qualified in accordance with an acceptable written practice.

S6. Liquid Penetrant Inspection

S6.1 Castings shall be examined for surface discontinuities by means of liquid penetrant inspection. The examination shall be in accordance with Test Method E 165. Areas to be inspected, time of inspection, methods and types of liquid penetrants to be used, developing procedure, and basis for acceptance shall be agreed upon between the manufacturer and purchaser. A specification which may be used as a basis for such agreement is A 903/A 903M.

S6.2 Personnel performing the examination shall be qualified in accordance with an acceptable written practice.

S7. Ultrasonic Inspection

S7.1 Castings shall be examined for internal defects by means of ultrasonic inspection. The inspection procedure shall be in accordance with Practice A 609/A 609M. Extent of examination methods of testing, and basis for acceptance shall be agreed upon between the manufacturer and purchaser.

S7.2 Ultrasonic examination of casting of carbon and low-alloy steels shall be performed after at least one heat treatment above the ~~critical~~ transformation temperature range but need not be repeated after subsequent heat treatment.

S7.3 Personnel performing the examination shall be qualified in accordance with an acceptable written practice.

S8. Charpy Impact Test

S8.1 Charpy impact test properties shall be determined on each master heat from a set of three Charpy V-notch specimens made from a test coupon in accordance with Test Methods and Definitions A 370, and tested at a test temperature agreed upon by the manufacturer and purchaser. The sampling requirements shall be agreed upon between the manufacturer and purchaser (see 4.4). The acceptance requirements shall be energy absorbed, lateral expansion, percent shear area or any combination thereof, and shall be agreed upon by the manufacturer and purchaser. Test specimens shall be prepared as Type A and tested in accordance with Test Methods and Definitions A 370.

S8.2 *Absorbed Energy*—Average energy value of three specimens shall not be less than specified, with not more than one value permitted to fall below the minimum specified and no value permitted below the minimum specified for a single specimen.

S8.3 *Lateral Expansion*—Lateral expansion value shall be agreed upon by the manufacturer and purchaser.

S8.4 *Percent Shear Area*—Percent shear area shall be agreed upon by the manufacturer and purchaser.

S9. Drop Weight Tests

S9.1 Drop weight test properties shall be determined from each heat by preparing and testing either Type P1, P2, or P3 specimens in accordance with Test Methods E 208. The crack starter weld shall be deposited on the surface of the specimen that was nearest to the casting surface. Each test shall consist of at least two specimens tested at a temperature agreed upon by the manufacturer and purchaser. Each specimen shall exhibit "no break" performance.

S10. Examination of Weld Preparation

S10.1 Magnetic particle or liquid penetrant examination of cavities prepared for welding shall be performed to verify removal of those discontinuities found unacceptable by the inspection method specified for the casting. The method of performing magnetic particle or liquid penetrant examination shall be in accordance with either Guide E 709 or Test Method E 165. Unless other degrees of shrinkage or types of discontinuities found in the cavities are specified, Type II, Internal Shrinkage, of Reference Photographs E 125, of Degree 2 in sections up to 2-in. [50-mm] thick, and of Degree 3 in sections over 2-in. [50-mm] thick shall be acceptable.

S11. Prior Approval of Major Weld Repairs

S11.1 Major weld repairs shall be subject to the prior approval of the purchaser.

S12. Hardness Test

S12.1 A hardness test shall be made in accordance with Test Methods and Definitions A 370. The test location and the hardness requirements shall be agreed upon between the manufacturer and the purchaser.

S14. Tension Test From Each Heat and Heat Treatment Charge

S14.1 One tension test shall be made for each master heat and heat-treatment charge combination.

S15. Quench and Temper Heat-Treatment

15.1 The castings shall be quenched and tempered. Castings so treated shall be marked QT.

S17. Tension Test From Castings

S17.1 In addition to the tensile test required in Section 6, test material shall be cut from heat treated castings. The mechanical properties and location for the test material shall be agreed upon by the manufacturer and purchaser.

S20. Weld Repair Charts

S20.1 Weld repairs made to correct leakage on hydrostatic testing, weld repairs for which the depth of the cavity required for welding exceeds 20 % of the actual wall thickness or 1 in. [25 mm], whichever is smaller, or weld repairs for which the area of the cavity required for welding exceeds approximately 10 $in.^2$ [65 mm^2] shall be documented.

S20.2 Weld repairs requiring documentation shall be documented on sketches or photographs, or both. The sketches or photographs shall show the location and major dimensions of cavities prepared for weld repair. The weld repair documentation shall be submitted to the purchaser at the completion of the order.

S21. Heat-Treatment Furnace Record

S21.1 A heat treatment chart showing time and temperature shall be prepared and be available for inspection by the purchaser.

S22. Heat Treatment

S22.1 Test specimens shall be heat-treated together with the castings they represent. Heat-treated specimens shall be tested and shall meet the tensile and impact properties specified.

S22.2 The remaining test specimens from Supplementary Requirement S22.1 representing the casting shall be treated thermally after the final (foundry) heat-treatment to simulate heat-treatments below the ~~critical~~ transformation temperature, which the casting may receive during fabrication, and then tested for mechanical properties. Time, temperature, and cooling rate shall be as stated in the order. In the case of postweld heat-treatment, the total time at temperature or temperatures for the test material shall be at least 80 % of the total time at temperature or temperatures during actual postweld heat-treatment of the fabrication of which the casting or castings are a part. The total time at temperature or temperatures for the test material may be performed in a single cycle. When this Supplementary Requirement is specified, the welding qualification test metal must be processed in the same manner.

S23. Macrotech Test

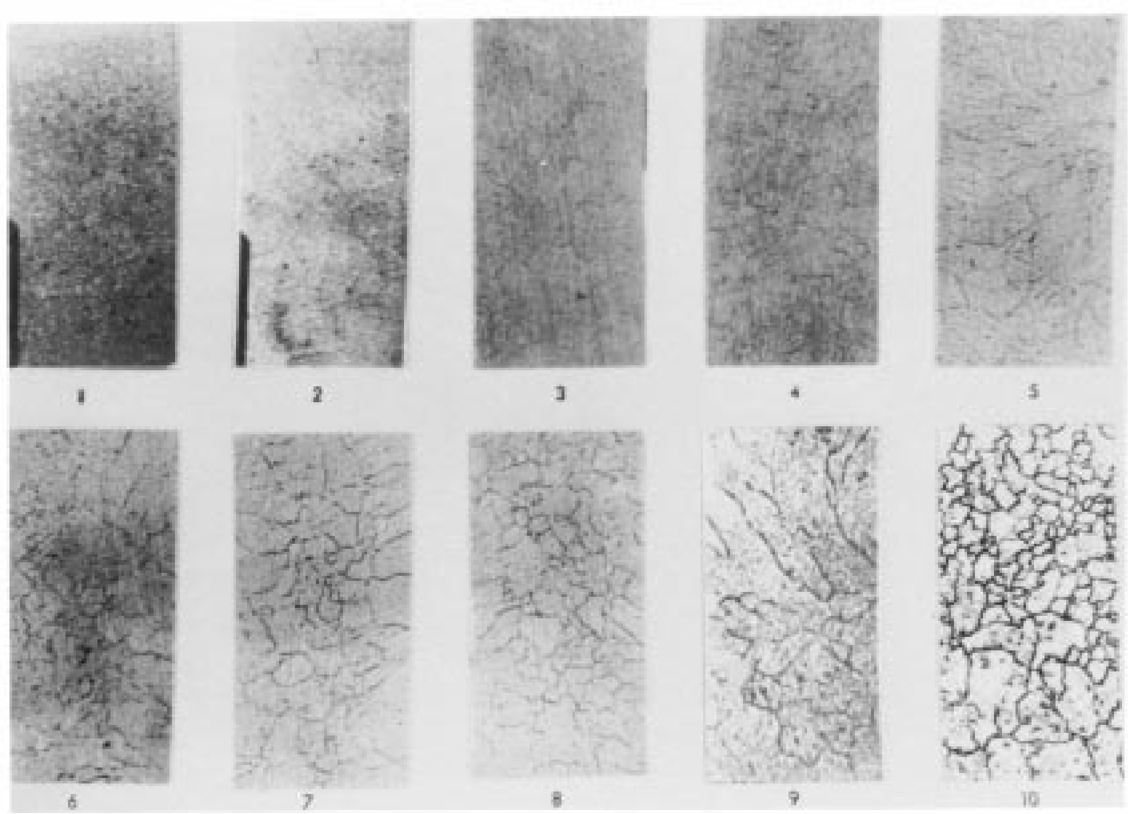
S23.1 Apply Supplementary Requirement S1 for the spectrographic determination and reporting of the total residual aluminum content of all heats of ferritic and martensitic steels subjected to this macroetch test.

S23.2 When the heat analysis indicates a total residual aluminum content in excess of 0.08 %, the manufacturer shall etch a cross section of the casting with the heaviest section for which this supplementary requirement is invoked, or a coupon attached to that heaviest section or an area directly under a riser (see Note S23.1). Cross sections, from a separately cast test block from the same heat and a thickness representative of the heaviest section of castings purchased under this supplementary requirement, also may be used for macrotch testing. The etching shall be performed on the selected section after its heat-treatment, that is, after annealing, normalizing, or quenching and tempering following the initial cooling of the steel below the transformation range.

NOTE S23.1—High-strength martensitic castings, in particular, may be damaged beyond use if the etch is applied directly to the casting.

S23.3 The preparation of the surface and the macroetching procedure with solution No. 1 (1:1 HC1) of Table 5 in Test Method E 340 shall be followed. The resulting etched surface shall be compared and rated with the reference photographs in Fig. S23.1 depicting ten levels of severity of intergranular network structures indicative of the presence of aluminum nitride, or other constituents prone toward precipitating at grain boundaries during solidification and subsequent cooling. Table S23.1 relates the severity levels shown in these photographs with specific delineation widths and percent of boundary outlining in the etched structures.

S23.4 Castings represented by etched structures exhibiting a network rating in excess of Severity Level 4 shall be considered unacceptable until further evaluations are completed. The acceptability of individual castings may be determined by etching sections of each casting to ascertain the network severity level. Disposition of unacceptable castings shall be a matter of agreement between the manufacturer and purchaser. Those castings exhibiting etched severity levels greater than four may be further evaluated by any of the following agreed upon methods.



NOTE—The 10 levels of severity of intergranular network structures shown are indicative of the presence of aluminum nitride precipitation in the primary austenitic grain boundaries.

FIG. S23.1 Reference Photographs of Macroetched Cast Steel

TABLE S23.1 Descriptive Data Applicable to Network Structures Shown in Fig. S23.1

NOTE—These ratings are based on the physical width and continuity of the precipitate pattern developed by the acid etchant on the primary austenitic grain boundaries of the cast steel. Supplementary testing is normally conducted to determine the final disposition of castings with ratings of 5 or greater.

Rating	Delineation Width, in.	Boundary Outline, %
1	Fine-0.001	20
2	Fine-0.001	40
3	Fine-0.001	60
4	Fine-0.002	80
5	Fine-0.002	100
6	Medium-0.005	100
7	Heavy-0.010	100
8	0.020	100
9	1⁄32	100
10	1⁄16	100

S23.4.1 Fracture testing to determine the amount of "rock candy" structure.

S23.4.2 Mechanical testing (bend, tensile, and so forth) to determine the ductility characteristics.

S23.4.3 Weld testing to determine crack susceptibility in the heat-affected zone of a circular groove welded with cellulose coated electrodes.

S23.5 Alternatively, by agreement, it is permissible to subject castings from an unacceptable heat to a high temperature solution treatment prior to the normal production heat-treatment and subsequently macroetch test each casting.

S24. Specified Ferrite Content Range

S24.1 The chemical composition of the heat shall be controlled such that the ferrite content, as determined by the chemical composition procedure of Practice A 800/A 800M, shall be in conformance with the specified ferrite content range.

S24.2 The specified ferrite content range shall be as agreed upon between the manufacturer and the purchaser. The minimum specified ferrite content range shall be 10 % with the minimum ferrite content being no lower than the percent necessary to achieve the minimum mechanical properties required for the alloy.

S24.3 Should the purchaser wish to have the ferrite content determined by either magnetic response or metallographic methods, the purchaser should impose supplementary requirement S1 or S2 of Practice A 800/A 800M.

S25. Heat-Treatment Certification

S25.1 Heat treatment temperature and cycle times shall be shown on the certification report.

S26. Alternative Tension Test Coupons and Specimen Locations for Castings (In-Lieu of Test Bars Poured from Special Blocks)

S26.1 Test blocks may be cast integrally with the castings or as separate blocks. Test blocks shall be heat-treated together with the castings they represent.

S26.2 The casting thickness, *T*, is the maximum thickness of the pressure containing wall of the casting exclusive of padding added for directional solidification, flanges, appendages, and sections designated by the designer as noncritical. The order, inquiry, and drawing shall designate what the test dimension, *T*, is for the casting.

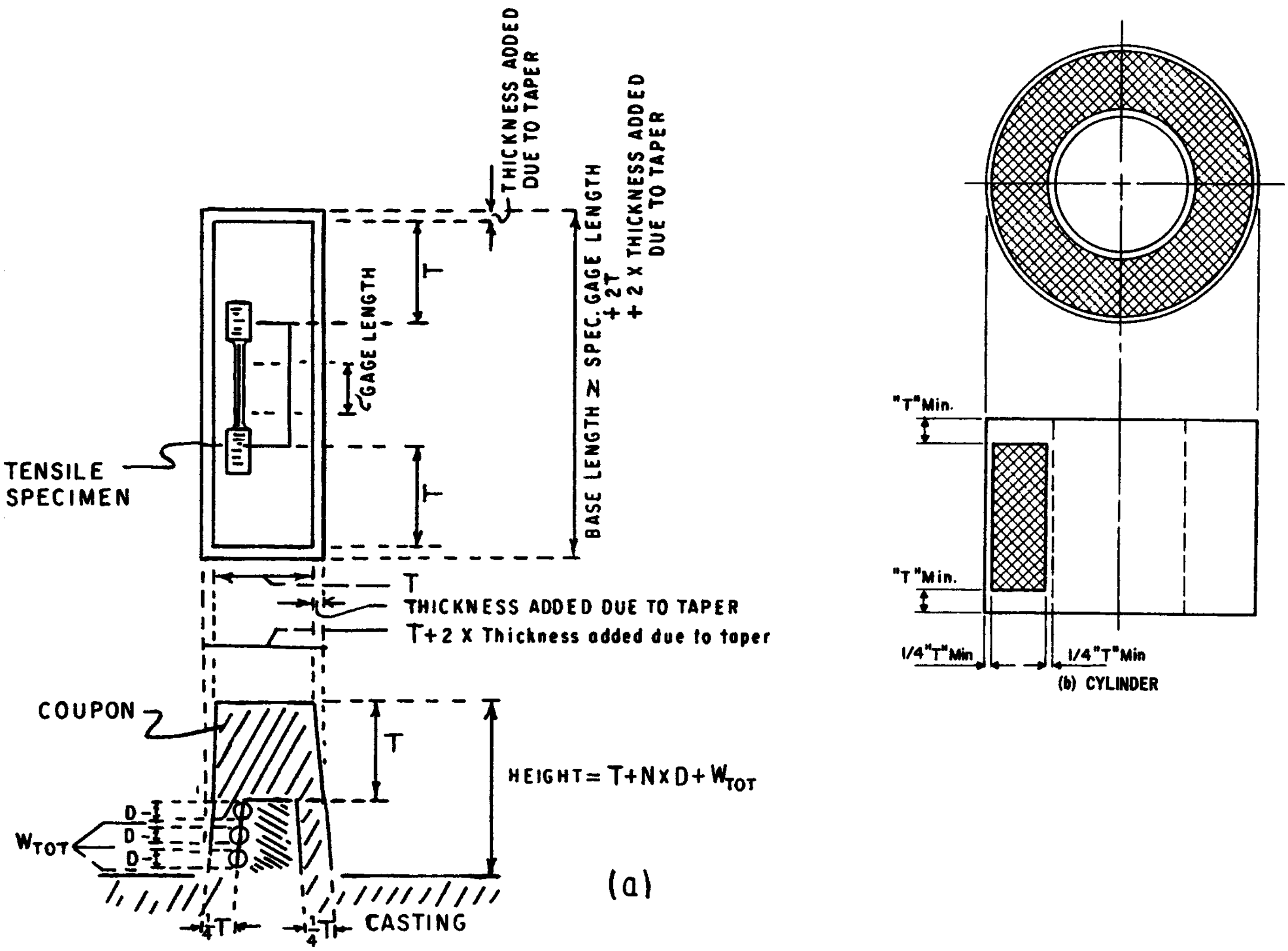
S26.3 One of the following shall apply:

S26.3.1 The longitudinal centerline of the test specimen shall be taken at least ¼ *T* from the *T* dimension surface and all of the gage length must be at least 1 *T* from any other heat-treated surface, exclusive of the surface opposite the *T* dimension surface (see Fig. S26.1 (a)). For cylindrical castings, the longitudinal centerline of the specimens shall be taken at least ¼ *T* from the outside or inside and all of the gage length must be at least *T* from the as-heat treated end (see Fig. S26.1 (b)).

S26.3.2 For ferritic and martensitic castings, partial severing of test blocks prior to final heat treatment is permitted.

S26.3.3 Where separately cast test coupons are used, the dimensions shall not be less than 3 *T* by 3 *T* by *T* and each specimen shall meet the requirements of S26.3.1, except that when *T* exceeds 5 in. [125 mm], the dimension may be 15 by 15 by 5 in. [375 by 375 by 125 mm], by agreement between the manufacturer and the purchaser. The test coupon shall be of the same heat of steel and shall receive substantially the same casting practices as the production casting it represents (see Fig. S26.2).

S26.3.4 When agreed upon between the manufacturer and the purchaser, castings that are cast or machined to essentially the finished configuration prior to heat-treatment, shall have test specimens removed from a prolongation or other stock on the casting at a location below the nearest heat-treated surface indicated on the order. The specimen location shall be at a distance below the nearest heat-treated surface equivalent to at least the greatest distance that the indicated high-tensile stress surface will be from the nearest heat-treated surface and a minimum of twice this distance from a second heat-treated surface, except that the test specimens shall be no nearer than ¾ in. [19 mm] to a heat-treated surface and 1-½ in. [33 mm] from a second heat-treated surface (see Fig. S26.3).



Minimum length of the base — Specimen gage length + 2x*T* + 2*x* the thickness due to the taper.
Minimum width of the base — *T* + 2*x* the thickness added due to the taper.
Minimum height — $T + NxD + W_{tot}$.

The taper is to be selected by the producer for ease of drawing the pattern from the mold.
where:

N = number of specimens to be cut from one side of the coupon,
D = diameter of the specimens, and
W_{tot} = total width of metal required to remove the coupon from the casting, and to machine specimens from the coupon.

NOTE—Longitudinal axis and gage length of test specimen must be within shaded zone.

FIG. S26.1 Specimen from Casting

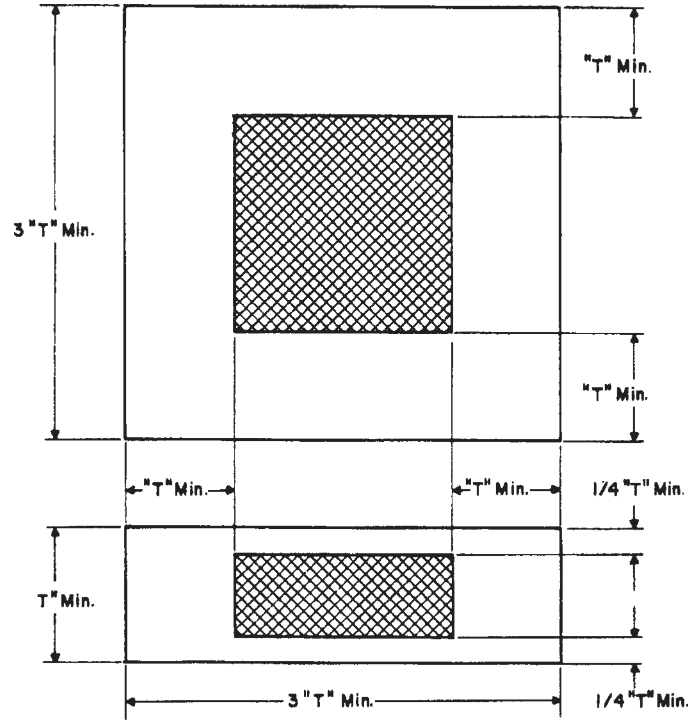
S26.3.5 Where specimens are to be removed from the body of quenched and tempered castings, either the requirements of S26.3.1 shall be met or a steel thermal buffer pad or thermal insulation or other thermal barriers shall be used during heat-treatment. Steel thermal buffer pads shall be a minimum of T by T by $3T$ in length and shall be joined to the casting surface by a partial penetration weld completely sealing the buffered surface. Test specimens shall be removed from the casting in a location adjacent to the center third of the buffer pad. They shall be located at a minimum distance of ½ in. [13 mm] from the buffered surface and ¼ T from other heat-treated surfaces (see Fig. S26.4). When thermal insulation is used, it shall be applied adjacent to the casting surface where the test specimens are to be removed. The producer shall demonstrate that the cooling rate of the test specimen location is no faster than that of specimens taken by the method described in S26.3.1.

S27. Increased Testing Frequency—Chemical Analysis

S27.1 Frequency of chemical analysis shall be as agreed upon between the purchaser and manufacturer.

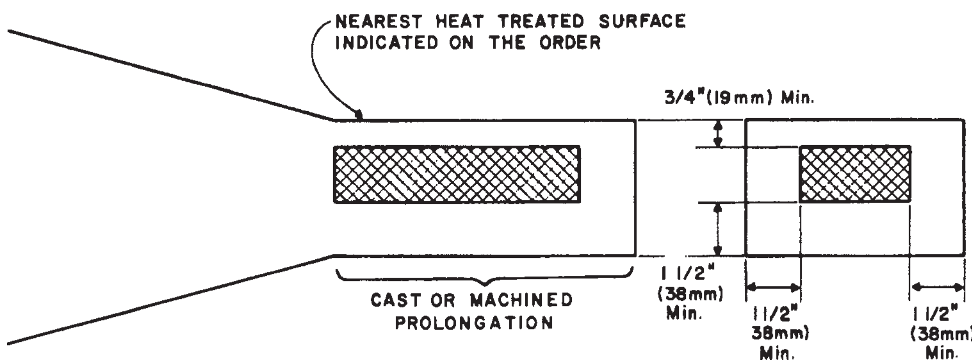
S28. Increased Testing Frequency—Tensile Testing

S28.1 Frequency of tension tests shall be as agreed upon between the purchaser and manufacturer.



NOTE—Longitudinal axis and gage length of test specimen must be within cross-hatched zone.

FIG. S26.2 Separately Cast Block



NOTE—Longitudinal axis and gage length of test specimen must be within cross-hatched zone.

FIG. S26.3 Prolongation Test Specimen

S29. Decarburization

S29.1 A representative casting or coupon shall be evaluated for total or complete decarburization, or both, in accordance with ARP 1341.

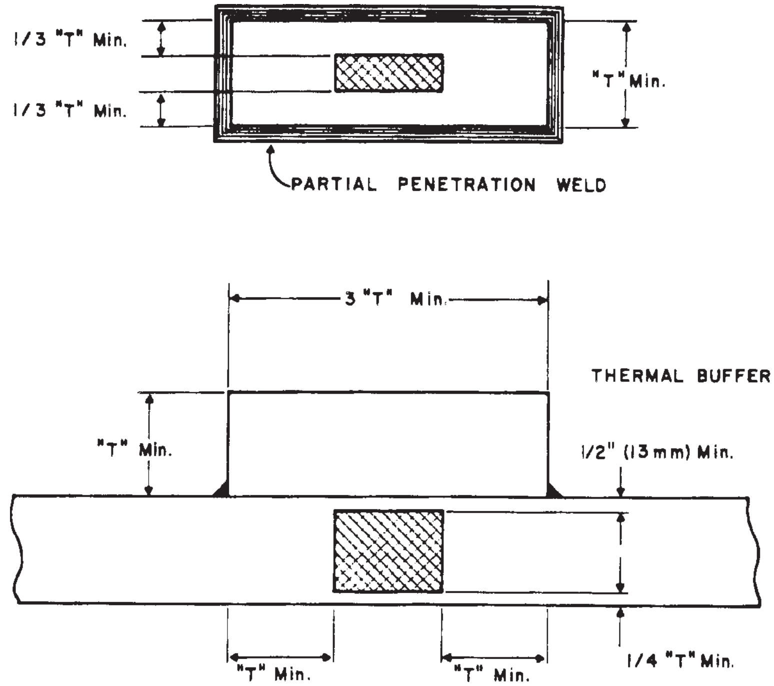
S29.2 The basis for acceptance shall be agreed upon between the purchaser and manufacturer. An example of an acceptance specification is zero total decarburization and no more than 0.020 in. partial decarburization.

S30. Metallurgical Cleanliness

S30.1 After polishing, each casting shall be visually inspected for nonmetallic inclusions and porosity.

S30.2 The details of the method for inspection and the basis for acceptance shall be agreed upon between the purchaser and manufacturer.

S30.3 It is realized that the foundry may be unable to perform the inspection for metallurgical cleanliness prior to shipment, or that the purchaser may wish to defer inspection until after additional work or machining has been performed on the casting. The foundry, however, is responsible for the satisfactory performance of the castings under the final inspection required in S30.1



NOTE—Longitudinal axis and gage length of test specimen must be within cross-hatched zone.

FIG. S26.4 Thermal Buffer Pads

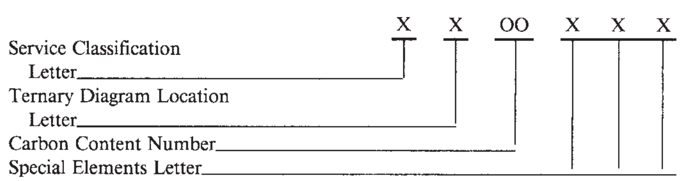
APPENDIX

(Nonmandatory Information)

X1. ALLOY DESIGNATIONS FOR CAST STAINLESS STEELS

X1.1 Cast stainless steels usually are specified on the basis of composition using the alloys designation system established by the Alloy Casting Institute (ACI). The ACI designations, for example, CF8M, have been adopted by ASTM and are preferred for cast alloys over the designations used by the American Iron and Steel Institute for similar wrought steels.

X1.2 This nomenclature system has served successfully to accommodate changes in old alloys and to designate new ones.



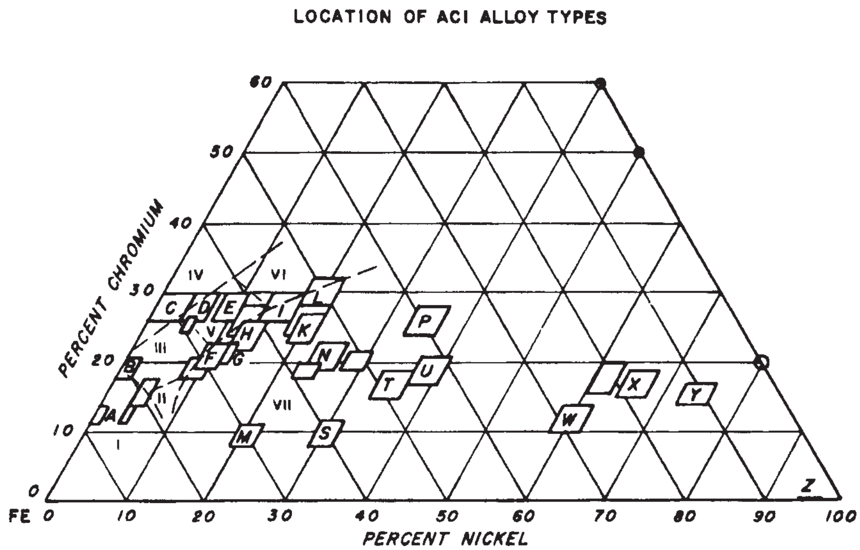
X1.2.1 *Service Classification Letter* —The first letter of the cast stainless steel designation system identifies the intended service application of the alloy. The letter *C* indicates corrosion-resistant service, and the letter *H* indicates the heat-resistant service at and above 1200°F [650°C].

X1.2.2 *Ternary Diagram Location Letter* —The second letter indicates the approximate location of the nickel and chromium contents of the alloy grade on the FeCrNi ternary diagram shown in Fig. X1.1.

X1.2.3 *Carbon Content Number*—For *C* service classifications, this single or dual digit numeral represents the maximum carbon content in units of 0.01 %. For *H* service classifications, this number represents the midpoint of the range of carbon content in terms of 0.01 % with a ±0.05 % limit.

X1.2.4 *Special Elements Letters*—Additional letters following the numeral represents special chemical elements in the alloy grade, such as M for molybdenum, C for columbium, Cu for copper, and W for tungsten. There are two exceptions. The letter A indicates “Controlled Ferrite,” and the letter F indicates “Free Machining.”

X1.3 In Fig. X1.1, unlettered NiCr ranges are associated with the nearest lettered location. They may be the result of differences between corrosion and heat-resistance types or because of the influence of additional elements, for example, the precipitation hardening grade CB-7 Cu.



NOTE—The approximate areas of microstructures to be expected at room temperature are indicated as follows:
I-Martensite
II-Martensite and untransformed austenite
III-Ferrite plus martensite and untransformed austenite
IV-Ferrite
V-Ferrite plus austenite
VI-Ferrite plus austenite plus sigma
VII-Austenite
Carbides also may be present depending on carbon content and thermal history.

FIG. X1.1 Letters Assigned to Chromium and Nickel Ranges in ACI Designation System

SUMMARY OF CHANGES

Committee A01 has identified the location of selected changes to this standard since the last issue (A 985 – 03) that may impact the use of this standard. (Approved April 1, 2004.)

(1) Removed Supplementary Requirement S31, Heat Treatment in the Working Zone of a Surveyed Furnace.
(2) Revised Supplementary Requirements S7 and S22 by changing “critical temperature” to “transformation temperature.”

Committee A01 has identified the location of selected changes to this standard since the last issue (A 985 – 01a $^{\epsilon 1}$) that may impact the use of this standard. (Approved April 10, 2003.)

(1) Changed 4.3 to include requirements for performing temperature uniformity surveys of heat treatment furnaces.

Designation: A 990 – 03

Standard Specification for Castings, Iron-Nickel-Chromium and Nickel Alloys, Specially Controlled for Pressure Retaining Parts for Corrosive Service[1]

This standard is issued under the fixed designation A 990; 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 iron-nickel-chromium and nickel alloy castings specially processed with restricted melt practices, weldability testing and nondestructive examination (NDE) requirements.

1.2 A number of grades of iron-nickel-chromium and nickel alloy castings are included in this specification. Since these grades possess varying degrees of suitability for service in corrosive environments, it is the responsibility of the purchaser to determine which grade shall be furnished. Selection will depend on design and service conditions, mechanical properties, and corrosion-resistant characteristics.

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 parentheses. 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 351/A 351M Specification for Castings, Austenitic, Austenitic-Ferritic (Duplex), for Pressure-Containing Parts[2]

A 370 Test Methods and Definitions for Mechanical Testing of Steel Products[2]

A 488/A 488M Practice for Steel Castings, Welding, Qualification of Procedures and Personnel[2]

A 494/A 494M Specification for Castings, Nickel and Nickel Alloy[2]

A 703/A 703M Specification for Steel Castings, General Requirements, for Pressure-Containing Parts[2]

A 743/A 743M Specification for Castings, Iron-Chromium, Iron-Chromium-Nickel, Corrosion Resistant, for General Application[2]

A 744/A 744M Specification for Castings, Iron-Chromium-Nickel, Corrosion-Resistant, for Severe Service[2]

A 802/A 802M Practice for Steel Castings, Surface Acceptance Standards, Visual Examination[2]

A 903/A 903M Specification for Steel Castings, Surface Acceptance Standards, Magnetic Particle and Liquid Penetrant Inspection[2]

A 941 Terminology Relating to Steel, Stainless Steel, Related Alloys, and Ferroalloys[3]

E 94 Guide for Radiographic Examination[4]

E 165 Test Method for Liquid Penetrant Examination[4]

E 186 Reference Radiographs for Heavy-Walled (2 to 4½-in. (51 to 114-mm)) Steel Castings[4]

E 272 Reference Radiographs for High-Strength Copper-Base and Nickel-Copper Alloy Castings[4]

E 280 Reference Radiographs for Heavy-Walled (4½ to 12-in. (114 to 305-mm)) Steel Castings[4]

E 446 Reference Radiographs for Steel Castings Up to 2 in. (51 mm) in Thickness[4]

2.2 *AWS Standards:*[5]

AWS A5.4, Specification for Stainless Steel Electrodes for Shielded Metal Arc Welding

AWS A5.9, Specification for Bare Stainless Steel Welding Electrodes and Rods

AWS A5.11, Specification for Nickel and Nickel Alloy Electrodes for Shielded Metal Arc Welding

AWS A5.14, Specification for Nickel and Nickel Alloy Bare

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[1] This specification is under the jurisdiction of ASTM Committee A01 on Steel, Stainless Steel, and Related Alloys and is the direct responsibility of Subcommittee A01.18 on Castings.

Current edition approved Sept. 10, 2003. Published October 2003. Originally approved in 1998. Last previous edition approved in 2000 as A 990–00$^{\epsilon 1}$.

[2] *Annual Book of ASTM Standards*, Vol 01.02.

[3] *Annual Book of ASTM Standards*, Vol 01.01.

[4] *Annual Book of ASTM Standards*, Vol 03.03.

[5] Available from the American Welding Society, 550 N.W. LeJeune Road, Miami, FL 33126.

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

Welding Electrodes and Rods

2.3 *ASME/ANSI Standard:*[6]

ASME/ANSI B16.34, Valves-Flanged, Threaded, and Welding End

3. Terminology

3.1 *Definitions*— The definitions in Test Methods and Definitions A 370 and Terminology A 941 are applicable to this specification.

3.2 *Definitions of Terms Specific to This Standard:*

3.2.1 *accessible surface*, *n*—surface that can be welded on without cutting access holes in the casting.

3.2.2 *revert*, *n*—gates, risers, and castings. Also includes scrapped machinery and fabricated items, chips and turnings.

3.2.3 *refined ingot*, *n*—metal processed by argon-oxygen-decarburization (AOD) or vacuum-oxygen-decarburization (VOD) and cast to a size and shape suitable for remelting.

4. General Conditions for Delivery

4.1 Material furnished to this specification shall conform to the requirements of Specification A 703/A 703M, including any supplementary requirements that are indicated in the purchase order. Failure to comply with the general requirements of Specification A 703/A 703M constitutes nonconformance with this specification. In case of conflict between the requirements of this specification an Specification A 703/A 703M, this specification shall prevail.

5. Ordering Information

5.1 It is the responsibility of the purchaser to specify all requirements that are necessary for material ordered to this specification. Such requirements may include, but are not limited to, the following:

5.1.1 Quantity.

5.1.2 Grade designation (Table 1).

TABLE 1 Chemical Requirements

Element, % (max, except where range is given)	Grade		
	CW-2M	CN3MCu	M35-1
C	0.020	0.030	0.35
Mn	1.00	1.50	1.50
Si	0.80	1.00	1.25
P	0.030	0.030	0.030
S	0.015	0.015	0.015
Mo	15.0-17.5	2.0-3.0	. . .
Fe	2.00	balance	3.5
Ni	balance	27.5-30.5	Balance
Cr	15.0-17.5	19.0-22.0	. . .
Cu	. . .	3.0-3.5	26.0-33.0
W	1.00	. . .	. . .

5.1.3 Description of the casting by pattern number or drawing. Dimensional tolerances should be included on the casting drawing.

[6] Available from the American Society of Mechanical Engineers, Three Park Avenue, New York, NY 10016..

5.1.4 Nondestructive inspection class required (Table 2). Class D will be supplied unless otherwise specified.

5.1.5 Wetted surfaces (Table 2).

5.2 The purchaser shall specify any supplementary requirements desired, including standards of acceptance, required to describe adequately the desired material.

6. Process and Manufacture

6.1 Alloys, except for nickel base, 25 to 35 % Cu alloys, shall be made by one of the two following processes:

6.1.1 Electric arc or induction furnace melting followed by AOD or VOD refining, or

6.1.2 Electric induction furnace melting of refined ingot.

6.2 Nickel base alloys with 25 to 35 % Cu shall be made by 6.1.1 or 6.1.2 or by electric furnace.

6.3 Additions of up to 5 % are permitted for compositional adjustments and deoxidation.

6.4 Revert shall not be used.

7. Chemical Composition

7.1 These alloys shall conform to the chemical composition requirements prescribed in Table 1. An analysis of every heat is required.

8. Tensile Properties

8.1 One tension test shall be made from each heat. Test results shall conform to the tensile requirements specified in Table 3. The bar shall be solution heat treated per the requirements of Table 4 in production furnaces to the same procedure as the castings it represents. If the casting grade does not require heat treatment, the bar used for the test specimen shall not be heat treated.

9. Weldability Qualification

9.1 Each heat shall be qualified by weldability testing.

9.2 *Sampling*:

9.2.1 The weldability test plate shall be cast in accordance with Fig. 1.

9.2.2 For heats produced under 6.1.1, at least one weldability test plate shall be cast from each heat.

9.2.3 For heats produced under 6.1.2, at least one weldability test plate shall be cast from the first heat in an uninterrupted series of heats, made in the same furnace from the same heat of refined ingot using the same melting procedure, and shall qualify all of the subsequent heats in that series made in the same shift.

9.3 *Procedure:*

9.3.1 The test plates required under 9.2 shall be processed and tested as follows:

9.3.1.1 Prior to welding, the test plate shall be solution heat treated according to the requirements of Table 4 in production furnaces to the same procedure as the castings it represents.

9.3.1.2 All forms of cold working, mechanical deformation, hammering or peening, in excess of that required for normal cleaning is prohibited.

9.3.1.3 Fill the groove in the plate with weld deposit according to the procedure used in Section 11 and the filler material grade specified in Table 5.

TABLE 2 Nondestructive Examination Requirements

Maximum Casting Thickness	Class	Visual Examination, Practice A 802/A 802M Minimum Acceptance Level	Radiographic Examination, Guide E 94 Number of Castings Severity Level per Table 6	Liquid Penetrant Examination, Test Method E 165	
				Coverage	Minimum Acceptance Level per Specification A 903/A 903M
less than ⅝ in. (15.9 mm)	A	Level I	100 %	All accessible surfaces	Level I
	B	Level II	100 %	All accessible wetted surfaces	Level II
	C	Level II	Initial casting off pattern	Weld repairs	Level II
	D	Level II	Initial casting off pattern	NA	NA
⅝ to 1 in. (15.9 to 25.4 mm)	A	Level I	100 %	All accessible surfaces	Level II
	B	Level II	100 %	All accessible wetted surfaces	Level III
	C	Level II	Initial casting off pattern	Weld repairs	Level III
	D	Level II	Initial casting off pattern	NA	NA
Over 1 to 2 in. (25.4 to 50.8 mm)	A	Level I	100 %	All accessible surfaces	Level III
	B	Level II	100 %	All accessible wetted surfaces	Level IV
	C	Level II	Initial casting off pattern	Weld repairs	Level IV
	D	Level II	Initial casting off pattern	NA	NA
Over 2 to 4 ½ in. (50.8 to 114 mm)	A	Level II	100 %	All accessible surfaces	Level IV
	B	Level II	100 %	All accessible wetted surfaces	Level IV
	C	Level III	Initial casting off pattern	Weld repairs	Level V
	D	Level III	Initial casting off pattern	NA	NA
Over 4 ½ in. (114 mm)	A	Level III	100 %	All accessible surfaces	Level V
	B	Level III	100 %	All accessible wetted surfaces	Level V
	C	Level IV	Initial casting off pattern	Weld repairs	Level V
	D	Level IV	Initial casting off pattern	NA	NA

TABLE 3 Tensile Requirements

	Grade		
	CW-2M	CN3MCu	M35-1
Tensile strength, min, psi [MPa]	72 000 (495)	62 000 [425]	65 000 [450]
0.2 % offset yield strength, min, psi [MPa]	40 000 (275)	25 000 [170]	25 000 [170]
Elongation in 2 in. (50 mm), min, %	20.0	35.0	25.0

TABLE 4 Heat Treat Requirements

Grade	Heat Treatment
CW-2M	Heat to 2250° ± 25°F (1232° ± 14°C) for a min of 1 h at temperature/1 in. (25 mm) of thickness. Quench in water.[A]
CN3MCu	Heat to 2050°F (1220°C) min for a min of 1 h at temperature/1 in. (25 mm) of thickness. Quench in water.[A]
M35-1	As-cast

[A]Quench in water or rapid cool by other means as agreed upon by the manufacturer and purchaser.

TABLE 5 Weld Filler Materials

Cast Grade	AWS A5.11 and AWS A5.14 Weld Filler Material
CW-2M	NiCrMo-7 or NiCrMo-10
CN3MCu	AWS A5.4 and AWS A5.9 320LR
M35-1	NiCu-7

9.3.1.4 For the purposes of the weldability test only, post weld heat treatment of the test plate is prohibited even if part of the procedure. Remove one ⅜-in. (10-mm) min thick bend coupon longitudinally from the center of the welded plate by machining, sawing, or abrasive cutting. Make a transverse side bend test of the welded joint in accordance with Practice A 488/A 488M.

9.4 *Acceptance:*

9.4.1 On the bent specimen, cracks or other open defects exceeding ⅛ in. (3.2 mm), measured in any direction on the convex surface shall be cause for rejection, except that cracks occurring on and limited to the corners while testing shall not be considered.

10. Nondestructive Examination

10.1 One of four different classes of nondestructive examination shall be imposed on castings ordered to this specification. Classes A, B, C and D are defined in Table 2. Each class imposes specific requirements for three different NDE methods. Class D will be supplied unless otherwise specified.

10.2 *Visual Examination*—Each casting shall be examined visually in accordance with Practice A 802. Fusion discontinuities, expansion discontinuities, and inserts are unacceptable. All other surface features must meet the acceptance criteria class in Table 2.

10.3 *Radiographic Examination*:

10.3.1 The number of castings to be examined radiographically and the acceptance criteria shall be in accordance with the specified class in Table 2 and Table 6.

10.3.2 The extent of coverage shall be agreed upon between the manufacturer and purchaser. Where applicable, the minimum coverage shall comply with ASME/ANSI B 16.34.

10.3.3 Personnel performing the examination shall be qualified in accordance with an acceptable written practice.

10.3.4 All castings that are radiographed and found acceptable shall be marked permanently RT.

TABLE 6 Radiographic Severity Level Requirements

Nickel Base			Severity Level, Min Acceptance Level Reference Radiographs E 272								Reference Radiographs E 186	
			Shrinkage		Dross		Porosity		Inclusions		Chaplets	
Casting Thickness in Area of interest	Class	Type	Reference Radiograph	Source	Reference Radiograph	Source	Reference Radiograph	Source	Reference Radiograph	Source	Reference Radiograph	Source
1 in. (25 mm) and less	Class A	Feathery	Cd 2	X-ray	Bb 1	X-ray	A3	X-ray	Ba 3	X-ray	None Acceptable	
		Spongy	Cd 2	Gamma								
		Linear	Ca 2	Gamma								
	Class B, C and D	Feathery	Cd 3	X-ray	Bb 2	X-ray	A4	X-ray	Ba 4	X-ray	None Acceptable	
		Spongy	Cd 3	Gamma								
		Linear	Ca 3	Gamma								
Over 1 in. (25 mm)	Class A	Feathery	Cd 3	X-ray	Bb 2	Gamma	A3	Gamma	Ba 3	Gamma	None Acceptable	
		Spongy	Cd 3	Gamma								
		Linear	Ca 3	Gamma								
	Class B, C and D	Feathery	Cd 4	X-ray	Bb 3	Gamma	A4	Gamma	Ba 4	Gamma	None Acceptable	
		Spongy	Cd 4	Gamma								
		Linear	Ca 4	Gamma								

Iron-Nickel-Chromium

Casting Thickness	Class	ASTM Standard	Shrinkage	Porosity	Inclusion	Hot Tear, Crack	Insert, Chaplet
Less than 1 in. (25 mm)	Class A	E 446	CA 2, CB 2, CC 2, CD 2	A 2	B 2	None	None
	Class B, C and D	E 446	CA 3, CB 3, CC 3, CD 3	A 3	B 3	None	None
1 to 2 in. (25 to 51 mm)	Class A	E 446	CA 2, CB 2, CC 2, CD 2	A 2	B 2	None	None
	Class B, C and D	E 446	CA 3, CB 3, CC 3, CD 3	A 3	B 3	None	None
Over 2 to 4-½ in. (251 to 114 mm)	Class A	E 186	CA 3, CB 3, CC 3	A 3	B 3	None	None
	Class B, C and D	E 186	CA 4, CB 4, CC 4	A 4	B 4	None	None
Over 4-½ in. (114 mm)	Class A	E 280	CA 3, CB 3, CC 3	A 3	B 3	None	None
	Class B, C and D	E 280	CA 4, CB 4, CC 4	A 4	B 4	None	None

10.3.5 For Classes C and D, if a rejectable indication is found, that first casting shall be scrapped or repaired and the second casting radiographed. If the second casting passes, then no additional radiography beyond the normal amount is required. If that second casting fails, all remaining castings shall be radiographed in only the rejectable areas found on the first and second castings.

10.4 *Liquid Penetrant Examination*:

10.4.1 All Class A, B, and C castings shall be liquid penetrant (LP) tested in accordance with Table 2 after the final specified heat treatment.

10.4.2 Personnel performing the examination shall be qualified in accordance with an acceptable written practice.

10.4.3 When welding is performed after the liquid penetrant examination, the repair weld and at least ¼ in. (6 mm) of the surrounding material shall be LP tested in accordance with Table 2.

11. Repair by Welding

11.1 All weld repairs shall be made with welders and procedures qualified in accordance with Practice A 488/A 488M. Only the filler material grades specified in Table 5 shall be used.

11.2 Major weld repairs are repairs required when a casting has leaked on hydrostatic test or when the depth of the cavity after preparation for repair exceeds 20 % of the actual wall thickness or 1 in. (25 mm), whichever is smaller, or when the extent of the welding exceeds approximately 10 in^2 (65 cm^2) or 5 % of the total surface area, whichever is smaller.

11.3 All weld repairs shall be subject to the same quality standards as are used to inspect the castings. Initial excavation of defects may be accomplished by any method including air-arc gouging, grinding, or machining; however, all visible traces of the air-arc process shall be removed by grinding or machining. All surfaces to be welded and at least 1 in. (25 mm) beyond shall be smooth and free of sand, scale, paint, oil or other foreign matter. The cleaning may be accomplished by grinding or by machining followed by solvent washing.

11.4 All forms of cold working, mechanical deformation, hammering or peening in excess of that required for normal cleaning is prohibited.

12. Heat Treatment

12.1 All castings shall be solution heat treated as specified in Table 4.

12.2 Post-weld solution heat treatment is required for all major weld repairs, except on M35-1, which is used in the as-cast condition. Post-weld solution heat treatment of other weld repairs is not required provided an interpass temperature of 250°F (121°C) is not exceeded.

13. Workmanship, Finish and Appearance

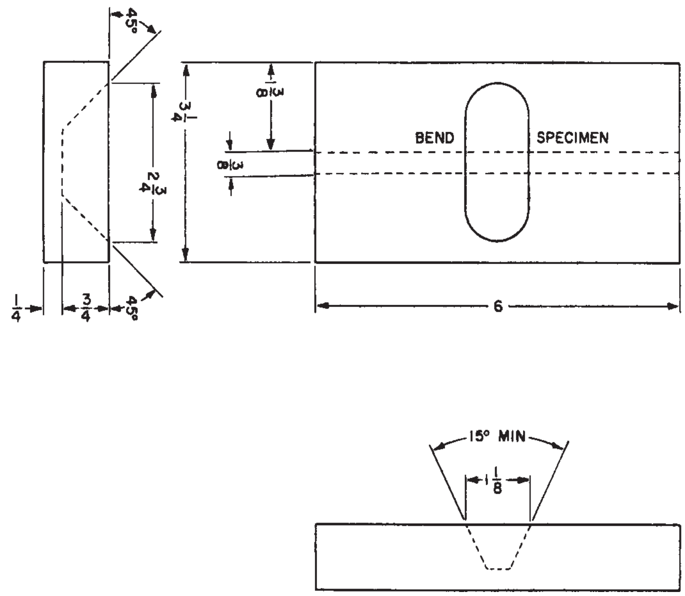
13.1 All surfaces shall be cleaned and free of scale. Final cleaning shall be accomplished by blasting with clean nonmetallic media not previously used on steel or iron parts, pickling, machining or other approved methods approved by the purchaser.

13.2 The castings shall not be peened, plugged, or impregnated.

14. Product Marking

14.1 Castings shall be marked with the ASTM specification designation and grade symbol, for example, CW-2M. The manufacturer's name or identification mark, the pattern number or part number, and the heat number shall be cast or stamped on all castings except those of such small size as to make such marking impractical.

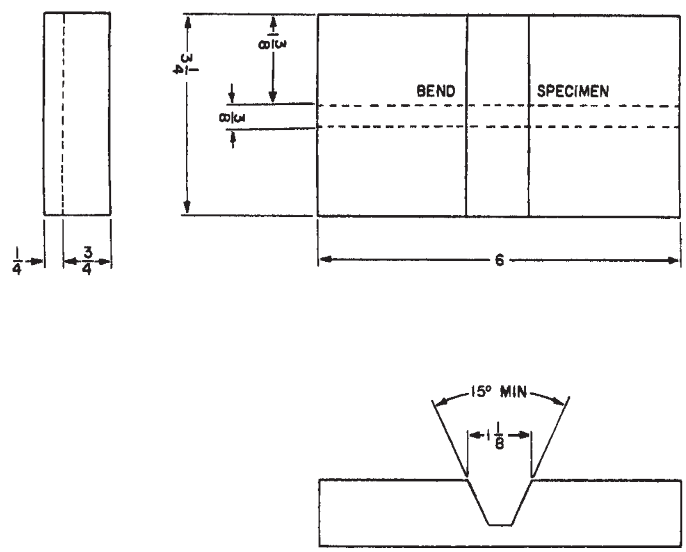
14.2 When the castings are too small to mark individually, a symbol traceable to the heat shall be placed on the castings and the required identification then placed on a tag affixed to the container in which these castings are shipped.



(A)

Metric Equivalents

in.	¼	⅜	¾	1 ⅛	2 ¾	3 ¼	6
[mm]	[5]	[10]	[20]	[30]	[70]	[85]	[155]



NOTE—May be used with the purchaser's approval when the molding process makes it impractical to cast the cavity into the test plate.

(B)

Metric Equivalents

in.	¼	⅜	¾	1 ⅛	3 ¼	6
[mm]	[5]	[10]	[20]	[30]	[85]	[155]

FIG. 1 (a) Weldability Test Plate (b) Optional Weldability Test Plate With a Machined Groove

ANNEX

(Mandatory Information)

A1. ACCEPTANCE CRITERIA FOR INCLUSION OF NEW IRON-NICKEL-CHROMIUM AND NICKEL ALLOYS IN THIS SPECIFICATION

A1.1 Specifications A 351/A 351M, A 494/A 493M, A 743/A 743M, and A 744/A 744M contain alloys similar to those listed in this specification. The distinguishing requirements of this specification are as follows.

A1.1.1 One of four classes of alloys all with 0.015 % S max.

A1.1.1.1 Nickel base with 15 % Cr min, 8 % Mo min, and 0.020 % C max.

A1.1.1.2 Nickel base with 25–35 % Cu and 0.020 % C min.

A1.1.1.3 Nickel base with 25–35 % Mo and 0.020 % C max.

A1.1.1.4 Iron base, fully-austenitic, with 18 % Cr min, 17 % Ni min, 2–8 % Mo and 0.030 % C max.

A1.1.2 AOD or VOD refined material, no revert except nickel base with 25 to 35 % Cu and 0.020 % C min.

A1.1.3 Weld bend test every heat in the as-welded condition.

A1.1.4 Levels of NDE with combinations of visual, LP and radiography with acceptance criteria.

A1.1.5 Restricted heat treat requirements for improved corrosion resistance, solution heat treat after all major weld repairs. With 250°F (121°C) max interpass temperature, solution heat treat is not required for minor repairs.

A1.1.6 Specified weld filler material.

A1.2 To be considered for inclusion in this specification, the following data must be presented to Subcommittee A01.18.

A1.2.1 Demonstrate that all heats in the data package passed the weld bend test in the as-welded condition as directed in Sections 9-9.4.

A1.2.2 The alloy shall fall within one of the four classes of materials listed in A1.1.1.1-A1.1.1.4 and meet the restricted compositional limits.

SUMMARY OF CHANGES

Committee A01 has identified the location of selected changes to this standard since the last issue (A 990 – $00^{\epsilon 1}$) that may impact the use of this standard.

(1) References to M35-1 were added throughout the standard.

Designation: A 993 – 98

AMERICAN SOCIETY FOR TESTING AND MATERIALS
100 Barr Harbor Dr., West Conshohocken, PA 19428

Standard Test Method for Dynamic Tear Testing of Cast Irons to Establish Transition Temperature[1]

This standard is issued under the fixed designation A 993; 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 test method covers dynamic tear testing and is applicable to graphitic cast irons and establishes the transition temperature from examination of fracture appearance. Details of apparatus, specimens, and procedures are included.

1.2 The values stated in SI units are to be regarded as the standard. The inch-pound units 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:*

A 644 Terminology Related to Iron Castings[2]

E 208 Test Method for Conducting Drop-Weight Test to Determine Nil-Ductility Transition Temperature of Ferritic Steels[3]

E 604 Test Method for Dynamic Tear Testing of Metallic Materials[3]

3. Summary of Test Method

3.1 The Dynamic Tear (DT) test involves a single-edge notched beam that is impact loaded in three-point bending.

3.2 The DT specimens are fractured with a drop-weight machine at a variety of temperatures.

3.3 The fracture surface of each specimen is examined to determine the ratio of ductile to brittle fracture and these values are then plotted against temperature to determine the transition temperature; the temperature at which the fracture surface shows 50 % ductile and 50 % brittle fracture, is the transition temperature.

3.4 If this test method is to be used solely to establish that the transition temperature is at or below a customer specified temperature, the specimens are tested at the specified temperature. Using the ratio of ductile to brittle fracture, the area is measured for each sample and the results of all samples tested at each temperature are averaged. The area of brittle (cleavage) fracture must be no more than 50 % of the fracture surface.

4. Test Specimen

4.1 Dynamic Tear (DT) specimens, with dimensions as specified in Fig. 1, are to be cast in green sand or dried, baked, or chemically bonded molds made with siliceous sand and appropriate binders. When placing more than one sample in a given mold, each sample shall be separated sufficiently to assure a cooling rate essentially independent of the adjacent samples. Each DT sample shall be cooled until totally black prior to shakeout.

4.2 Machining will be required on at least two faces of the test piece. One side is to be notched and the other impacted. A notch is milled or sawn into each specimen as shown in Fig. 1.

5. Apparatus

5.1 A typical fracture test drop tower is shown in Fig. 2.

5.2 A drop weight with a non-instrumented tup is used. The standard combined weight for these two items is 22.7 kg (50 lb). Tup design is to be as defined in Test Method E 604.

5.3 The weight is allowed to fall via guide rails to cause DT specimen fracture. Frictional effects that slow the velocity of the falling weight, prior to specimen fracture, are to be kept to a minimum.

5.4 At the time of weight release, the standard distance between the bottom of the tup and the top (impact) surface of the specimen is 760, ± 7.6 mm (30 ± 0.30 in.), as illustrated in Fig. 2.

5.5 The fixture on which the specimen rests at the time of impact is shown in Fig. 1. Each anvil is to have a radius of 12.7 ± 0.25 ± mm (0.500 ± 0.01 in.). The distance between anvil centers is to be 165.0 ± 1.65 mm (6.500 ± 0.403 in.).

5.6 The force used must be sufficient to break the specimen in a single blow. If use of the standard height and weight do not produce this result for the iron being evaluated, the weight or drop distance must be increased. The weight and drop distance used must be reported. A weight increase is preferable.

6. Procedure

6.1 Test temperatures are typically in the range between -73°C (-100° F) and room temperature 22°C (72°F). To establish transition temperature, samples must be tested at a minimum of two temperatures. The transition temperature

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[1] This test method is under the jurisdiction of ASTM Committee A-4 on Iron Castings and is the direct responsibility of Subcommittee A04.21 on Testing.

Current edition approved December 10, 1998. Published March 1999.

[2] *Annual Book of ASTM Standards*, Vol 01.02.

[3] *Annual Book of ASTM Standards*, Vol 03.01.

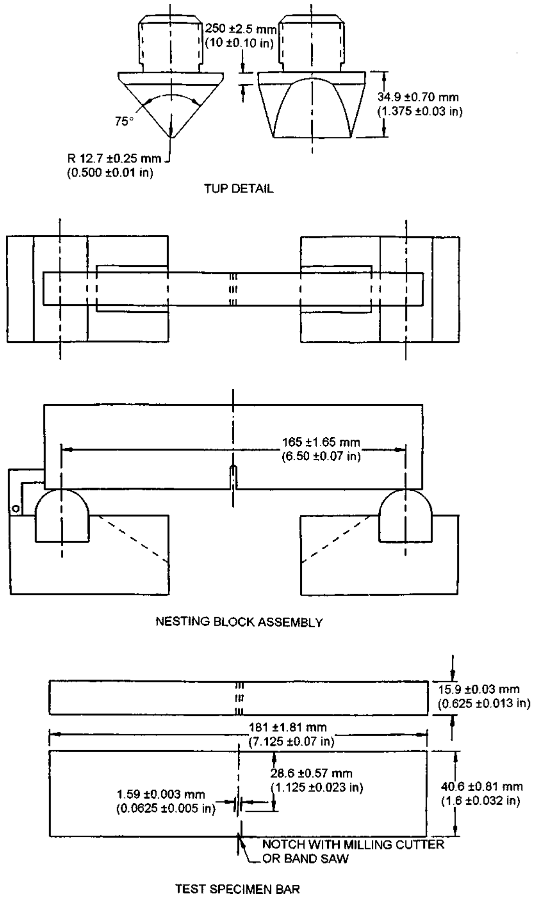

FIG. 1 Assembly Details of Transformation Temperature Test Machine

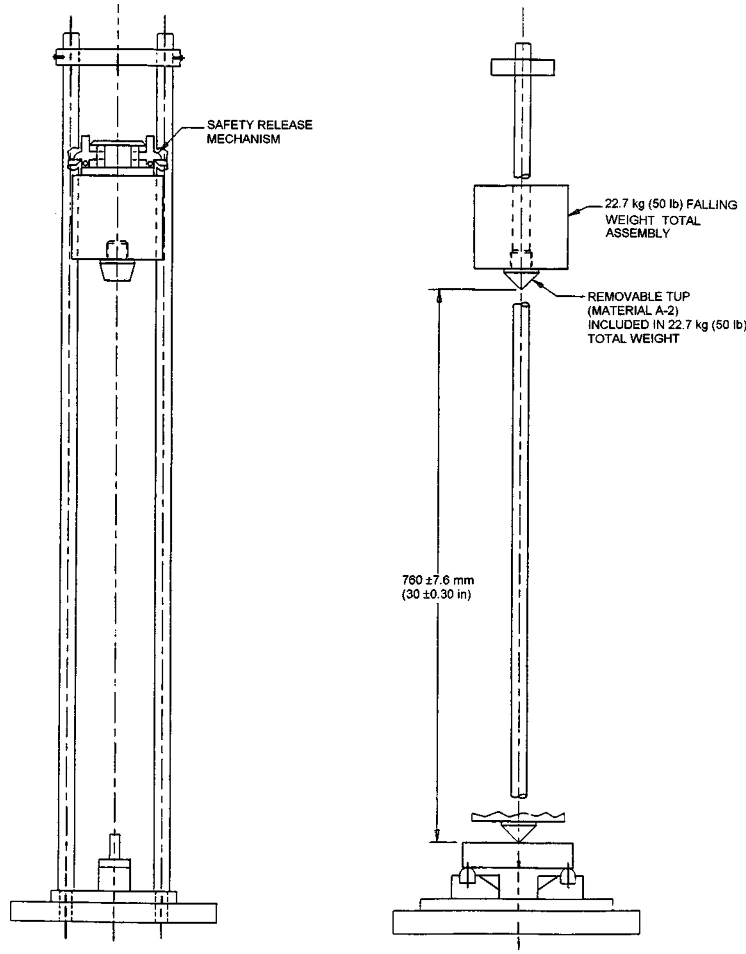

FIG. 2 Assembly Views

must lie between the two test temperatures. The two test temperatures must be bracketing the transition temperature and be no more than 14, ± 1° C, (25, ± 2°F) apart. To establish that the transition temperature is no higher than a specified temperature, all samples are tested at the specified temperature.

6.2 A minimum of three specimens are to be tested at each temperature. A minimum of six specimens are required if statistics are to be applied to the data.

6.3 Prior to testing, the DT specimens are to be heated or cooled to the desired test temperature and, in accordance with Test Method E 208, held at the test temperature for a minimum of 45 min before removal from the heating or cooling medium for testing.

6.4 To ensure that all specimens are at the desired temperature prior to testing, a thermocouple is to be kept adjacent to the test specimens in the heating or cooling medium.

6.5 For each test, handle the DT specimens carefully and rapidly with tongs designed to minimize specimen temperature changes.

6.6 For each test, place a DT specimen of known temperature on the anvil, with the notch side down, and release the drop weight within 15 s from the time of specimen removal from the heating or cooling medium.

6.7 Rate the percent ductile fracture (dark) and percent brittle fracture (cleavage, bright) on the fractured surface of each specimen. This can be done by visual estimation, or preferably by a quantitative method such as photographing the fracture surface and using a correctly sized transparent film grid to point count the number of intersections on each type fracture.

6.8 For the transition temperature determination, plot the percent of ductile to brittle fracture area for each specimen versus test temperature and then put a best fit curve through the data points. The temperature corresponding to a 50 % of brittle fracture area is the transition temperature. The report shall include the number of samples tested at each temperature and the transition temperature determined.

6.9 For confirmation that the transition temperature is no greater than a specified temperature, calculated the mean value of the percent brittle (cleavage) fracture for all samples tested at the specified temperature. The mean value calculated must be less than, or equal to, 50 % for conformance. The report shall include the number of samples tested, the test temperature, and the mean value.

7. Report

7.1 The report shall include material identification, cast date, sample identification, and the transition temperature results.

7.2 If non-standard drop heights, drop weights, or sample thicknesses are used, these must be reported along with the results in the test report.

Designation: A 995/A 995M – 98 (Reapproved 2003)

Standard Specification for Castings, Austenitic-Ferritic (Duplex) Stainless Steel, for Pressure-Containing Parts[1]

This standard is issued under the fixed designation A 995/A 995M; 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 austenitic-ferritic (duplex) stainless steel castings for valves, flanges, fittings, and other pressure-containing parts.

1.2 The duplex stainless steels offer a combination of enhanced mechanical properties and corrosion resistance when properly balanced in composition and properly heat treated. Ferrite levels are not specified, but these grades will develop a range of approximately 30 to 60 % ferrite with the balance austenite. It is the responsibility of the purchaser to determine which grade shall be furnished depending on design and service conditions, mechanical properties, and corrosion-resistant characteristics.

NOTE 1—Because of the possibility of precipitation of embrittling phases, the grades included in this specification are not recommended for service at temperatures above 600°F [315°C].

1.3 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 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 488/A 488M Practice for Steel Castings, Welding, Qualification of Procedures and Personnel[2]

A 703/A 703M Specification for Steel Castings, General Requirements, for Pressure-Containing Parts[2]

E 125 Reference Photographs for Magnetic Particle Indications on Ferrous Castings[3]

E 165 Test Method for Liquid Penetrant Examination[3]

E 562 Test Method for Determining Volume Fraction by Systematic Manual Point Count[4]

TABLE 1 Heat Treatment Requirements

Grade	Heat Treatment
1B	Heat to 1900°F [1040°C] minimum, hold for sufficient time to heat casting uniformly to temperature, quench in water or rapid cool by other means.
2A	Heat to 2050°F [1120°C] minimum, hold for sufficient time to heat casting uniformly to temperature, quench in water or rapid cool by other means.
3A	Heat to 1950°F [1070°C] minimum, hold for sufficient time to heat casting uniformly to temperature, quench in water or rapid cool by other means.
4A	Heat to 2050°F [1120°C] minimum for sufficient time to heat casting uniformly to temperature and water quench, or the casting may be furnace cooled to 1850°F [1010°C] minimum, hold for 15 min minimum and then water quench. A rapid cool by other means may be employed in lieu of water quench.
5A	Heat to 2050°F [1120°C] minimum, hold for sufficient time to heat casting to temperature, furnace cool to 1910°F [1045°C] minimum, quench in water or rapid cool by other means.
6A	Heat to 2010°F [1100°C] minimum, hold for sufficient time to heat casting uniformly to temperature, quench in water or cool rapidly by other means.

3. Terminology

3.1 *Definitions of Terms Specific to This Standard:*

3.1.1 *duplex stainless steel*—an iron-chromium-nickel-molybdenum alloy which when properly heat treated consists of approximately 30 to 60 % ferrite with the balance austenite.

4. General Conditions for Delivery

4.1 Material furnished to this specification shall conform to the applicable requirements of Specification A 703/A 703M, including the supplementary requirements that are indicated on the purchaser order. Failure to comply with the general requirements of Specification A 703/A 703M constitutes nonconformance with this specification. In case of conflict between the requirements of the specification and Specification A 703/A 703M, this specification shall prevail.

5. Ordering Information

5.1 It is the responsibility of the purchaser to specify all requirements that are necessary for material ordered under this

[1] This specification is under the jurisdiction of ASTM Committee A01 on Steel, Stainless Steel and Related Alloys and is the direct responsibility of Subcommittee A01.18 on Castings.

Current edition approved April 10, 2003. Published April 2003. Originally approved in 1998. Last previous edition approved in 1998 as A 995 – 98.

[2] *Annual Book of ASTM Standards*, Vol 01.02.

[3] *Annual Book of ASTM Standards*, Vol 03.03.

[4] *Annual Book of ASTM Standards*, Vol 03.01.

TABLE 2 Chemical Requirements

Grade	1B	2A	3A	4A	5A[A]	6A[A]
Type	25Cr-5Ni-M0-Cu-N	24Cr-10Ni-Mo-N	25Cr-5Ni-Mo-N	22Cr-5Ni-Mo-N	25Cr-7Ni-Mo-N	25Cr-7Ni-Mo-N
UNS	J93372	J93345	J93371	J92205	J93404	J93380
ACI	CD4MCuN	CE8MN	CD6MN	CD3MN	CE3MN	CD3MWCuN
Composition:						
Carbon, max	0.040	0.080	0.060	0.030	0.030	0.030
Manganese, max	1.00	1.00	1.00	1.50	1.50	1.00
Silicon, max	1.00	1.50	1.00	1.00	1.00	1.00
Phosphorus, max	0.040	0.040	0.040	0.040	0.040	0.030
Sulfur, max	0.040	0.040	0.040	0.020	0.040	0.025
Chromium	24.5-26.5	22.5-25.5	24.0-27.0	21.0-23.5	24.0-26.0	24.0-26.0
Nickel	4.7-6.0	8.0-11.0	4.0-6.0	4.5-6.5	6.0-8.0	6.5-8.5
Molybdenum	1.70-2.30	3.0-4.5	1.75-2.50	2.5-3.5	4.0-5.0	3.0-4.0
Copper	2.7-3.3	. . .	. . .	1.00, max	. . .	0.50-1.00
Tungsten	. . .	. . .	. . .	. . .	. . .	0.50-1.00
Nitrogen	0.10-0.25	0.10-0.30	0.15-0.25	0.10-0.30	0.10-0.30	0.20-0.30

[A] % Cr + 3.3 % Mo + 16 % N $\geq$ 40.

TABLE 3 Tensile Requirements

Grade	1B	2A	3A	4A	5A	6A
Type	25Cr-5Ni-Mo-Cu-N	24Cr-10Ni-Mo-N	25Cr-5Ni-Mo-N	22Cr-5Ni-Mo-N	25Cr-7Ni-Mo-N	25Cr-7Ni-Mo-N
Tensile strength, ksi [MPa], min	100 [690]	95 [655]	95 [655]	90 [620]	100 [690]	100 [690]
Yield strength (0.2 % offset), ksi [MPa], min	70 [485]	65 [450]	65 [450]	60 [415]	75 [515]	65 [450]
Elongation in 2 in. [50 mm], %, min[A]	16	25	25	25	18	25

[A] When ICI test bars are used in tensile testing as provided for in this specification, the gage length to reduced section diameter ratio shall be 4:1.

specification. Such requirements may included, but are not limited to, the following:

5.1.1 A description of the casting by pattern number or drawing (dimensional tolerances shall be included on the casting drawing),

5.1.2 Quantity (weight and number of castings),

5.1.3 Specification designation and date of issue,

5.1.4 Grade of steel,

5.1.5 Supplementary requirements including acceptance criteria, and

5.1.6 Additional requirements.

6. Process

6.1 The steel shall be made by the electric furnace process with or without separate refining.

7. Heat Treatment

7.1 All castings shall be heat treated in accordance with Table 1.

8. Chemical Composition

8.1 The steel shall conform to the requirements as to chemical composition prescribed in Table 2.

9. Tensile Properties

9.1 One tension test shall be made from each heat and shall conform to the requirements as to tensile properties prescribed in Table 3.

10. Quality

10.1 When additional inspection is desired, Supplementary Requirements S5, S6, and S10 may be ordered.

11. Repair by Welding

11.1 Repairs shall be made using procedures and welders qualified under Practice A 488/A 488M.

11.2 The composition of the deposited weld metal may be similar to that of the casting or may be suitably alloyed to achieve the desired corrosion resistance and mechanical properties.

11.3 Weld repairs shall be subject to the same quality standards as used to inspect the castings.

11.4 When postweld heat treatment is believed necessary for adequate corrosion resistance or impact toughness, Supplementary Requirement S11, Post Weld Heat Treatment, shall be included in the purchase order.

12. Post Weld Heat Treatment After Major Weld Repair

12.1 Weld repairs shall be considered major in the case of a casting that has leaked on hydrostatic testing or when the depth of the cavity after preparation for repair exceeds 20 % of the actual wall thickness, or 1 in. [25 mm], whichever is smaller, or when the extent of the cavity exceeds approximately 10 in.^{2} [65 cm^2]. All other weld repairs shall be considered minor.

12.2 Castings shall be heat-treated after major weld repairs. Heat treatment after minor weld repairs is not required except upon agreement between the manufacturer and the purchaser.

12.3 Post weld heat treatment shall be in accordance with Table 1.

13. Keywords

13.1 austenitic-ferritic; duplex stainless steel; pressure-containing; steel castings

SUPPLEMENTARY REQUIREMENTS

The following supplementary requirements shall not apply unless specified in the purchase order. A list of standardized supplementary requirements for use at the option of the purchaser is included in Specification A 703/A 703M. Those which are ordinarily considered suitable for use with this specification are given below. Others enumerated in Specification A 703/A 703M may be used with this specification upon agreement between the manufacturer and purchaser.

S1. Unspecified Elements

S2. Destruction Tests

S5. Radiographic Inspection

S6. Liquid Penetrant Inspection

S8. Charpy Impact Test

S10. Examination of Weld Preparation

S10.1 Liquid penetrant examination of cavities prepared for welding shall be performed to verify removal of those discontinuities found unacceptable by the inspection method specified for the casting. The method of performing liquid penetrant examination shall be in accordance the with Practice E 165. Unless other degrees of shrinkage or types of discontinuities found in the cavities are specified, Type II, Internal Shrinkage, of Reference Photographs E 125, of Degree 2 in sections up to 2 in. [50 mm] thick and of Degree 3 in sections over 2 in. [50 mm] thick shall be acceptable.

S11. Post Weld Heat Treatment

S11.1 Castings shall be given a post weld solution heat treatment in accordance with Table 1.

S12. Prior Approval of Major Weld Repairs

Other supplementary requirements considered suitable for use with this specification are:

S50. Estimating Ferrite Content

S50.1 Ferrite contents shall be determined by point count (Practice E 562), by other quantitative metallographic methods such as image analysis, by measurement of magnetic response, or by other methods upon agreement between the manufacturer and the purchaser. Frequency of testing and location of tests shall be by agreement between the manufacturer and the purchaser.

S51. Prior Approval of Weld Material

S51.1 The purchaser must give approval of all weld filler materials to be used prior to any weld repairs.

Standard Practice for Investment Castings, Surface Acceptance Standards, Visual Examination[1]

This standard is issued under the fixed designation A 997; 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 practice covers the acceptance criteria for surface inspection of investment castings by visual examination.

1.2 The values stated in SI units are to be regarded as the standard.

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. Terminology

2.1 *Definitions of Terms Specific to This Standard:*

2.1.1 *linear discontinuity*, *n*—a discontinuity whose length is equal to or greater than three times its width. Cracks and cold shuts are examples of linear discontinuity.

2.1.2 *positive metal*, *n*—raised metal on the casting surface usually associated with the breakdown of the mold and its replacement with the casting metal.

2.1.3 *surface pit*, *n*—a non linear depression in the cast surface whose length is less than three times its width. Surface pits may be the result of gas or non metallic inclusions.

2.1.4 *surface roughness*, *n*—a measure of surface texture usually determined by the use of a comparator.

3. Ordering Information

3.1 The inquiry or order should specify the following information:

3.1.1 *Acceptance Level*—More than one acceptance level may be specified for different surfaces of the same casting (see Section 4),

3.1.2 If any types of discontinuities are unacceptable,

3.1.3 Casting surfaces to be examined,

3.1.4 Number of castings to be examined, and

3.1.5 Additional acceptance criteria as applicable to all or portions of the casting surface.

4. Acceptance Criteria

4.1 Levels of acceptance for visual inspection are listed in Table 1.

TABLE 1 Visual Inspection Acceptance Criteria[A,B]

Surface Feature	Level II	Level III	Level IV
Surface Pits[C,D,E]	0.030 in. (0.76 mm) diameter by 0.015 in. (0.38 mm) deep with no more than 1 per in.^{2} (645 mm^2)	0.060 in. (1.52 mm) diameter by 0.030 in. (0.76 mm) deep with no more than 1 per in.^{2} (645 mm^2)	0.060 in. (1.52 mm) diameter by 0.030 in. (0.76 mm) deep with no more than 4 per in.^{2} (6445 mm^2)
Positive Metal[D,E]	0.060 in. (1.52 mm) diameter by 0.015 in. (0.38 mm) high with no more than 1 per in.^{2} (645 mm^2)	0.125 in. (3.18 mm) diameter by 0.030 in. (0.76 mm) high with no more than 1 per in.^{2} (645 mm^2)	0.125 in. (3.18 mm) diameter by 0.030 in. (0.76 mm) high with no more than 4 per in.^{2} (645 mm^2)
Parting Line and Ejector Pin Marks Height	0.005 in. (0.13 mm)	0.010 in. (0.25 mm)	0.020 in. (0.51 mm)
Gate Height[F]	0.015 in. (0.38 mm)	0.030 in. (0.76 mm)	0.45 in. (1.14 mm)
Surface Roughness[E]	100 µin. (2.5 µm)	125 µin. (3.2 µm)	200 µin. (5.0 µm)

[A] Features in excess of those specified in the table are not acceptable.
[B] Level I criteria may be established in the future depending on need.
[C] Maximum surface pit depth shall not violate drawing minimum wall thickness.
[D] Surface pits or positive metal less than 0.010 in. (0.25 mm) diameter and less than 0.010 in. (0.25 mm) deep or high shall be considered non-relevant.
[E] Determined by comparator or tactile source.
[F] Machined and non-machined surfaces

4.2 Parts shall not exhibit any linear discontinuities.

4.3 Surface roughness and surface pits that will be removed by machining are considered acceptable.

4.4 Surface discontinuities not covered in this practice shall be a matter of agreement between the purchaser and the manufacturer.

[1] This practice is under the jurisdiction of ASTM Committee A01 on Steel, Stainless Steel and Related Alloys and is the direct responsibility of Subcommittee A01.18 on Castings.

Current edition approved April 10, 2003. Published April 2003. Originally approved in 1998. Last previous edition approved in 1998 as A 997 – 98.

Designation: A 1001 – 01

Standard Specification for High Strength Steel Castings in Heavy Sections[1]

This standard is issued under the fixed designation A 1001; 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 cast alloy steels in the normalized and tempered or quenched and tempered condition, in section sizes through 37 in. (940 mm), suitable for high strain gradient conditions such as those encountered in hooks, shackles, support frames, and other lifting devices. The classes of steel in this specification are weldable only with qualified procedures.

1.2 Section range and class selection will depend on design and service conditions. Users should note that this specification contemplates mechanical property gradients.

1.3 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. Combining values from the two systems may result in non-conformities with the specification. Inch-pound units are applicable for material ordered to this Specification and SI units for material ordered to this Specification.

1.4 If, by agreement, castings are to be supplied in a partially completed condition, that is, all of the provisions of the product specification have not been filled, then the material marking (see Section 15) and certification (see Section 14) are to reflect the extent to which the product specification requirements have been met.

2. Referenced Documents

2.1 *ASTM Standards:*

A 370 Test Methods and Definitions for Mechanical Testing of Steel Products[2]

A 488/A 488M Practice for Steel Castings, Welding, Qualifications of Procedures and Personnel[2]

A 609/A 609M Practice for Castings, Carbon, Low-Alloy, and Martensitic Stainless Steel, Ultrasonic Examination Thereof[2]

A 703/A 703M Specification for Steel Castings, General Requirements, for Pressure-Containing Parts[2]

E 94 Guide for Radiographic Examination[3]

E 165 Test Method for Liquid Penetrant Examination[3]

E 709 Practice for Magnetic Particle Examination[3]

E 1019 Test Methods for Determination of Carbon, Sulfur, Nitrogen, and Oxygen, in Steel and in Iron, Nickel, and Cobalt Alloys[4]

E 1447 Test Method for Determination of Hydrogen in Titanium and Titanium Alloys by the Inert Gas Fusion Thermal Conductivity Method[4]

E 1806 Practice for Sampling Steel and Iron for Determination of Chemical Composition[5]

2.2 *ASNT Standard:*

SNT-TC-1A Recommended Practice for Non-Destructive Testing Personnel Qualification and Certification[6]

2.3 *Manufacturers Standardization of the Value and Fittings Industry Standards:*

MSS SP-55 Quality Standard for Steel Castings – Visual Method[7]

3. General Conditions for Delivery

3.1 Materials furnished to this Specification shall conform to the applicable requirements of Specification A 703/A 703M, including the supplementary requirements that are indicated on the purchase order.

3.2 Terminology and test methods shall be in accordance with Test Methods and Definitions A 370.

3.3 In the case of conflict between requirements of this specification and referenced specifications, the former shall prevail.

4. Ordering Information

4.1 It shall be the responsibility of the purchaser to specify all requirements that are necessary for material ordered under this specification. Such requirements to be considered include, but are not limited to, the following:

4.1.1 A description of the casting by pattern number or a fully dimensional and toleranced drawing,

4.1.2 ASTM designation and year of issue,

4.1.3 Section range and class of steel (see Table 1),

[1] This specification is under the jurisdiction of ASTM Committee A01 on Steel, Stainless Steel, and Related Alloys and is the direct responsibility of Subcommittee A01.18 on Castings.

Current edition approved Sept. 10, 2001. Published November 2001.

[2] *Annual Book of ASTM Standards*, Vol 01.02.

[3] *Annual Book of ASTM Standards*, Vol 03.03.

[4] *Annual Book of ASTM Standards*, Vol 03.05.

[5] *Annual Book of ASTM Standards*, Vol 03.06.

[6] Available from American Society for Nondestructive Testing, 1711 Arlingate Ln., PO Box 28518, Columbus, OH 43228-0518.

[7] Available from Manufacturers Standardization Society of the Valve and Fittings Industry, 127 Park St., NE, Vienna, VA 22180–4602.

TABLE 1 Required Mechanical Properties

		Chemistry Grade[A]	Tensile Strength ksi (MPa)		Yield Strength, min ksi (MPa) at 0.2 % Offset		Elongation, 2 in (50 mm) or 4d, min, %		Reduction of Area, min %		Charpy V-Notch, Min Average, ft-lb (J)	
Section Range	Class		T/8[B]	3T/8[B]	T/8[B]	3T/8[B]	T/8[B]	3T/8[B]	T/8[B]	3T/8[B]	T/8[B]	3T/8[B]
1	A	I, II	110 (760)	100 (690)	90 (620)	80 (550)	18	15	36	30	25 (34)	15 (20)
1	B	I	105 (725)	95 (655)	85 (585)	76 (525)	15	11	30	22	25 (34)	15 (20)
1	C	I	90 (620)	80 (550)	70 (485)	63 (435)	17	13	34	26	25 (34)	15 (20)
2	A	I	110 (760)	100 (690)	90 (620)	80 (550)	18	15	36	30	25 (34)	15 (20)
2	B	I	105 (725)	95 (655)	85 (585)	76 (525)	16	12	32	24	25 (34)	15 (20)
2	C	I	90 (620)	80 (550)	70 (485)	63 (435)	18	14	36	28	25 (34)	15 (20)
3	A	I, III	110 (760)	100 (690)	90 (620)	80 (550)	18	15	36	30	25 (34)	15 (20)
3	B	I	105 (725)	95 (655)	85 (585)	76 (525)	17	13	34	26	25 (34)	15 (20)
3	C	I	90 (620)	80 (550)	70 (485)	63 (435)	19	16	38	32	25 (34)	15 (20)
4	A	I, II	110 (760)	100 (690)	90 (620)	80 (550)	18	15	36	30	25 (34)	15 (20)
4	B	I	105 (725)	95 (655)	85 (585)	76 (525)	19	16	38	32	25 (34)	15 (20)
4	C	I	90 (620)	80 (550)	70 (485)	63 (435)	21	18	42	36	25 (34)	15 (20)
5	A	I, II	110 (760)	100 (690)	90 (620)	80 (550)	18	15	36	30	25 (34)	15 (20)
5	B	I	105 (725)	95 (655)	85 (585)	76 (525)	19	16	38	32	25 (34)	15 (20)
5	C	I	90 (620)	80 (550)	70 (485)	63 (435)	21	18	42	36	25 (34)	15 (20)
6	A	I	110 (760)	100 (690)	90 (620)	80 (550)	18	15	36	30	25 (34)	15 (20)
6	B	I	105 (725)	95 (655)	85 (585)	76 (525)	19	16	38	32	25 (34)	15 (20)
6	C	I	90 (620)	80 (550)	70 (485)	63 (435)	21	18	42	36	25 (34)	15 (20)
7	A	I	110 (760)	100 (690)	90 (620)	80 (550)	18	15	36	30	25 (34)	15 (20)
7	B	I	105 (725)	95 (655)	85 (585)	76 (525)	19	16	38	32	25 (34)	15 (20)
7	C	I	90 (620)	80 (550)	70 (485)	63 (435)	21	18	42	36	25 (34)	15 (20)

[A] See 7.1. Chemistry other than these listed can be used if properties are met.
[B] See Fig. 1

4.1.4 Definition of inspection methods, extent of examination, frequency, casting quality zones, and acceptance criteria (see Section 11).

4.1.5 Product marking locations (see Section 15),

4.1.6 Certification report options (see Section 14),

4.1.7 Options in the specification (see 1.4 and 11.6), and

4.1.8 The supplementary requirements desired.

5. Test Block Requirements

5.1 The supplier shall produce a minimum of one test block for each heat.

5.2 Test block configuration shall be in accordance with Fig. 1. A standard draft angle is permitted over the length "L" of the test block provided the minimum cylinder diameter is greater than "T" given in Table 2.

5.3 Test block size shall be in accordance with Table 2 for specified section range. The section range selection made by the purchaser (see 4.1.3) should consider casting section size and geometry, service conditions, mechanical property correlations developed by the supplier, or other important factors.

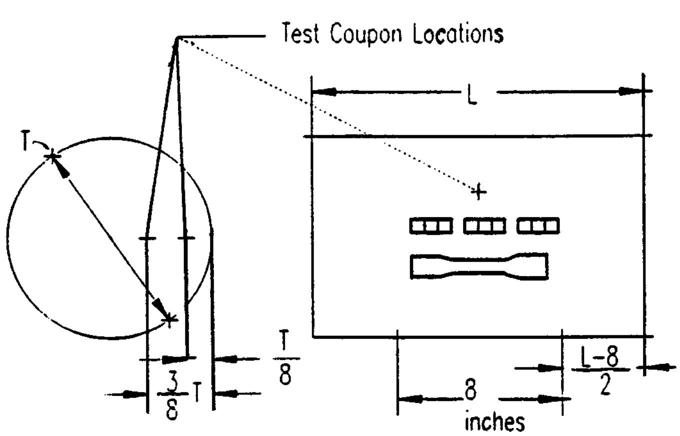

FIG. 1 Test Block Configuration

TABLE 2 Section Range Definition and Test Block Dimensions

Section Range	Section Size, in (mm)		Test Block Dimensions, in (mm)[A]	
	Over	Not Over	T	L
1	3 (76)	5 (127)	4 (102)	8 (203)
2	5 (127)	7 (178)	6 (152)	8 (203)
3	7 (178)	11 (279)	9 (229)	9 (229)
4	11 (279)	15 (381)	13 (330)	13 (330)
5	15 (381)	21 (533)	18 (457)	18 (457)
6	21 (533)	29 (737)	25 (635)	25 (635)
7	29 (737)	37 (940)	33 (813)	33 (813)

[A] See Fig. 1.

5.4 Tension and Charpy impact tests shall be performed on specimens taken from both the 1/8T and 3/8T locations and shall be oriented within the 8-in. (203-mm) midsection as shown in Fig. 1.

5.5 Oxygen and nitrogen gas content tests shall be performed on specimens taken from the 3/8T location and shall be within the 8 in. (203 mm) midsection as shown in Fig. 1.

6. Materials and Manufacture

6.1 The steel shall be made by electric furnace process with methods to conform to the maximum gas levels given in Table 3. These methods may include a special refining process such as argon-oxygen-decarburization (AOD).

6.2 Heat treatment procedure shall be reported to the purchaser by the supplier for the specified section range, class, and grade.

6.2.1 Multiple austenitizing is permitted.

6.2.2 Multiple tempering is permitted. The minimum final tempering temperature shall not be less than 1100°F (593°C). Post weld heat treatment shall not be less than 1050°F (566°C).

6.3 Test block(s) may be heat treated separately from the castings they represent.

TABLE 3 Maximum Gas Content Levels

Section Range	Nitrogen, ppm	Oxygen, ppm	Oxygen Analysis Tolerance, ppm	Oxygen Analysis Limit, ppm[A]
1	110	100	30	130
2	110	100	30	130
3	100	90	27	117
4	100	90	27	117
5	90	80	24	104
6	80	70	21	91
7	70	60	18	78

[A] Specification compliance level is average value of three determinations, see 10.3

6.3.1 Test block(s) shall be heat treated in the same production heat treat equipment, in the same facility, and to the same procedure as the castings to be produced. Test block(s) are excluded from post weld heat treatment (see 12.2.9).

6.3.2 The test block(s) tempering temperature shall be within ± 25°F (14°C) of the casting tempering temperature.

6.4 Heat treatment charts showing time and temperature shall be prepared and held available for inspection by the purchaser.

7. Chemical Composition

7.1 Supplier shall select the casting chemistry Grade from Table 1 for the section range, and class specified by the purchaser.

7.1.1 Chemical composition shall conform to Table 4 for Grades II and III.

7.1.2 Grade I designates the use of an alternate chemistry selected by the supplier. Alternate chemistries shall conform to the allowable element ranges and limits given in Table 5.

7.2 A product analysis shall be made for specification conformance. The product analysis shall be performed on a specimen taken from the test block(s) in Section 5 and shall be from the 3/8T location and shall be within the 8 in. (203 mm) midsection as shown in Fig. 1. The supplier shall perform the product analysis in addition to any other process control analysis.

TABLE 4 Chemical Grade Composition (Maximum Percent Unless Range is Given)

	Grade		
	I	II	III
Element:	SeeTable 5	. . . to	. . . to
Carbon	. . .	0.20 to 0.28	0.20 to 0.28
Manganese	. . .	1.00 to 1.40	1.00 to 1.40
Phosphorus	. . .	0.02	0.03
Sulfur	. . .	0.015	0.025
Silicon	. . .	0.30 to 0.60	0.30 to 0.60
Nickel	. . .	1.00 to 1.30	1.00 to 1.30
Chromium	. . .	0.80 to 1.20	0.80 to 1.20
Molybdenum	. . .	0.60 to 0.85	0.60 to 0.85
Aluminum	. . .	0.03	0.07
Residual Elements:	See Table 5		
Zirconium	. . .	A	A
Copper	. . .	A	A
Titanium	. . .	A	A
Tungsten	. . .	A	A
Vanadium	. . .	A	A
Columbium	. . .	A	A
Boron	. . .	A	A
Total Content of Residual Elements	. . .	0.60	0.60

[A] Reported for Information Only

TABLE 5 Element Tolerance Ranges and Maximum Limits for Alternate Chemistries

Element	Average of Declared Range, (%)	Maximum Range (%)	Maximum Limit (%)
Carbon	All	0.08	0.35
Manganese	<1.00	0.30	. . .
	≥1.00	0.40	. . .
Phosphorus	All	. . .	0.02
Sulfur	All	. . .	0.015
Nickel	<1.50	0.30	. . .
	≥1.50	0.50	. . .
Chromium	<1.50	0.40	. . .
	≥1.50	0.50	. . .
Molybdenum	All	0.25	. . .
Aluminum	All	0.04	0.06
Vanadium	All	0.10	. . .
Copper[A]	. . .	. . .	. . .
Titanium[A]	. . .	. . .	. . .
Columbium[A]	. . .	. . .	. . .
Zirconium[A]	. . .	. . .	. . .
Nitrogen[A]	. . .	. . .	. . .

[A] Reported for information only.

7.3 Retests for conformance are permitted in accordance with Section 13.

8. Tension Test

8.1 Tension tests shall be performed on test specimens taken from test block(s) as determined in Section 5.

8.1.1 One tension test specimen is required at each of the 1/8T and 3/8T locations and shall be oriented within the 8 in. (203 mm) midsection as shown in Fig. 1.

8.1.2 Tension test specimens shall be machined to the form and dimension shown in Fig. 4 of Test Methods and Definitions A 370 and tested in accordance with those test methods.

8.2 Mechanical properties shall conform to the requirements given in Table 1.

8.3 Retests for conformance are permitted in accordance with Section 13.

9. Charpy Impact Test

9.1 Charpy impact tests shall be performed on test specimens taken from test block(s) as determined in Section 5. One set of Charpy impact test specimens is required at each of the 1/8T and 3/8T locations and shall be oriented within the 8 in. (203 mm) midsection as shown in Fig. 1.

9.2 Charpy impact tests shall be performed in accordance with A 703/A 703M S8.1 at −40°F (−40°C) temperature.

9.3 Acceptance criteria shall be in accordance with A 703/A 703M S8.2 method and conform to the average absorbed energy values given in Table 1.

9.4 Minimum single specimen value shall not be less than 5 ft·lbs (7 J) below the average absorbed energy values given in Table 1.

9.5 Retests for conformance are permitted in accordance with Section 13.

10. Gas Content Requirements

10.1 Oxygen and nitrogen gas content tests shall be performed on test specimens taken from the test block(s) as determined in Section 5. Gas content tests shall be performed on specimens taken from the 3/8T location and shall be within the 8 in. (203 mm) midsection as shown in Fig. 1.

10.2 Hydrogen gas content tests shall be performed on ladle specimens for section ranges 4-7 and results reported. A carrier gas infusion method may be used with samplers and instrumentation in accordance with Practice E 1806 and Test Method E 1447 respectively.

10.3 Oxygen and nitrogen gas content tests shall be performed in accordance with Test Methods E 1019. Oxygen content for specification compliance shall be taken as the average value of three determinations.

10.4 Oxygen and nitrogen gas content requirements of steel used for the castings shall conform to the requirements given in Table 3.

10.5 Retests for conformance are permitted in accordance with Section 13.

11. Quality

11.1 The purchaser shall establish casting quality zones that include, at a minimum, a shell and a core depth zone (See Fig. 2).

11.2 Non-destructive examination for specification conformance shall be of the final heat treated condition.

11.3 Casting shell zone surface shall be visually examined and graded in accordance with MSS SP-55. Acceptance criteria shall be as specified in the purchase order.

11.4 Casting shell zone surface shall be examined for discontinuities by magnetic particle or liquid penetrant inspection, or both, in accordance with Practice E 709 and Test Method E 165 respectively. Personnel performing the examination shall have at least ASNT Level II qualification in the inspection method used and shall be qualified by persons having ASNT Level III qualification. Inspection method, extent of examination, frequency, and acceptance criteria shall be as specified in the purchase order.

11.5 Casting shell and core zones shall be examined for internal defects by ultrasonic or radiographic inspection, or both, in accordance with Practice A 609/A 609 M and Guide E 94 respectively. Personnel performing the examination shall have at least ASNT Level II qualification in the inspection method used and shall be qualified by persons having ASNT Level III qualification. Inspection method, extent of examination, frequency, and acceptance criteria for each zone shall be as specified in the purchase order.

11.6 Purchaser may select representative castings from each heat for destructive examination of internal defects in accordance with terms of Specification A 703/A 703M S2 and the acceptance criteria specified in the purchase order.

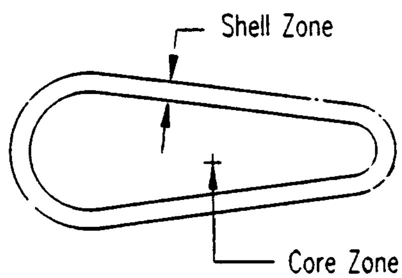

FIG. 2 Quality Zones

12. Repair Methods

12.1 *Grinding*—Indications rejected under Section 11 may be removed by grinding, consistent with the following:

12.1.1 Grinding shall not reduce final section thickness below the minimum permitted by the design drawing. Grinding shall be smoothly fared into the surrounding surface.

12.1.2 Grinding surface area shall be re-examined and evaluated in accordance with 11.4.

12.2 *Welding*—Indications rejected under Section 11 may be removed and repair welded, consistent with the following:

12.2.1 Indication removal may be accomplished by grinding or use of thermal methods. High temperature methods may require pre-heat in accordance with the weld procedure.

12.2.2 Weld repair to be made on castings in which the depth of any cavity prepared for welding is more than the lesser of T/5 or 2 in. (51 mm) shall be approved by the purchaser prior to welding. "T" is the test block diameter as shown in Fig. 1 and given in Table 2.

12.2.3 Weld repair to be made on castings in which the open surface of any cavity prepared for welding is greater than the lesser of T in.^{2} or 10 in.^{2} (64 cm^2) shall be approved by the purchaser prior to welding. "T" is the test block diameter as shown in Fig. 1 and given in Table 2.

12.2.4 Weld repair charts for weld repairs requiring purchaser approval shall be provided in accordance with Specification A 703/A 703M S20.1.

12.2.5 Weld repair cavities shall be examined and evaluated in accordance with 11.4.

12.2.6 Repairs shall be made using procedures and welders qualified under Section IX of the ASME Boiler and Pressure Vessel Code.[8]

12.2.7 The entire casting should be raised to temperature when pre- and postweld heat treatment is required by the weld procedure. Use of localized pre- and postweld heat treatment shall be in accordance with procedure approved by the purchaser.

12.2.8 Finished weld repairs shall be examined and evaluated in accordance with 11.4 and 11.5.

12.2.9 After repair welding, all heat treated castings shall be post-weld heat treated below the final tempering temperature. The post-weld heat treatment temperature shall be no more than 50°F (28°C) below the final tempering temperature.

13. Retests

13.1 Reheat treatment in accordance with 6.2 and 6.3 is permitted before retesting.

13.2 If mechanical property, Charpy impact, or oxygen gas content certification test fails to conform to requirements of this specification, two additional specimens from the same test block shall be tested. Retest specimens shall be taken from the appropriate 1/8T and 3/8T locations and shall be oriented

[8] Available from American Society of Mechanical Engineers, Three Park Ave., New York, NY 10016–5990.

within the 8 in. (203 mm) midsection as shown in Fig. 1. Both test results shall conform to applicable requirements of this specification.

13.3 If nitrogen gas content certification test fails to conform to requirements of this specification, an aluminum nitride test shall be conducted in accordance with Specification A 703/A 703M S23.3. Severity level greater than four shall be cause for casting rejection. Retest specimen shall be taken from the 3/8T location and shall be within the 8 in. (203 mm) midsection as shown in Fig. 1.

14. Certification

14.1 Supplier shall furnish to the purchaser certification report complete with options specified in the order.

14.2 Certification report shall include the following:

14.2.1 Purchase order number,

14.2.2 Casting component number(s),

14.2.3 Material specification number, year-date, and the section range, class, and grade symbols (see 15.1),

14.2.4 Heat number(s),

14.2.5 Results of chemical composition conformance test (see Section 7),

14.2.6 Results of mechanical properties conformance test (see Section 8),

14.2.7 Results of Charpy impact conformance test (see Section 9),

14.2.8 Results of gas content conformance test (see Section 10).

14.2.9 Results of non-destructive examinations (see Section 11 and 12.2.8),

14.3 Certification report may include the following:

14.3.1 Weld repair charts (see 12.2.4),

14.3.2 Heat treatment procedure (see 6.2),

14.3.3 Heat treatment time and temperature charts (see 6.4),

14.3.4 Extent to which the casting is incomplete (see 1.4 and 15.5), and

14.3.5 Results of supplementary requirements testing.

15. Product Marking

15.1 Castings shall be marked for material identification with the section range, class, and grade symbols. For example: 3-A-III.

15.2 Heat numbers or serial numbers that are traceable to heat numbers shall be marked on all castings.

15.3 Castings shall be marked with the manufacturer's identification or symbol.

15.4 Marking location shall be shown on the purchaser's casting drawing.

15.5 Castings furnished partially complete shall include the suffix Y following the section range, class, and grade designation specified in 15.1.

16. Keywords

16.1 aluminum nitride; AOD; heavy section; hydrogen gas; nitrogen gas; oxygen gas

SUPPLEMENTARY REQUIREMENTS

S1. Property Gradient Report

S1.1 Tensile and Charpy property values shall be determined from the surface to the center of the test block at 1-in. (25-mm) increments.

S1.2 The tensile and Charpy property values shall be reported to the purchaser.

S1.3 The macrohardness survey shall be made at ¼-in. (6-mm) increments from the surface to the center of the test block and reported to the purchaser.

S2. Hydrogen Gas Content

S2.1 Hydrogen gas content shall be controlled with gas level and test method specified in the purchaser order.

Designation: A 1002 – 99 (Reapproved 2003)

Standard Specification for Castings, Nickel-Aluminum Ordered Alloy[1]

This standard is issued under the fixed designation A 1002; 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 nickel-aluminum ordered alloy castings intended for heat-resisting and elevated-temperature applications such as heat-resistant alloy structural members, containers, supports, hangers, spacers, and so forth, in environments up to 2300°F (1260°C).

1.2 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 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 370 Test Methods and Definitions for Mechanical Testing of Steel Products[2]

A 781/A 781M Specification for Castings, Steel and Alloy, Common Requirements, for General Industrial Use[2]

3. General Conditions for Delivery

3.1 Material furnished to this specification shall conform to the requirements of Specification A 781/A 781M, including any supplementary requirements that are indicated in the purchase order. Failure to comply with the general requirements of Specification A 781/A 781M constitutes nonconformance with this specification. In case of conflict between the requirements of this specification and Specification A 781/A 781M, this specification shall prevail.

4. Ordering Information

4.1 The purchaser should specify the alloy grade desired and whether tension or impact tests are required, and shall include standards of acceptance where necessary.

5. Materials and Manufacture

5.1 *Process*—The alloy for the castings shall be by any method unless otherwise agreed upon between the manufacturer and the purchaser. Casting may be poured in sand, shell, investment, or centrifugal molds.

5.2 *Heat Treatment*—Castings may be shipped in the as-cast condition. If heat treatment is required the treatment shall be established by mutual consent between the manufacturer and the purchaser and shall be so specified in the inquiry, purchase order, or contract.

6. Chemical Composition

6.1 The castings shall conform to the requirements as to chemical composition prescribed in Table 1.

7. Mechanical Properties

7.1 Mechanical properties are not required unless specified in the purchase order.

7.2 *Tensile properties*, if required, of the alloy used for the castings shall conform to the requirements prescribed in the purchase order.

7.3 *Impact properties*, if required, of the alloy used for the castings shall conform to the requirements prescribed in the purchase order.

8. Test Specimens

8.1 Test specimens, if required, shall be prepared in accordance with Test Methods and Definitions A 370. Test bars shall be poured in special blocks from the same heat as the castings represented. Test bars, if required, shall be furnished in sufficient number to furnish specimens for the tests required in Section 9.

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[1] This specification is under the jurisdiction of ASTM Committee A01 on Steel, Stainless Steel, and Related Alloys and is the direct responsibility of Subcommittee A01.18 on Castings.

Current edition approved Oct. 1, 2003. Published October 2003. Originally approved in 1999. Last previous edition approved in 1999 as A 1002 – 99.

[2] *Annual Book of ASTM Standards*, Vol 01.02.

TABLE 1 Chemical Requirements

Element	Composition, % by Weight
Carbon, max	0.08
Sulfur, max[A]	0.020
Aluminum	7.3–8.3
Chromium	7.5–8.5
Molybdenum	1.20–1.70
Zirconium	1.6–2.10
Boron	0.003–0.012
Silicon, max[A]	0.20
Iron, max	1.00
Nickel	Balance

[A] For welding applications, see S18 for restrictions on sulfur and silicon.

8.2 The test coupons shall be cast from the same melt from which the castings they represent are poured, and shall represent the full melting practice. Chemical composition of the test coupons shall conform to the requirements prescribed in Table 1.

8.3 Tension test specimens shall be machined to the form and dimensions of the standard 2-in. [50-mm] gage length specimen shown in Fig. 4 of Test Methods and Definitions A 370.

8.4 Impact test specimens shall conform to the length and cross-section dimensions shown in Fig. 10 of Test Methods and Definitions A 370. The impact specimens are to be broken unnotched.

9. Number of Tests and Retests

9.1 *Tension Test*—One tension test, if required by the purchase order, shall be made from each heat.

9.2 *Impact Test*—One unnotched Charpy impact test, if required by the purchase order, shall be made from each heat.

9.3 *Retests*:

9.3.1 Retests of a duplicate specimen will be allowed if the results of the mechanical tests for any lot does not conform to the requirements specified in the purchase order.

9.3.2 If the elongation of any tension test specimen is less than specified, and any part of the fracture is more than ¾ in. [19.0 mm] from the center of the gage length, as indicated by scribe scratches marked on the specimen before testing, a retest shall be allowed.

10. Keywords

10.1 casting; elevated temperature; heat-resistant alloy; heat-resisting; nickel aluminide; nickel aluminum

SUPPLEMENTARY REQUIREMENTS

Supplementary requirements only apply when specified in the purchase order. A list of standardized supplementary requirements for use at the option of the purchaser is included in Specification A 781/A 781M. Supplementary Requirements S1 and S11 of Specification A 781/A 781M are not appropriate for this specification and shall not be specified. In addition, the following Supplementary Requirement S18, for welding applications, is not listed in Specification A 781/A 781M.

S18. Welding Applications

S18.1 The sulfur shall be 0.003 % by weight or less and the silicon shall be 0.05 % by weight or less. Detailed information concerning welding is available from Materials Processing, Metals and Ceramics Div., Oak Ridge National Laboratory, P.O. Box 2008, Oak Ridge, TN 37831-6083.

Designation: A 1025 – 02

Standard Specification for Ferroalloys, General Requirements[1]

This standard is issued under the fixed designation A 1025; 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 a group of common requirements that, unless otherwise specified in an individual specification, shall apply to ferroalloys and other charge materials under each of the following ASTM specifications:

Title of Specification	ASTM Designation
Ferromanganese	A 99
Ferrosilicon	A 100
Ferrochromium	A 101
Ferrovanadium	A 102
Ferromolybdenum	A 132
Molybdenum oxide products	A 146
Ferroboron	A 323
Ferrotitanium	A 324
Chromium metal	A 481
Ferrochrome-silicon	A 482
Silicomanganese	A 483
Calcium-silicon alloys	A 495
Ferrocolumbium	A 550
Electrolytic manganese metal	A 601
Nickel oxide sinter	A 636
Ferromanganese silicon	A 701
Titanium scrap for use in deoxidation and alloying of steel	A 845
Aluminum scrap for use in deoxidation and alloying of steel	A 846
Silicon metal	A 922

1.2 This specification also covers a group of supplementary requirements which may be applied to the above specifications as indicated therein. These are provided for use when additional testing or inspection is desired and apply only when specified individually by the purchaser in the order.

1.3 In case of conflict between the requirements of the individual specification and this general specification, the former shall prevail.

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 requirements prior to use.*

2. Referenced Documents

2.1 *ASTM Standards:*

A 99 Specification for Ferromanganese[2]
A 100 Specification for Ferrosilicon[2]
A 101 Specification for Ferrochromium[2]
A 102 Specification for Ferrovanadium[2]
A 132 Specification for Ferromolybdenum[2]
A 146 Specification for Molybdenum Oxide Products[2]
A 323 Specification for Ferroboron[2]
A 324 Specification for Ferrotitanium[2]
A 481 Specification for Chromium Metal[2]
A 482 Specification for Ferrochrome-Silicon[2]
A 483 Specification for Silicomanganese[2]
A 495 Specification for Calcium-Silicon Alloys[2]
A 550 Specification for Ferrocolumbium[2]
A 601 Specification for Electrolytic Manganese Metal[2]
A 610 Test Methods for Sampling and Testing Ferroalloys for Determination of Size[2]
A 636 Specification for Nickel Oxide Sinter[2]
A 701 Specification for Ferromanganese-Silicon[2]
A 845 Specification for Titanium Scrap for Use in Deoxidation and Alloying of Steel[2]
A 846 Specification for Aluminum Scrap for Use in Deoxidation and Alloying of Steel[2]
A 922 Specification for Silicon Metal[2]
E 29 Practice for Using Significant Digits in Test Data to Determine Conformance with Specifications[3]
E 32 Practices for Sampling Ferroalloys and Steel Additives for Determination of Chemical Composition[4]

3. Ordering Information

3.1 Orders for material should include the following as required, to describe the material adequately:

3.1.1 ASTM designation and year of issue,

3.1.2 Grade of material,

3.1.3 Size of material,

3.1.4 Quantity,

3.1.5 Packaging requirements, and

3.1.6 Supplementary requirements desired, including the standards of acceptance.

[1] This specification is under the jurisdiction of ASTM Committee A01 on Steel, Stainless Steel and Related Alloys and is the direct responsibility of Subcommittee A01.18 on Castings.

Current edition approved September 10, 2002. Published October 2002.

[2] *Annual Book of ASTM Standards*, Vol 01.02.

[3] *Annual Book of ASTM Standards*, Vol 14.02.

[4] *Annual Book of ASTM Standards*, Vol 03.05.

4. Chemical Analysis

4.1 The chemical analysis method shall be agreed upon by the purchaser and supplier.

4.2 The manufacturer shall furnish a certificate referencing the chemical analysis and appropriate supplementary requirements in the material specification.

4.3 For purposes of determining conformance with this specification, the reported analysis shall be rounded to the nearest unit in the last right-hand place of figures, used in expressing the limiting value, in accordance with the rounding method of Practice E 29.

5. Sampling

5.1 Unless otherwise specified, the material shall be sampled for determination of chemical composition in accordance with Practices E 32 and for determination of size in accordance with Test Methods A 610.

5.2 In the case of a discrepancy, Practices E 32 or Test Methods A 610, as applicable, shall be used for referee.

6. Inspection

6.1 The manufacturer shall afford the inspector representing the purchaser all reasonable facilities, without charge, to satisfy the purchaser that the material is being furnished in accordance with the material specification.

7. Rejection

7.1 Any rejections based on tests made in accordance with the material specification shall be reported to the manufacturer within 45 days from receipt of material by the purchaser.

8. Certification

8.1 The manufacturer's certification shall be furnished to the purchaser at the time of shipment stating that the material was manufactured, sampled, tested, and inspected in accordance with the material specification and was found to meet the requirements.

9. Packaging and Package Marking

9.1 Each lot/shipment shall be identified with appropriate identification showing the material, the ASTM designation, the size, the lot number, and name brand or trademark.

9.2 When the shipment is made in containers, each shall be marked on the container or on a label or tag attached to the container.

10. Keywords

10.1 ferroalloy; general requirements

SUPPLEMENTARY REQUIREMENTS

The following standardized supplementary requirements are for use when desired by the purchaser and when allowed by and listed in the individual specifications. They shall not apply unless specified in order, in which event the specified tests shall be made by the manufacturer before shipping.

S1. Supplementary Chemical Requirements

S1.1 Restrictions on the chemical requirements shall be agreed upon by the purchaser and supplier.

S2. Size

S2.1 Screened products shall conform to the sizes given in Table S2.1.

S2.2 The sizes listed in Table S2.1 are typical as shipped from the manufacturer's plant. The size and friability of the product shall be agreed upon by the purchaser and supplier.

NOTE —Ferroalloys exhibit varying degrees of friability; therefore, some attrition may be expected in transit and handling. A quantitative test is not available for rating friability of ferroalloys. A code system has been developed for this purpose, and a number rating for each product type is given.

TABLE S2.1 Requirements for Screened Products[A]

Nominal Size, in.	Standard Ordered Size, in.[B]	Maximum Allowable Oversize		Maximum Allowable Undersize		Friability Rating Code No.[C]
		Size	Percent	Size	Percent	
		Lump to Crushed Sizes:				
6	8 by 4	to 10 in.	10 %	through 4 in.	10 %	1-6
5	8 by 2	to 10 in.	10 %	through 2 in.	10 %	1-6
4	6 by 2	to 8 in.	10 %	through 2 in.	10 %	1-6
3½	5 by 2	to 7 in.	10 %	through 2 in.	10 %	1-6
3 (A)	5 by 1	to 7 in.	10 %	through 1 in.	10 %	1-6
3 (B)	4 by 2	to 6 in.	10 %	through 2 in.	10 %	1-6
2½	4 by 1	to 6 in.	10 %	through 1 in.	10 %	1-6
2¼	4 by ½	to 5 in.	10 %	through ½ in.	10 %	1-6
2	3 by 1	to 4 in.	10 %	through 1 in.	10 %	1-6
1½	3 by ½	to 4 in.	10 %	through ½ in.	10 %	1-6
1¼	2 by ½	to 3 in.	10 %	through ½ in.	10 %	1-6
1⅛	2 by ¼	to 3 in.	10 %	through ¼ in.	10 %	1-6
		Small Crushed Sizes by Down:				
2	4 by D	to 5 in.	10 %	through ½ in.	15 %	1-6
1½	3 by D	to 4 in.	10 %	through ⅛ in.	15 %	1-6
1	2 by D	to 3 in.	10 %	through ⅛ in.	15 %	1-4
		to 3 in.	8 %	through No. 8	20 %	5,6
½	1 by D	to 1½ in.	10 %	through No. 16	15 %	1-4
		to 1½ in.	8 %	through No. 20	15 %	5,6
	½ by D	to ¾ in.	10 %	through No. 20	15 %	1-4
		to ¾ in.	8 %	through No. 70	20 %	5,6

[A] For screened products below ½ in. by down-crushed sizes, size tolerances should be agreed upon between manufacturer and purchaser.
[B] 1 in. = 25.4 mm.
[C] See Appendix X1 for description of rating code.

APPENDIXES

(Nonmandatory Information)

X1. APPLICABLE SIEVE DESIGNATIONS

X1.1

TABLE X1.1 Sieve Designation

Standard	Alternative
250 mm	10 in.
200 mm	8 in.
175 mm	7 in.
150 mm	6 in.
125 mm	5 in.
100 mm	4 in.
75 mm	3 in.
50 mm	2 in.
25 mm	1 in.
19 mm	¾ in.
12.5 mm	½ in.
6.3 mm	¼ in.
3.1 mm	⅛ in.
2.36 mm	No. 8
1.18 mm	No. 16
850 µm[A]	No. 20
212 µm	No. 70

[A] 1000 µm = 1 mm.

X2. FRIABILITY RATINGS OF FERROALLOYS

X2.1 Descriptions of material of each friability rating are given in Table X2.1.

TABLE X2.1 Friability Ratings of Ferroalloys

Friability Code No.	Description
1	Very tough materials which are susceptible to little, if any, breakage during shipment or handling. (Example: low-carbon ferrochrome)
2	Some breakage of large pieces probable in shipping and handling. No appreciable fines produced from either lump or crushed sizes. (Example: chrome metal)
3	Appreciable reduction in size of large pieces possible in shipping and handling. No appreciable production of fines in handling of crushed sizes. (Example: ferrotitanium)
4	Appreciable reduction in size of large pieces upon repeated handling. Some fines produced upon repeated handling of crushed sizes. (Example: standard ferromanganese)
5	Appreciable reduction in size in repeated handling of large pieces. Appreciable fines may be produced in the handling of crushed sizes. (Example: 50 % ferrosilicon)
6	This category represents the most friable alloys. (Example: calcium silicon)

Designation: C 564 – 03a

Endorsed by the
Cast Iron Soil Pipe Institute

Standard Specification for Rubber Gaskets for Cast Iron Soil Pipe and Fittings[1]

This standard is issued under the fixed designation C 564; 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 preformed rubber gaskets used to seal joints in cast iron soil pipe and fittings.

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

1.3 The following safety hazards caveat pertains only to the test methods section 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.*

1.4 The committee with jurisdiction over this standard is not aware of another comparable standard for materials covered in this standard.

2. Referenced Documents

2.1 *ASTM Standards:* [2]

C 717 Terminology of Building Seals and Sealants

D 395 Test Methods for Rubber Property—Compression Set

D 412 Test Methods for Vulcanized Rubber and Thermoplastic Rubbers and Thermoplastic Elastomers—Tension

D 471 Test Method for Rubber Property—Effect of Liquids

D 573 Test Method for Rubber—Deterioration in an Air Oven

D 624 Test Method for Tear Strength of Conventional Vulcanized Rubber and Thermoplastic Elastomers

D 1149 Test Method for Rubber Deterioration—Surface Ozone Cracking in a Chamber

D 1415 Test Method for Rubber Property—International Hardness

D 2240 Test Method for Rubber Property—Durometer Hardness

2.2 *Other Documents*

RMA *Class 3 Dimensional Tolerances, RMA Manual*[3]

3. Terminology

3.1 *Definitions*—For definitions of terms in this standard see Terminology C 717.

3.2 *Definitions of Terms Specific to This Standard:*

3.2.1 *flash*—the excess material protruding from the surface of a molded article at the mold junction.

3.2.2 *virgin rubber, n*—a term that may be used interchangeably with raw rubber (raw thermoset elastomer). A rubber or thermoset elastomer that has not had any additional work, diluents incorporated, processes performed on it, or any combination thereof. A rubber that is in an unmodified state or one in which no attempt has been made to alter it in any fashion as received from the manufacturer or supplier.

4. Materials and Manufacture

4.1 Gaskets shall be made of a properly vulcanized virgin compound containing virgin rubber as the sole elastomer with no scrap or reclaim.

5. Physical Requirements

5.1 Sample gaskets selected as specified in Section 8 shall conform to the requirements for physical properties listed in Table 1 when tested in accordance with the methods specified in Section 9.

6. Dimensions and Permissible Variations

6.1 Gaskets shall conform to the dimensions specified by the manufacturer.

6.2 All cross-sectional dimensions shall have an RMA Class 3 tolerance as shown in Annex A1, and all diametral dimensions shall have a tolerance of ± 1 percent.

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[1] This specification is under the jurisdiction of ASTM Committee C24 on Building Seals and Sealants and is the direct responsibility of Subcommittee C24.75 on Gaskets and Couplings for Plumbing and Sewer Piping.

Current edition approved Dec. 1, 2003. Published January 2004. Originally approved in 1965. Last previous edition approved in 2003 as C564–03.

[2] 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.

[3] Rubber Manufacturer's Association, 1400 K Street NW, No. 900, Washington, DC 20005 – 2455.

TABLE 1 Physical Requirements of Gaskets

Property	Requirements			ASTM Test Method
Hardness (nominal durometer ±5) as specified by the pipe manufacturer	50	60	70	D 2240
Elongation, min, %	350	300	250	D 412
Tensile strength, min, MPa	10	10	10	D 412
(psi)	(1500)	(1500)	(1500)	
Tear strength, min, N/cm	268	268	268	D 624
(lbf/in.)	(150)	(150)	(150)	
Compression set, max, %	25	25	25	D 395
Heat aging, 96 h at 70 ± 1°C (158 ± 2°F):				D 573
Hardness increase, max, durometer points	10	10	10	...
Loss in tensile strength, max,%	15	15	15	...
Loss in elongation, max, %	20	20	20	...
Water absorption:				D 471
Weight increase, max, %	20	20	20	...
Ozone resistance	no cracks	no cracks	no cracks	D 1149
Oil immersion:				
Volume increase, max, %	80	80	80	D 471

7. Workmanship

7.1 The surface of the gasket shall be smooth and free of pitting, cracks, blisters, air marks, and any other imperfections that will affect its behavior in service. The body of the gasket shall be free of porosity and air pockets.

7.2 Neither the flash thickness nor the flash extension shall exceed 0.8 mm (1⁄32 in.), at any point on the sealing ring.

7.3 The offset, or failure of the mold to register accurately, shall not exceed 0.4 mm (1⁄64 in.).

8. Sampling

8.1 For each of the tests, gaskets shall be selected at random as required by the method of test specified.

9. Test Methods

9.1 *Hardness*—The gasket material shall be tested for hardness in accordance with ASTM Test Method D 2240. Test Method D 1415 shall be used as the referee method. Hardness measurements shall be made on specimens prepared in accordance with 9.2. However, hardness readings for guidance purposes shall be permitted to be taken directly on the gasket, recognizing that these readings may vary slightly from those taken on the dumb-bell specimens.

9.2 *Elongation and Tensile Strength*—The gasket material shall be tested for elongation and tensile strength in accordance with Test Methods D 412. Standard ASTM Type C dumb-bell specimens conforming to Fig. 1 (Apparatus for Tensile Set Test) of Test Methods D 412 shall be cut from a section of the gasket for this test. To obtain a uniform thickness, these gasket sections shall be permitted to be buffed prior to cutting into dumb-bell specimens, so as to produce a finely ground surface without cuts or burns.

9.3 *Tear Strength*— The gasket material shall be tested for tear strength in accordance with Test Method D 624 using Die C.

9.4 *Compression Set*— The gasket material shall be tested for compression set in accordance with Test Methods D 395 using Method B. Specimens shall be aged in an oven for 22 h at 70 ± 1°C (158 ± 2°F). Where plied specimens are necessary, the results shall comply with the requirements of Table 1.

9.5 *Heat Aging*—The gasket material shall be tested for effects of heat aging in accordance with 9.2, and shall be aged for 96 h at 70 ± 1°C (158 ± 2°F). Hardness measurements shall be made as specified in 9.1.

9.6 *Water Absorption*—The gasket material shall be tested for weight increase due to water absorption in accordance with Test Method D 471. If a 25.4-mm (1-in.) specimen cannot be cut from the sample gasket, the greatest width obtainable shall be used. The test specimen shall be immersed in distilled water at 70 ± 1°C (158 ± 2°F) for 7 days.

9.7 *Ozone Resistance*—The gasket material shall be tested for ozone resistance in accordance with Test Method D 1149, using specimens and procedure specified under Method B. The ozone concentration shall be 150 parts/100 000 000 of air by volume. Specimens shall be aged 100 ± 1h at 40 ± 1°C (104 ± 2°F). A two-power hand magnifying glass shall be used to examine the gasket for cracks.

9.8 *Oil Immersion*— The gasket material shall be tested for volume decrease due to oil absorption in accordance with Test Method D 471. If a 25.4 mm (1-in.) specimen cannot be cut from the sample gasket, the greatest width obtainable shall be used. The test specimen shall be immersed in IRM 903 for 70 ± 0.7 h at 100 ± 1°C (212 ± 2°F).

10. Certification

10.1 When specified in the purchase order or contract, the purchaser shall be furnished certification stating samples representing each lot have been tested and inspected as indicated 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.

11. Marking

11.1 Mark each gasket with clearly legible letters not exceeding 6.35 mm (1⁄4 in.) in height. These markings shall include the gasket manufacturer's name or symbol, the pipe size and class (such as NH for no hub, SV for service, XH for extra heavy), country of origin and the ASTM specification designation. Rubber Compression gaskets shall be required to have the year of manufacture in addition to the other required markings of this section.

12. Keywords

12.1 cast iron; fittings; gaskets; pipe; rubber

ANNEX

(Mandatory Information)

A1. RUBBER MANUFACTURERS ASSOCIATION, INC. TOLERANCES

See Table A1.1.

TABLE A1.1 RMA Class 3 Dimensional Tolerances (Commercial Tolerances)

Size, mm, (in.)	Fixed[A]	Closure[B,C]
0 to 12.67 (0 to 0.499)	±0.254 (±0.010)	±0.381 (±0.015)
12.7 to 25.37 (0.500 to 0.999)	±0.254 (±0.010)	±0.457 (±0.018)
24.4 to 50.77 (1.000 to 1.999)	±0.381 (±0.015)	±0.508 (±0.020)
50.8 to 76.17 (2.000 to 2.999)	±0.508 (±0.020)	±0.635 (±0.025)
76.2 to 101.57 (3.000 to 3.999)	±0.635 (±0.025)	±0.762 (±0.030)
101.6 to 126.97 (4.000 to 4.999)	±0.762 (±0.030)	±0.889 (±0.035)
127.0 to 203.17 (5.000 to 7.999)	±0.889 (±0.035)	±1.27 (±0.050)
Greater than 203.2 (Greater than 8.000)	multiply by	1.27 (0.0050)

[A] Fixed dimensions are those that are parallel to the mold parting line or major mold sections and that are not affected by flash thickness variations. Tolerances apply individually to each fixed dimension according to its own size.
[B] Closure dimensions are those vertical to the mold parting line or parting lines of major sections and are affected by flash thickness variation.
[C] The tolerance on closure dimensions is that tolerance for the largest closure dimension. This tolerance is then applied to all other closure dimensions.

Standard Specification for Flexible Transition Couplings for Underground Piping Systems[1]

This standard is issued under the fixed designation C 1173; 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 These specifications describe the properties of devices or assemblies suitable for use as flexible transition couplings, hereinafter referred to as couplings, for underground drainage and sewer piping systems.

1.2 Couplings that may include bushings or inserts and that meet the requirements of this standard are suitable for joining plain end pipe or fittings. The pipe to be joined shall be of similar or dissimilar materials, size, or both.

1.3 The values stated in inch-pound units shall be regarded as standard.

1.4 The ASTM standards referenced herein shall be considered mandatory.

1.5 The committee with jurisdiction over this standard is not aware of another comparable standard for materials covered in this standard.

2. Referenced Documents

2.1 *ASTM Standards:*

C 717 Terminology of Building Seals and Sealants[2]

D 412 Test Methods for Vulcanized Rubber and Thermoplastic Rubbers and Thermoplastic Elastomers—Tension[3]

D 471 Test Method for Rubber Property—Effect of Liquids[3]

D 518 Test Method for Rubber Deterioration—Surface Cracking[3]

D 543 Practice for Evaluating Resistance of Plastics to Chemical Reagents[4]

D 573 Test Method for Rubber—Deterioration in an Air Oven[3]

D 638 Test Method for Tensile Properties of Plastics[4]

D 1149 Test Method for Rubber Deterioration Surface Ozone Cracking in a Chamber[3]

D 2240 Test Method for Rubber Property—Durometer Hardness[3]

D 3045 Practice for Heat Aging of Plastics Without Load[5]

3. Terminology

3.1 *Definitions*—For definitions of terms used in this standard, see Terminology C 717.

3.2 *Definitions of Terms Specific to This Standard:*

3.2.1 *center stop*—an integral part of the gasket centered on its axial length intended to limit the insertion depth of the pipe to be coupled.

3.2.2 *fitting*—parts of a pipeline other than the straight pipe couplings, or valves.

3.2.3 *flexible transition couplings*—devices used to form a leakproof joint between sections of plain end pipe or fittings of the same or different materials, of the same or different size, or any combination of materials or pipe sizes.

3.2.4 *free torque*—the torque value expressed in lbf·in./Nm when the clamp is tightened four revolutions of the screw nut; while in the free state, this value does not include any breakaway effects due to staking or passage of the band ends beyond the screw heads.

3.2.5 *inserts*—a bushing or ring placed into the coupling socket to accommodate pipe materials of differing outside diameters.

3.2.6 *joint*—the completed assembly of parts consisting of the flexible transition coupling and the joined pipes, or fittings, or both.

3.2.7 *lot*—a specific quantity of similar material or collection of similar units from a common source; the quantity offered for inspection and acceptance at any one time. A lot might comprise a shipment, batch, or similar quantity.

3.2.8 *plain end pipe*—any pipe that does not include any bell, hub, threaded area, or other means of joining.

3.2.9 *shear ring*—an interior or exterior element which is used to span the distance between the pipe ends within a coupling so as to provide increased resistance to axial displacement.

4. Classification

4.1 The couplings shall be permitted to have a center stop. The components shall be designed so that the elastomeric material is compressed to form a hydrostatic seal when the

[1] These specifications are under the jurisdiction of ASTM Committee C24 on Building Seals and Sealants and are the direct responsibility of Subcommittee C24.75on Gaskets and Couplings for Plumbing and Sewer Piping.

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[2] *Annual Book of ASTM Standards*, Vol 04.07.

[3] *Annual Book of ASTM Standards*, Vol 09.01.

[4] *Annual Book of ASTM Standards*, Vol 08.01.

[5] *Annual Book of ASTM Standards*, Vol 08.02.

joint is assembled. The couplings shall be of the types described in 4.1.1-4.1.3.

4.1.1 *Type A*—A coupling consisting of an elastomeric sleeve incorporating corrosion resistance tension bands and a tightening mechanism. Couplings shall be fabricated with or without shear rings, and with or without a center stop.

4.1.2 *Type B*—A coupling consisting of an elastomeric or rubber sleeve incorporating a corrosion resistant outer sleeve and tension bands, or tightening mechanism, or both (Note 1).

4.1.3 *Type C*—A coupling fabricated with elastomeric compression seals.

NOTE 1—The provisions of this standard are not intended to prevent the use of any alternate material or method of construction, provided any such alternate meets the requirements of this standard.

5. Materials and Manufacture

5.1 Elastomeric materials used in the manufacturing of couplings and inserts shall comply with the requirements set forth in Table 1.

5.2 Stainless steel tension bands shall be of the 300 series stainless steel.

5.3 Couplings or bushings/inserts, or both, of multi-piece construction or with splices shall show no separation, peeling, or other defects when tested in accordance with Section 9.

5.4 The coupling shall be free from porosity and air pockets. Its surface shall be smooth and free from pitting, cracks, blisters, air marks, or any other imperfections that affect its performance in service. The flash extension shall not exceed 1 mm at any point where the presence of flash affects performance.

TABLE 1 Test Requirements

Properties	Physical Requirements	ASTM Test Method
Elastomeric Materials		
Hardness, Nominal Shore "A" Durometer as specified by the coupling manufacturer	50–75	D 2240
Hardness, Nominal Shore "D" Durometer as specified by the coupling manufacturer	35–45	D 2240
Tensile strength, min psi (KPa)	1000 (6894)	D 412, Die C, Fig. 2 or D638
Elongation at rupture, min, %	200	D 412, Die C, Fig. 2 or D638
Heat aging, 70 h, 158 ± 3.6°F (70 ± 2°C)		D 573 or D3045
Hardness increase, maximum Durometer points	10	
Change in tensile strength, max, %	25	
Change in elongation, max, %	35	
Ozone resistance At 20 % elongation For 100 h at 104± 3.6°F (40 ± 2°C) With 50 parts per 100 million	No cracks	D 1149
Water absorption, weight gain, %, max	20	D 471
Chemical resistance, 48 h, 74± 3.6°F (23 ± 2°C)	no weight loss	D 543
Stainless Steel Materials		
Torque resistance, 60 in.-lb (6.8 Nm)	no failure	9.2 of C1173
Manufacturers required torque resistance	no failure	9.2 of C1173
Joint Assemblies		
Deflection resistance 4.3 psi (30 kPa)	as given in Table 2	9.3.1 of C1173
Shear loading resistance (optional)	as given in Table 3	9.3.2 of C1173

6. Requirements

6.1 The physical and chemical properties of the coupling materials shall conform to the requirements specified in Table 1.

7. Dimensions

7.1 Couplings and bushing dimensions shall be compatible with the dimensions and tolerances of the specific material to which it is designed to join.

8. Sampling, Tests, and Retests

8.1 Test specimens representative of the couplings to be used shall be randomly selected from the manufactured lot for testing.

8.2 No less than two couplings for each size or type shall be tested, unless otherwise specified or waived by the purchaser.

8.3 Where there is a failure in the original test, the entire test shall be rerun with twice the number of samples and any failure shall be cause for rejection.

9. Test Methods

9.1 *Elastomeric Materials*:

9.1.1 *Hardness*—Hardness shall be measured on either a finished surface, a squarely cut end, or a flat sliced or buffed surface, depending on the size and shape of the specimen. See Test Method D 2240.

9.1.2 *Tensile Strength and Elongation*— The dumbbells shall be prepared from sections of the finished material. See Test Methods D 412.

9.1.3 *Heat Aging*, for hardness, tensile and elongation shall be performed in accordance with Test Method D 573. Specimens shall be oven-aged for 96 h at 158 ± 3.6°F (70 ± 2°C).

9.1.4 *Ozone Resistance*—Test specimens shall be used as described in Test Method D 518, Procedure A, stretched 20 % and exposed to an ozone concentration of 50 parts per 100 million for 100 h at 104 ± 3.6°F (40 ± 2°C). See Test Method D 1149.

9.1.5 *Water Absorption*—Size and time determinations shall be set in accordance with Test Method D 471. A specimen 0.075 by 1 by 2 in. (1.9 by 25 by 50 mm) shall be immersed in distilled water at 158 ± 3.6°F (70 ± 2°C) for 7 days. After seven days the specimen shall be removed, the surface moisture blotted and the specimen weighed. The percent gain shall be determined by the following equation:

$$\frac{(WF - WO)}{WO} \cdot 100$$

where:

WF = weight of specimen after immersion for 7 days, and
WO = dry weight of specimen before immersion.

9.1.6 *Chemical Resistance*—Samples shall be aged for 48 h at 74 ± 3.6°F (23 ± 2°C) using solutions of 1N sulfuric acid and 1N hydrochloric acid. See Test Method D 543.

9.2 *Tension Band Performance*:

9.2.1 *Torque Resistance*—Stainless steel tension bands shall be tested to withstand the manufacturers required torque or a minimum of 60 in.-lb (8.5 Nm) of applied torque without visible signs of failure. The band shall be tested over a steel mandrel of the appropriate coupling diameter and torqued as required.

9.2.2 The maximum free running torque shall be 4 in.-lb (0.45 Nm).

9.2.2.1 Stainless steel tension bands with torque resistance in excess of 100 in.-lb shall have a maximum free running torque of 8 in.-lb.

9.2.3 *Test Procedure for Free Running Torque*:

9.2.3.1 With the nonstressed clamp hand held and the slotted band fully engaged, the screw shall be rotated clockwise 10 revolutions with the maximum value of the torque meter recorded.

9.2.3.2 The equipment required shall be a hand held torque meter with a 0 to 15 in.-lb range.

9.3 *Joint Assemblies*:

9.3.1 *Deflection Sealing Resistance*— The joint shall have sufficient flexibility to permit deflection in any direction as defined by Table 2 and shall show no visible leakage when so deflected while under an internal hydrostatic pressure of 4.3 psi (30 KPa). The ends of the test pipe shall be restrained only by an amount necessary to prevent longitudinal movement. The deflection shall be measured as the distance the free end of the one pipe has moved away from the center line of the fixed pipe. See Fig. 1.

9.3.2 *Shear Loading Resistance*—The joint shall have sufficient resistance to shear loading to meet the requirements of the following test. Two lengths of pipe shall be joined by a coupling with the two joined lengths of pipe supported on blocks at three locations. One length of pipe shall be supported on two blocks, one near the unjoined end, and the other immediately adjacent to the joint. This length shall then be firmly restrained in position. The other length of pipe shall be supported by a single block located 36 in. (0.9 m) from the centerline of the joint. A load of 50 lb/in. (220N/25 mm) of nominal pipe diameter adjusted by the weight of pipe extending beyond the support times its moment arm divided by the moment arm to the test load, shall be uniformly applied over an arc of 120° and along a longitudinal length of 24 in. (0.6 m) immediately adjacent to the joint of the pipe having one support (see Fig. 2). While thus loaded, an internal hydrostatic pressure of 4.3 psi (30 KPa) shall be maintained for a period of 1 h with the temperature of water, pipe, and atmosphere within the range between 60 and 75°F (15.5 and 23.8°C) (Note 2).

NOTE 2—Fig. 2 and Table 3 in 9.3.1 are not mandatory at this time because Subcommittee C24.75 is attempting to verify the procedure and values.

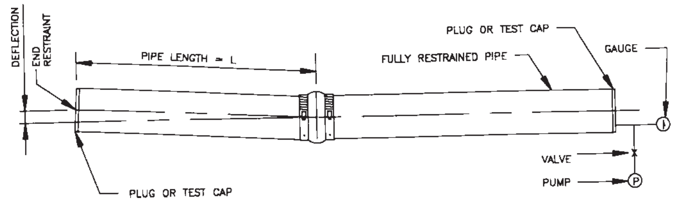
10. Certification

10.1 When specified in the purchase order or contract, the purchaser shall be furnished certification stating samples representing each lot have been tested and inspected as indicated 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.

TABLE 2 Requirements—Deflection per Foot of Pipe Length[A]

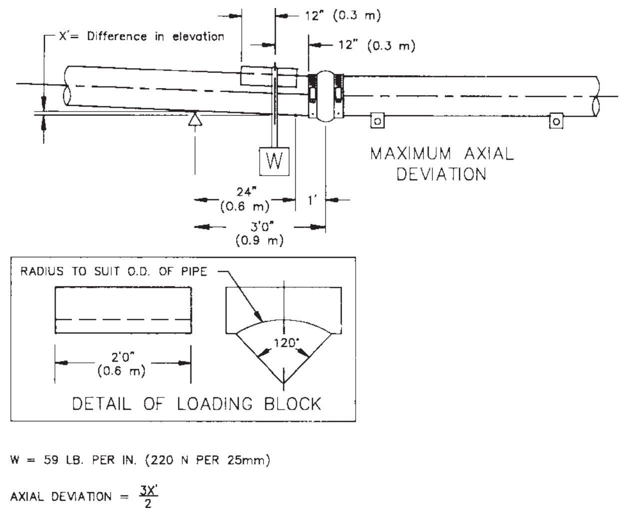
Nominal ID, in. (mm), incl.	Offset in./linear ft (mm/linear m)
2–12 (50–300)	½ (42)
15–24 (375–600)	⅜ (31)
27–36 (675–900)	¼ (21)
39–42 (975–1050)	3⁄16 (15)

[A] See 9.3.1.



NOTE 1—Deflection (in.(mm)) = L(ft(m)) × offset (in./linear ft (mm/linear m)). See Table 2.

FIG. 1 Deflection Test (Plan View)



NOTE 1—For maximum axial deviation values, see Table 3.

FIG. 2 Shear Test

TABLE 3 Maximum Axial Deviation[A]

Nominal ID, in. (mm), incl.	Axial Deflection, in. (mm)
2–6 (50–150)	⅜ (9)
8–12 (200–300)	⅞ (22)
15–24 (375–600)	1⅛ (28)
27–36 (675–900)	¾ (19)
39–42 (975–1050)	9⁄16 (14)

[A] See 9.3.2.

11. Product Marking

11.1 Each coupling shall be marked with the manufacturers name or trademark, or both.

11.2 The type and size of pipe for which the coupling is intended or the manufacturer's product shall be marked on or attached to each coupling.

11.3 All couplings shall be marked with the designation ASTM C 1173 showing compliance to this standard.

12. Keywords

12.1 couplings; drainage; elastomeric; flexible; sewer; transition; underground piping

Designation: C 1277 – 03

Standard Specification for Shielded Couplings Joining Hubless Cast Iron Soil Pipe and Fittings[1]

This standard is issued under the fixed designation C 1277; 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 materials and testing of shielded hubless couplings to join hubless cast iron soil pipe and fittings.

1.2 Several different types of hubless couplings are available for use in hubless cast iron sanitary and storm drain, waste and vent piping applications to connect hubless cast iron soil pipe and fittings by using a sleeve-type, or some other type coupling device. It is the purpose of this specification to furnish information as to the characteristics of one such sleeve type couplings when applied to cast iron soil pipe and fittings manufactured in accordance with Specification A 888, latest revision, and CISPI Designation 301, latest revision.

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

1.4 The committee with jurisdiction over this standard is aware of other comparable standard published by the Cast Iron Soil Pipe Institute, CISPI-310, FM 1680 published by Factory Mutual, and Specification C 1540 published by ASTM.

1.5 The following precautionary caveat pertains only to the test method portion, Section 7, 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 888 Specification for Hubless Cast Iron Soil Pipe and Fittings for Sanitary and Storm Drain, Waste, and Vent Piping Applications[2]

C 564 Specification for Rubber Gaskets for Cast Iron Soil Pipe and Fittings[3]

C 717 Terminology of Building Seals and Sealants[3]

C 1540 Specification for Heavy Duty Shielded Couplings Joining Hubless Cast Iron Soil Pipe and Fittings

2.2 *CISPI Standard:*

CISPI-301 Specification for Hubless Cast Iron Soil Pipe and Fittings for Sanitary and Storm Drain, Waste and Vent Piping Applications[4]

CISPI-310 Specification for Couplings for Use in Connection with Hubless Cast Iron Soil Pipe and Fittings for Sanitary and Storm Drain, Waste, and Vent Piping Applications[4]

FM 1680 Couplings Used in Hubless Cast Iron Systems for Drain, Waste or Vent, Sewer, Rainwater or Storm Water System, Above or Below Ground, Industrial, Commercial and Residential[5]

3. Terminology

3.1 *Definitions:*

3.1.1 Definitions of the following terms used in this specification are found in Terminology C 717, paragraph 4.1: elastomeric, durometer and dynamic.

3.2 *Definitions of Terms Specific to This Standard:*

3.2.1 *center stop*, *n*—an integral part of the gasket centered on the axial length of the gasket intended to limit the insertion depth of the pipe to be coupled.

3.2.2 *clamp assembly*, *n*—that portion of the coupling excluding the gasket and shield.

3.2.3 *corrugated*, *n*—any method of embossing.

3.2.4 *coupling*, *n*—the complete assembly.

3.2.5 *fitting*, *n*—parts of a pipeline other than straight pipes, valves, or couplings.

3.2.6 *gasket*, *n*—the elastomeric portion of the coupling.

3.2.7 *joint*, *n*—the point of assembly consisting of the coupling and the joined pipes or fittings, or both.

3.2.8 *shield*, *n*—an external metallic protective device designed to protect the sealing gasket from external elements that could cause failure of the sealing gasket.

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[1] This specification is under the jurisdiction of ASTM Committee C24 on Building Seals and Sealants and is the direct responsibility of Subcommittee C24.75 on Gaskets and Couplings for Plumbing and Sewer Piping.

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[2] *Annual Book of ASTM Standards*, Vol 01.02.

[3] *Annual Book of ASTM Standards*, Vol 04.07.

[4] Available from Cast Iron Soil Pipe Institute, 5959 Shallowford Rd., Suite 419, Chattanooga, TN 37421.

[5] Available from Factory Mutual Research, 1151 Boston Pprovidence Turnpike, Norwood, MA, 02062.

4. Materials and Manufacture

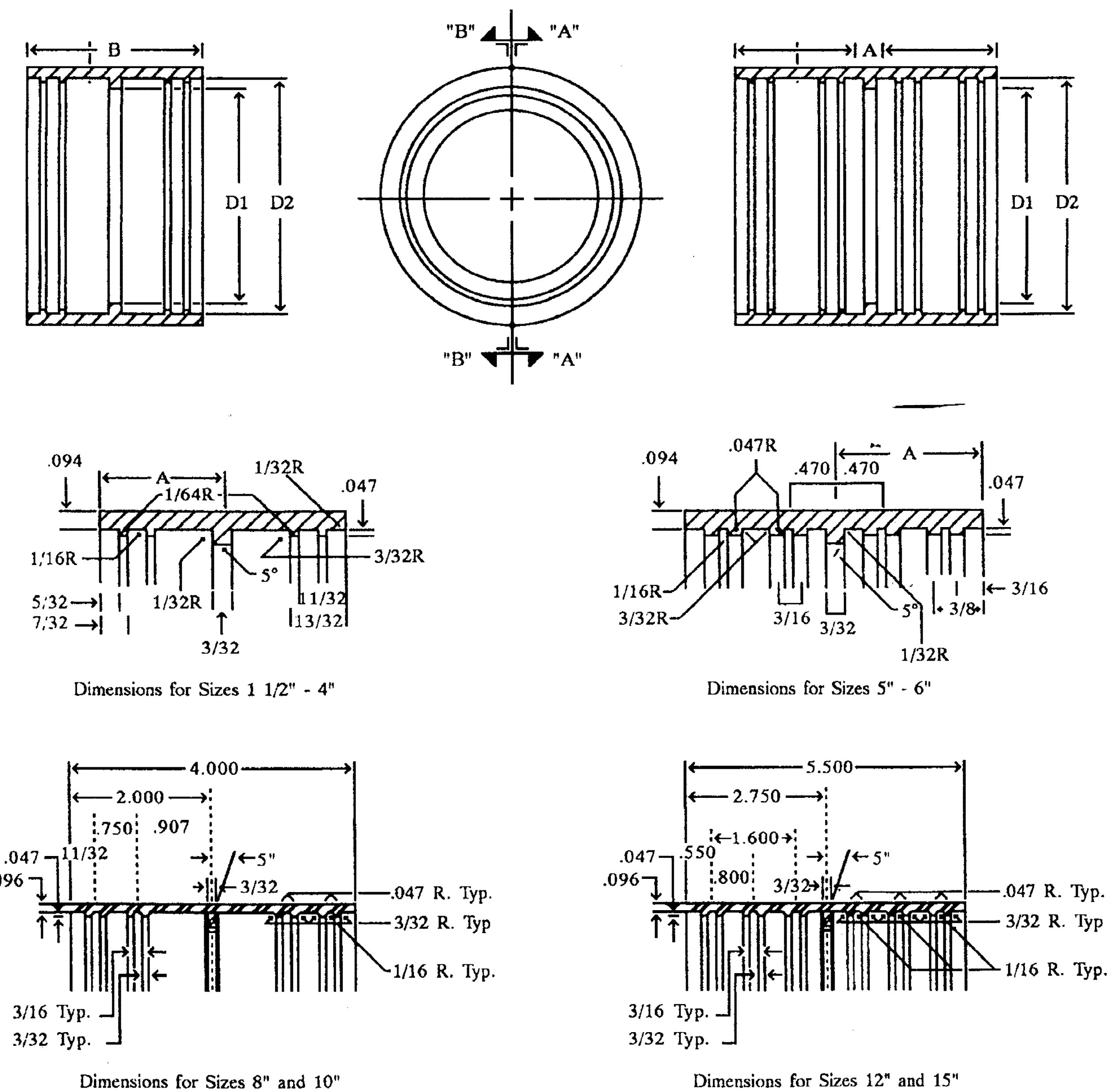
4.1 Physical properties of gaskets shall comply with Specification C 564 and the dimensions, material specifications, physical and chemical properties as shown in Fig. 1, Fig. 2, Table 1, and Table 2.

4.2 Clamp assembly screws or bolts shall not have screwdriver slots.

5. Elastomeric Gasket Requirements

5.1 The elastomeric gasket shall consist of one piece conforming to the physical requirements of Specification C 564.

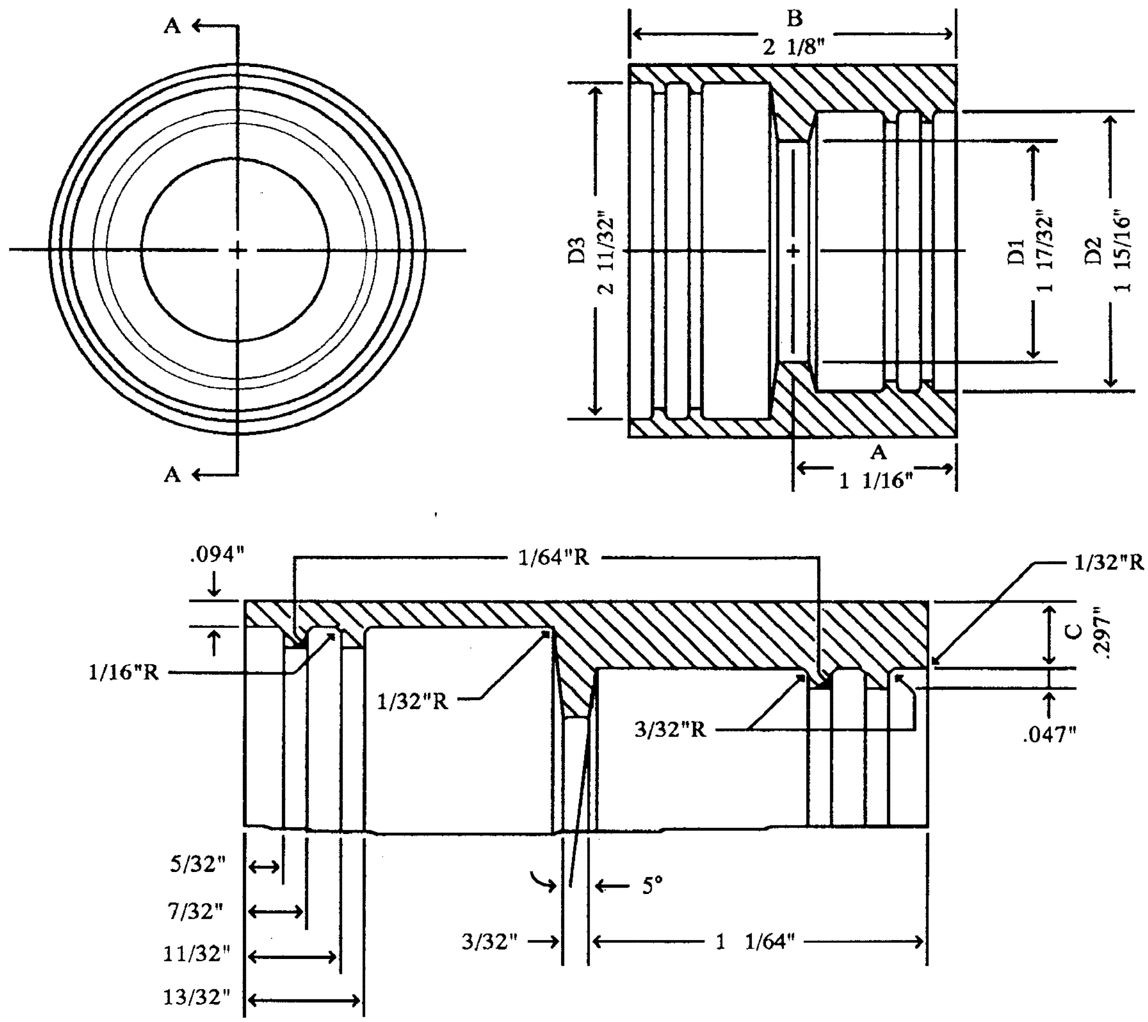
5.1.1 The elastomeric gasket shall have an inside center stop that does not create an enlargement chamber or recess with a ledge, shoulder, or reduction of pipe area or offer an obstruction to flow.



	Dimensions									
	1½ in.	2 in.	3 in.	4 in.	5 in.	6 in.	8 in.	10 in.	12 in.	15 in.
A	1.062	1.062	1.062	1.062	1.500	1.500	2.000	2.000	2.750	2.750
B	2.125	2.125	2.125	2.125	3.000	3.000	4.000	4.000	5.500	5.500
D1	1.531	1.968	2.968	4.000	4.968	5.968	7.968	9.975	12.000	15.200
D2	1.937	2.343	3.343	4.406	5.343	6.343	8.343	10.350	12.430	15.650

Dimensional Tolerances to be RMA Class 3 (See Table 1).

FIG. 1 Rubber Gasket



	Dimensions for Reducing Sleeves		
	2 × 1-½	3 × 2	4 × 3
A	1.062	1.062	1.062
B	2.125	2.125	2.125
C	0.297	0.594	0.625
D1	1.531	1.968	2.968
D2	1.937	2.343	3.343
D3	2.343	3.343	4.406

Dimensional Tolerances to be RMA Class 3 (See Table 1).

FIG. 2 Reducing Rubber Gasket

TABLE 1 Dimensional Tolerances for Rubber—Standard Dimensional Tolerances RMA CLASS 3

Size, in.	Fixed, ±	Closure, ±
0 to 0.499	0.010	0.015
0.500 to 0.999	0.010	0.018
1.000 to 1.999	0.015	0.020
2.000 to 2.999	0.020	0.025
3.000 to 3.999	0.025	0.030
4.000 to 4.999	0.030	0.035
5.000 to 7.999	0.035	0.050

8.000 and over—multiplied by 0.0050. These are commercial tolerances.

5.1.2 The elastomeric gasket shall be free of defects that affect the use and serviceability.

6. Clamp Assembly Requirements

6.1 The shield and clamp assembly shall be made of material conforming to the requirements as outlined in Section 6, Table 3 and Fig. 3.

6.1.1 All parts shall be of 300 series stainless steel. All parts made from round stock shall be of 300 series stainless steel (excluding copper bearing alloys). The shield shall be corrugated or otherwise provided with a mechanism to accommodate maximum and minimum OD's of pipe and fittings and include 2 stainless steel bands for sizes 1½ to 4 in. and 4 bands for 5 to 10 in. and 6 bands for 12 and 15 in. Each tightening device housing shall interlock with a band at the unslotted end. The bands are to be fastened to the shield by riveting or such

TABLE 2 Rubber Gasket Physical Requirements

NOTE 1—Material: The sealing sleeve shall be made from an elastomeric compound that meets the requirements of Specification C 564.
NOTE 2—Physical Tests: The test specimens shall be obtained from finished sleeves and tested pursuant to the methods described in the following table.

Test	Physical Tests, Min or Max Requirements	ASTM Method
Tensile Strength	1500 psi min	D 412
Elongation	250 min	D 412
Durometer (Shore A)	70 ± 5°F at 76 ± 5°F	D 2240
Accelerated Aging	15 % max tensile and 20 % max elongation deterioration, 10 points max; increase in hardness, all determinations after oven aging for 96 h at 158°F	D 573
Compression Set	25 % max after 22 h at 158°F	D 395 Method B
Oil Immersion	80 % max. volume change after immersion in ASTM oil no. IRM903 for 70 h at 212°F	D 471
Ozone Cracking	No visible cracking at 2 times magnification of the gasket after 100 h. Exposure in 1.5 ppm ozone concentration at 100°F. Testing and inspection to be on gasket which is loop mounted to give approximately 20 % elongation of outer surface	D 1149
Tear Resistance	Die C; 150 lb min per inch of thickness	D 624
Water Absorption	20 % max by weight after 7 days at 158°F	D 471

TABLE 3 Material Specifications

Band	Type 301 AISI Stainless Steel—Minimum Tensile 165 000 psi for 1½ to 15 in.; Type 304 AISI Stainless Steel is permitted Type 304 AISI Stainless Steel—Minimum Tensile 140 000 psi
Eyelets/Rivets	Type 300 AISI Stainless Steel
Screw Housing	Type 301 AISI Stainless Steel for 1½ to 15 in.; Type 304 AISI Stainless Steel is permitted
Screw	Type 305 AISI Stainless Steel—5⁄16 Hex Head/Shoulder for 1½ to 10 in.; 3⁄8 Hex Head/Shoulder for 12 and 15 in. is required for couplings which require installed torque greater than 60 in.-lbf When other than 3⁄8 in. hex head screw is used on 12 and 15 in. couplings, the coupling shall be labeled with the required installation torque
Shield	Type 301 AISI Stainless Steel—Bright Annealed Only (Annealed and Pickled Not Acceptable) Hardness—Rockwell B-85 Max (Max Burr Height Not to Exceed 25 % of Thickness) for Type 301 AISI Stainless Steel; Rockwell B-95 Max (Max Burr Height Not to Exceed 25 % of Thickness) for Type 304 AISI Stainless Steel

(1) Construction for sizes 1½ thru 10 in. shields have corrugations tapering in height from 0.000 to 0.030 in. at dimension "Y." Y equals maximum of 1 in. (Type A Only)
(2) Position clamps on shield as shown from inside end of clamp. Shield overlap to be as shown or reversed on 5, 6, 8, 10, 12, and 15 in. only.
(3) Securely fasten each clamp to shield, two places for sizes 1½ to 4 in., three places for sizes 5, 6, 8, 10, 12, and 15 in.
(4) Details of detent on 5, 6, 8, and 10 in. bands are shown in Fig. 4 (optional for 12 and 15 in.).
(5) Max "X" is that dimension to which the clamp must open and still maintain positive engagement of the screw in the slots of the clamping band. Min. "X" is that dimension to which the clamping band must close and still maintain positive engagement of the screw in the slots of the clamping band.

other method that will insure that the bands will not become separated from the shield. The shield and clamp assembly shall comply with dimensions and material specifications, as are given in Table 3, Fig. 3, and Fig. 4.

6.1.2 Clamp assemblies shall be tested to withstand no less than 125 % of manufacturers stated installation torque or a minimum of 60 lbf·in. (6.78 N·m) of applied torque, whichever is greater, without visible signs of failure. The clamp assembly shall be tested over a steel mandrel of the appropriate diameter and torqued as required.

6.1.3 The clamped shield shall meet the requirements of Table 3.

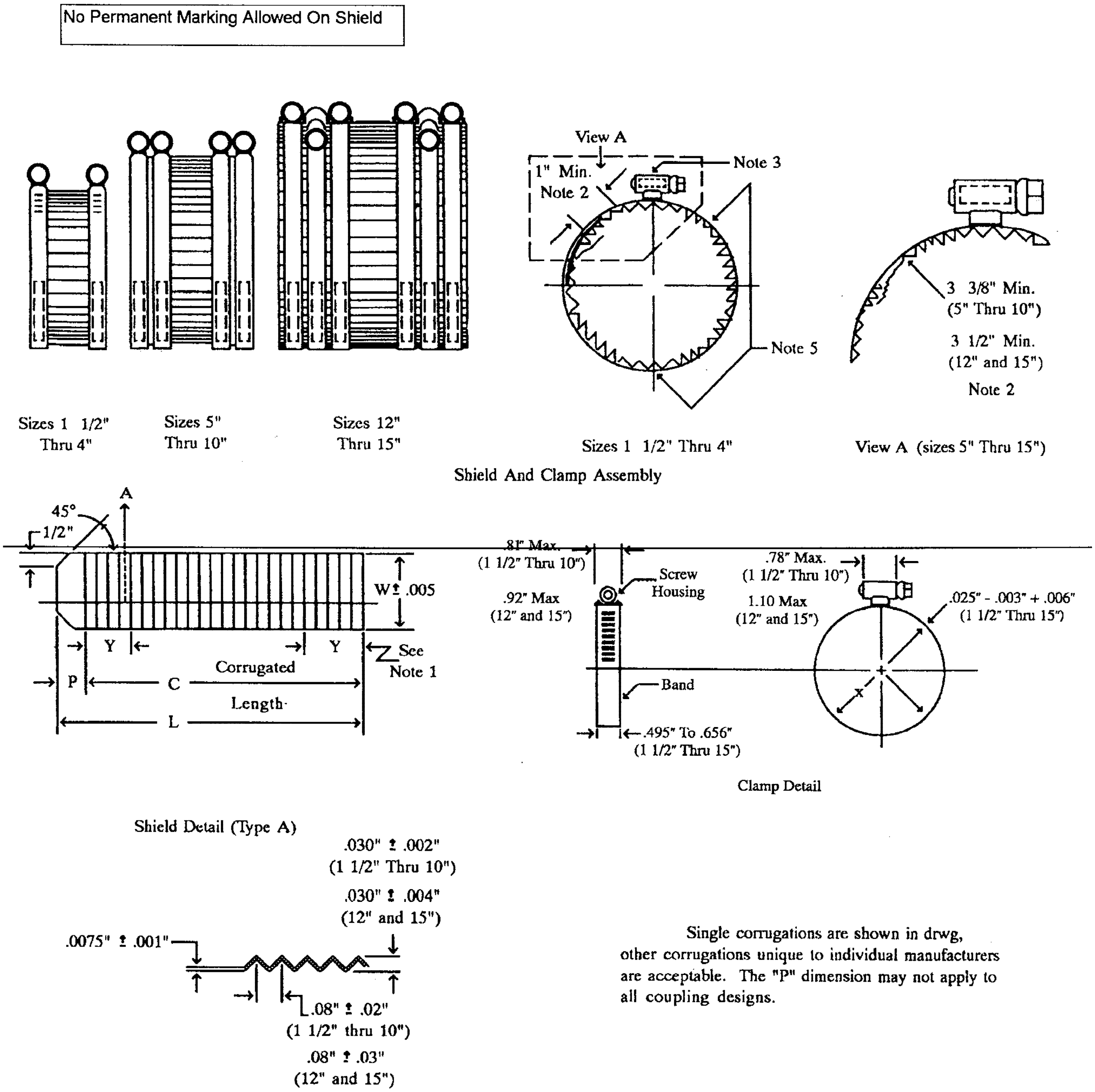
6.1.4 The couplings shall meet the dimensional requirements of Fig. 3.

7. Couplings Requirements and Test Methods

7.1 Assemble each coupling tested according to the manufacturer's instructions between two sections of randomly selected hubless cast iron soil pipe meeting the requirements of CISPI-301 or Specification A 888 and conduct the following test: deflection and shear. In addition, an unrestrained hydrostatic test will be performed between two sections of machined steel pipe.

7.1.1 *Deflection Test*:

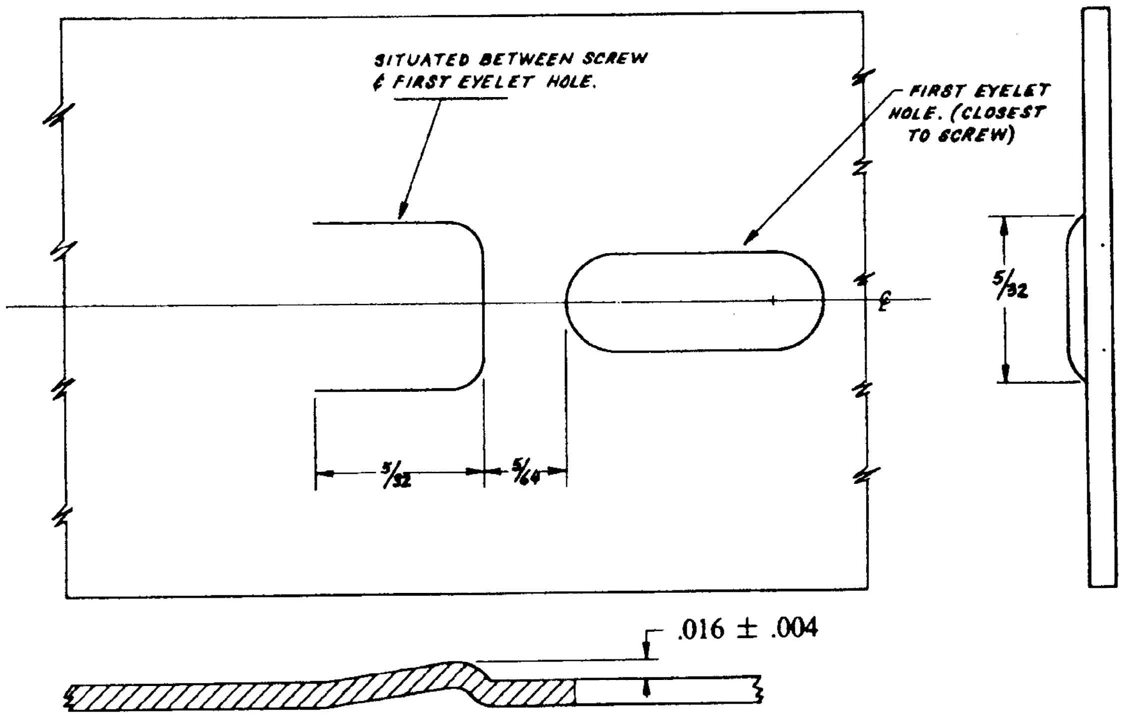
7.1.1.1 A test apparatus such as the one shown in Fig. 5 is suggested. Other testing apparati that provide restraint to the assembly shall also be permitted. Close the outboard ends of the pipe with test plugs.



NOTE—Marking allowed of couplings using non-corrugated shields

Pipe Size, in.	Dimensions, in.					
	P	C	L	W	X^7, min	X^7, max
1½	0.813 ± 0.188	6.688	7.5 ± 0.125	2.125	1.50	2.50
2	0.813 ± 0.188	8.188	9.0 ± 0.125	2.125	2.00	3.00
3	0.813 ± 0.188	11.438	12.25 ± 0.125	2.125	3.00	4.00
4	0.813 ± 0.188	14.813	15.63 ± 0.125	2.125	4.00	5.00
5	2.375 ± 0.125	17.563	19.94 ± 0.125	3.000	5.30	6.20
6	2.375 ± 0.125	20.250	22.63 ± 0.125	3.000	6.30	7.20
8	3.000 ± 0.125	26.000	29.00 ± 0.125	4.000	8.30	9.20
10	3.000 ± 0.125	33.250	36.25 ± 0.250	4.000	10.45	11.35
12	3.500 ± 0.125	39.100	42.60 ± 0.250	5.500	12.53	13.27
15	3.500 ± 0.125	49.200	52.70 ± 0.250	5.500	15.75	16.49

FIG. 3 Shield and Clamp Assembly



NOTE—Detail of typical coupling is shown. Other couplings are allowed to have different designs such as spot welding.

FIG. 4 Details of Detent on 5, 6, 8, and 10 in. Bands (Optional on 12 and 15 in.)

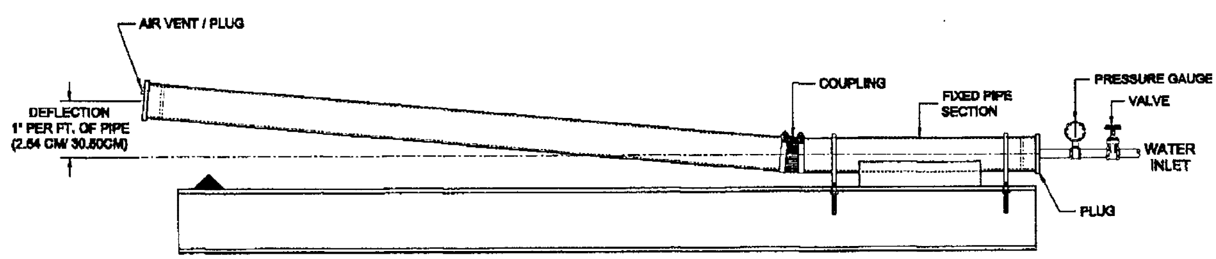


FIG. 5 Deflection Test

7.1.1.2 Fill the assembly with water, expel all air, and hydrostatically pressurize to 4.3 psi (29.6 kPa) for the duration of the test. One pipe shall be rigidly supported and while the assembly is under pressure, raise the opposite end of the other pipe ½ in. (12.7 mm) per lineal foot of pipe. Maintain the pressure for 5 min. Any leakage shall mean failure.

7.1.2 *Shear Test*:

7.1.2.1 Support two joined lengths of randomly selected hubless cast iron soil pipe on blocks, a minimum of 1½ in. (38.1 mm) high, at three locations. One length shall be a minimum of 24 in. (609.6 mm) in length, supported on blocks, one near the uncoupled end, and the other immediately adjacent to the couplings. Firmly restrain this length in position as shown in Fig. 6. The other coupled length shall be a minimum of 5 ft (1.52 m) in length and supported by a single block 6 in. (152.4 mm) from the end of the pipe.

7.1.2.2 Fill the assembly with water and expel all air. Apply a load of 50 lb/in. of nominal diameter at a point 6 in. (152.4 mm) from the edge of the coupling upon a 12 in. (304.8 mm) length of (3 by 3) angle iron or load distribution pad located on the top of the pipe immediately adjacent to the coupling of the pipe having one support only. Under this loading there shall be no visible leakage or displacement of more than ⅜ in. (9.53 mm) from true alignment adjacent to the coupling, when an internal pressure equivalent to a 10 ft (3.05 m) head of water 4.3 psi (29.6 kPa) is applied. Maintain the load and internal pressure for 15 min.

7.1.3 *Unrestrained Hydrostatic Test*:

7.1.3.1 Assemble each coupling tested according to the manufacturer's instruction between two sections of machined steel pipe and conduct the thrust test.

7.1.3.2 The assembly shall consist of a maximum outside diameter pipe connected to a minimum outside diameter pipe with diameters as referenced in Table 4 and lengths as shown in Fig. 7. Machine the plain ends of the pipe to be used for the thrust test to the correct diameters. Plain ends shall have 0.015

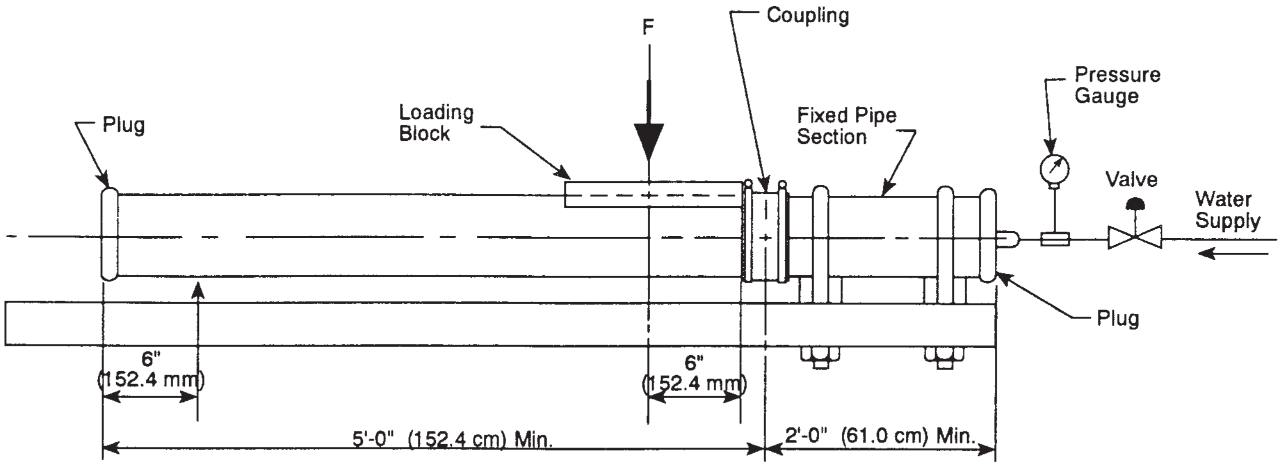


FIG. 6 Shear Test

TABLE 4 Dimensions and Tolerances for Hubless Pipe and Fittings

Size, in. (mm)	Outside Diameter, in. (mm)
1½ (38)	1.90 ± 0.06 (48.26 ± 1.52)
2 (51)	2.35 ± 0.09 (59.69 ± 2.29)
3 (76.2)	3.35 ± 0.09 (85.09 ± 2.29)
4 (102)	4.38 ± 0.09/−0.05 (111.25 + 2.29/−1.27)
5 (127)	5.30 ± 0.09/−0.05 (134.62 + 2.29/−1.27)
6 (152)	6.30 ± 0.09/−0.05 (160.02 + 2.29/−1.27)
8 (203)	8.38 ± 0.13/−0.09 (212.85 + 3.30/−2.29)
10 (254)	10.56 ± 0.09 (268.22 ± 2.29)
12 (305)	12.50 ± 0.09 (317.5 ± 2.29)
15 (380)	15.83 ± 0.09 (402.8 ± 2.29)

in. (0.38 mm) deep grooves machined circumferentially around them at ⅛ in. (3.18 mm) intervals down the pipe section for a distance equal to that covered by the elastomeric sleeve of the coupling being tested. The tool used to machine the grooves shall have a 60° inclined angle and cut into the pipe from a perpendicular position. The surface between the grooves shall be a lathe turned surface of 125 RMS.

7.1.3.3 The plain ends of the pipe for the thrust test shall be uncoated and cleaned with acetone and thoroughly dried before each assembly.

7.1.4 *Test Method*:

7.1.4.1 Support the pipe assemblies in a manner that does not restrain joint movement as shown in Fig. 7.

7.1.4.2 Fill the pipe assembly (as required in 7.1.3) with water, expelling all air. Increase the hydrostatic pressure at a rate of 1 psi (6.9 kPa) every 30 s until the specified test pressure is reached. The specified test pressure shall be 20 psi (137.9 kPa) for 1½ in. (38.1 mm) through 5 in. (127 mm), 18 psi (124.1 kPa) for 6 in. (152.4 mm), 10 psi (68.9 kPa) for 8 in. (203.2 mm), and 6 psi (41.4 kPa) for 10 in. (254 mm) pipe, 12 in. (305 mm), and 15 in. (380 mm). When the specified test pressure is reached, hold it for 10 min. Any leakage or axial joint movement of more than 0.150 in. (3.81 mm) shall mean failure.

8. Markings and Identification

8.1 *Marking*—The gasket shall be marked with raised letters. This marking shall consist of pipe size, country of origin, manufacturer's identifying mark, and Specification C 564, latest revision. Such marking shall not exceed 0.02 in. in relief.

8.2 The shield and clamp assembly shall be marked with indented letters. All marking shall be placed on the band assemblies. Marking on the band shall consist of pipe size. Marking on the screw housing shall consist of coupling manufacturer's name or registered. Trademark with a national registry of trademarks in the country in which the product is installed, the words ALL STAINLESS, country of origin. No marking is permitted on couplings with corrugated shield.

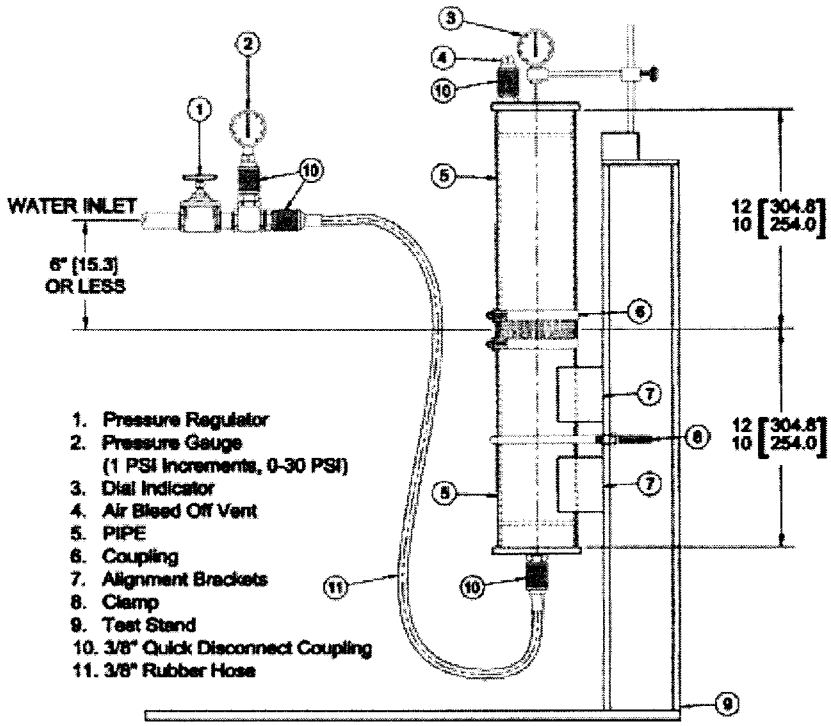


FIG. 7 Unrestrained Hydrostatic Test

Standard Specification for Thermoplastic Elastomeric (TPE) Gasket Materials for Drain, Waste, and Vent (DWV), Sewer, Sanitary and Storm Plumbing Systems[1]

This standard is issued under the fixed designation C 1440; 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 thermoplastic elastomeric (TPE) gasket materials for preformed elastomeric gaskets used in shielded and non-shielded mechanical couplings. These couplings are used in gravity flow drain, waste and vent (DWV), sewer, sanitary and storm plumbing systems. They include couplings to join similar and dissimilar piping sizes and material.

1.2 The values stated in metric or inch/pound units shall be regarded separately as normative for this specification. The values in each system are not exact equivalents; therefore, each system shall be used independently without combining values.

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:* [2]

C 717 Terminology of Building Seals and Sealants
C 395 Test Methods for Rubber Property-Compression Set
D 412 Test Methods for Rubber Properties in Tension
D 471 Test Method for Rubber Property-Effect of Liquids
D 573 Test Method for Rubber-Deterioration in an Air Oven
D 624 Test Method for Tear Strength of Conventional Vulcanized Rubber and Thermoplastic Elastomers
D 1149 Test Method for Rubber Deterioration-Surface Ozone Cracking in a Chamber
D 1415 Test Method for Rubber Property-International Hardness
D 2240 Test Method for Rubber Property-Durometer Hardness
D 5964 Standard Practice for Rubber IRM 902 and IRM 903 Replacement Oils for ASTM No. 2 and ASTM No. 3 Oils

3. Terminology

3.1 *Definitions*—Refer to Terminology C 717 for definitions of the following terms used in this specification *elastomer, elastomeric, elongation, gasket, hardness, preformed gasket-(see gasket), thermoplastic elastomer.*

4. Materials and Manufacture

4.1 Gaskets shall be made of virgin thermoplastic elastomeric compound containing only clean reworked thermoplastic elastomer material from the manufacturer's own production of the same compound.

4.2 Where splices are made in the gasket, the strength of the splice shall be such that the gasket will withstand the stretch test described in 8.9 with no visible separation or peeling.

4.3 Many thermoplastic elastomeric materials (TPE) are temperature sensitive. Designed operating temperature range for the 87 Shore A TPE materials is 0° to 130° F (–18° to 55°C). These materials are not designed or intended for prolonged operation outside this range.

5. Physical Properties

5.1 Gaskets representative of the manufacturer's production shall be selected as specified in Section 7 and shall conform to the requirements for physical properties listed in Table 1 when tested in accordance with the methods specified in Section 8.

6. Workmanship, Finish and Appearance

6.1 The surface of the gasket shall be smooth and free of pitting, cracks, blisters, air marks, and any other imperfections that will affect its behavior in service. The body of the gasket shall be free of porosity and air pockets.

6.2 Neither the flash thickness nor the flash extension shall exceed 1/32 in. (0.8 mm), at any point on the ring.

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[1] This Specification is under the jurisdiction of ASTM Committee C24 on Building Seals and Sealants and is the direct responsibility of Subcommittee C24.75 on Gaskets and Couplings for Plumbing and Sewer Piping.

Current edition approved Dec. 1, 2003. Published January 2004. Originally approved in 1999. Last previous edition approved in 1999 as C 1440–99$^{\epsilon 1}$.

[2] 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.

TABLE 1 Physical Requirements of Gasket Materials

Properties Tested	ASTM Test Method	TPE[A]
Hardness, Shore A (±5 pts)	D 2240	87 (5 s Delay)
Elongation, min, %	D 412	250
Tensile Strength, min. psi (kPa)	D 412	1500 (10 342)
Heat Aging	D 573	
96 h at 70 ± 2°C (158±4°F)		
Hardness increase, max, pts. Shore A		10
Loss in tensile strength, max, %		15
Loss in elongation, max, %		20
Tear Strength, min. lbf/in (N/cm)	D 624	150(268)
Water Absorption	D 471	
7 days at 70 ± 2°C(158 ± 4°F)		
Weight increase, max %		20
Ozone Resistance	D 1149	No cracks
100 h at 40 ± 2°C (104 ± 4°F)		
Ozone Concentration *150 pphm*		
20 % Extension		
Compression Set, max %	D 395	12
22 h at 70 ± 1°C (158 ± 2°F)	Method A	
Oil Immersion in IRM 903 Oil	D 471	
70 h at 100 ± 2°C (212 ± 4°F)		
Max Volume Increase, %		80
Max Volume Decrease, %		15

[A]Designed operating temperature for Shore A TPE materials is 0° to 130°F (–18° to 55°C). These materials are not designed or intended for prolonged operation outside this range.

6.3 The offset, or failure of the mold to register accurately, shall not exceed 1/64 in. (0.4 mm).

7. Sampling

7.1 For the stretch test specified in 8.9, sample gaskets shall be selected at random from each shipment of gaskets. For each of the other tests, gaskets shall be selected at random as required by the method of test specified.

8. Test Methods

8.1 *Hardness*—Test the gasket material for hardness in accordance with Test Method D 2240. As required, use Test Method D 1415 as the referee method. Make hardness measurements on specimens prepared in accordance with 8.2. However, hardness readings for guidance purposes shall be taken directly on the gasket, recognizing that these shall be permitted to vary slightly from those taken on the dumbbell specimens.

8.2 *Elongation and Tensile Strength*—Test the gasket material for elongation and tensile strength in accordance with Test Method D 412. Cut standard ASTM Type C dumbbell specimens conforming to Fig. 1 (Apparatus for Tensile Set Test) of Test Method D 412 from sections of the gasket for this test. To obtain a uniform thickness, these sections shall be permitted to be buffed prior to cutting into dumbbell specimens, so as to produce a finely ground surface without cuts or burns.

8.3 *Tear Strength*—Test the gasket material for tear strength in accordance with Test Method D 624 using Die C.

8.4 *Compression Set*—Test the gasket material for compression set using Test Method D 395. For materials with a hardness of 90 IRHD or higher Method A must be used. For materials with a hardness less than 90 IRHD Method B must be used. Oven age samples for 22 h at 70 ± 1°C (158° ± 2°F). When using Test Method A, there shall be a maximum dimensional change of 12 %. When using Test Method B, there shall be a maximum dimensional change of 25 %.

8.5 *Heat Aging*—Test the gasket material for heat aging in accordance with Test Method D 573. Prepare specimens in accordance with 8.2, and for 96 h at 70 ± 2° C (158 ± 4°F). Make hardness measurements as specified in 8.1.

8.6 *Water Absorption*—Test the gasket material for weight increase due to water absorption in accordance with Test Method D 471. If a 1 in. (25.4 mm) specimen cannot be cut from the sample gasket, use the greatest width obtainable. Immerse the test specimen in distilled water at 70 ± 2°C (158 ± 4°F) for seven days.

8.7 *Ozone Resistance*—Test the gasket material for ozone resistance in accordance with Test Method D 1149, using specimens and procedure specified under Method B. The ozone concentration shall be 150 pphm of air by volume. Age specimens 100 h at 40 ± 2°C (104 ± 4°F) with a 20 % extension. Use a two-power hand magnification glass to examine the gasket

8.8 *Oil Immersion*—Test the gasket material for volume decrease due to oil absorption in accordance with Test Method D 471. If a 1-in. (25.4 mm) specimen cannot be cut from the sample gasket, use the greatest width obtainable. The test specimen shall be immersed in IRM 903 oil for 70 h at 100 ± 2°C (212 ± 4°F).

8.9 *Stretch Test for Spliced Gaskets*—Stretch gaskets until the circumference is increased by 50 %, then visually inspect for defects as described in 4.2 and 6.1. One percent of the total spliced gaskets shall be tested with no failures.

9. Certification

9.1 When specified in the purchase order or contract, the purchaser shall be furnished certification stating samples representing each lot have been tested and inspected as indicated 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.

10. Marking

10.1 Each gasket shall be permanently marked with clearly legible letters. These markings shall include the gasket manufacturer's name or registered trademark, the pipe size and class, the year of manufacture, the country of origin, and the ASTM standard specification designation.

Designation: C 1460 – 04

Standard Specification for Shielded Transition Couplings for Use With Dissimilar DWV Pipe and Fittings Above Ground[1]

This standard is issued under the fixed designation C 1460; 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 performance of shielded transition couplings to join dissimilar DWV pipe and fittings above ground up to and including 10 in. pipe and fittings.

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.

1.3 The following precaution comment pertains only to the test method portion, Section 7, 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.*

1.4 The committee with jurisdiction over this standard is not aware of any comparable standards published by other organizations.

2. Referenced Documents

2.1 *ASTM Standards:* [2]

A 493 Specification for Stainless and Heat-Resisting Steel Wire and Wire Rods for Cold Heading and Cold Forging

C 564 Specification for Rubber Gaskets for Cast Iron Soil Pipe and Fittings

C 717 Terminology of Building Seals and Sealants

3. Terminology

3.1 *Definitions*— The following definitions used in this specification are found in Terminology C 717: elastomeric, thermoset, and thermoplastic

3.2 *Definitions of Terms Specific to This Standard:*

3.2.1 *center stop*, *n*—an integral part of the gasket centered on the axial length of the gasket intended to limit the insertion depth of the pipe to be coupled.

3.2.2 *clamp assembly*, *n*—that portion of the coupling excluding the gasket.

3.2.3 *coupling*, *n*—the complete assembly.

3.2.4 *dissimilar DWV pipe and fittings*, *n*— pipe and fittings made of different materials or different outside diameters, or both.

3.2.5 *fitting*, *n*—parts of a pipeline other than straight pipes, valves, or couplings.

3.2.6 *gasket*, *n*—the elastomeric portion of the coupling.

3.2.7 *joint*, *n*—the point of assembly consisting of the coupling and the joined pipes or fittings, or both.

3.2.8 *shield*, *n*—an external metallic protective device designed to protect the sealing gasket from external elements that could cause failure of the sealing assembly.

4. Materials and Manufacture

4.1 Physical properties of gaskets shall be in accordance with Table 1 of Specification C 564, using the Durometer hardness column as specified by the manufacturer.

4.2 All steel parts made from round stock shall be 300 series stainless steel and shall conform to the requirements of Specification A 493 (excluding copper bearing alloys).

5. Elastomeric Gasket Requirements

5.1 The elastomeric gasket shall consist of one piece in accordance with the physical requirements of 4.1

5.1.1 The elastomeric gasket shall have an inside center stop-ring spaced equal distance from the ends to serve as a stop between the pipe/fitting ends that does not create an enlargement chamber or recess with a ledge, shoulder, or reduction of pipe area or offer an obstruction to flow. A gasket without an inside center stop shall be permitted where telescoping of the piping is necessary.

5.1.2 The elastomeric gasket shall be free of defects that affect the use and performance.

6. Clamp Assembly Requirements

6.1 Clamp assemblies shall be tested to withstand no less than 125 % of the manufacturer stated installation torque (60 lb. in. minimum 6.78 N.m) of applied torque whichever is greater without visible signs of failure. The clamp assembly shall be tested over a steel mandrel sized within the range of the clamp and torqued as required.

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[1] This specification is under the jurisdiction of ASTM Committee C24 on Building Seals and Sealants and is the direct responsibility of Subcommittee C24.75 on Gaskets and Couplings for Plumbing and Sewer Piping .

Current edition approved February 1, 2004. Published March 2004. Originally approved in 2000. Last previous edition approved in 2000 as C 1460 - 00.

[2] 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.

6.2 Clamp assembly screws or bolts shall not have screwdriver slots.

7. Coupling Requirements and Test Methods

7.1 Assemble each coupling tested in accordance with the manufacturer's instructions between two sections of randomly selected pipe not to exceed 20 ft in length manufactured to appropriate standards for the type of pipe the couplings are expected to join, and conduct the following tests:

7.1.1 *Deflection Test*— Mount each coupling tested between two pieces of pipe as provided in 7.1. Close the out bound ends of the pipe with test plugs. Fill the assembly with water, expel all air, and hydrostatically pressurize to 4.3 psi for the duration of the test. Rigidly support one pipe while the assembly is under pressure, raise the opposite end of the other pipe one-half inch per lineal foot of pipe. Maintain the pressure for 5 min and do not permit leakage. A test apparatus such as the one shown in Fig. 1 is suggested.

7.1.2 *Shear Test*—Fill the assembly with water, expel all air, and hydrostatically pressurize to 4.3 psi for the duration of the test. Support two joined lengths of pipe selected in accordance with 7.1 on blocks at three locations. Support one length on blocks, one near the uncoupled end, and the other immediately adjacent to the couplings. Firmly restrain this length in position (see Fig. 2). Support the other coupled length by a single block at the end of the pipe. Apply a load of 50 lb/in. of nominal diameter at a point 6 in. from the edge of the coupling upon a 12-in. length of (3 by 3) angle iron or load distributing pad located on the top of the pipe immediately adjacent to the coupling of the pipe having one support only. When testing reducing couplings, apply the load to the reduced size. Under this loading there shall be no visible leakage displacement of more than ⅜ in. from true alignment when an internal pressure equivalent to a 10-ft head of water (4.3 psi) is applied. Maintain the load and internal pressure 15 min and do not permit leakage.

7.2 *Unrestrained Hydrostatic Joint Test*:

7.2.1 Each coupling tested shall be assembled in accordance with the manufacturer's instructions between two sections of machined steel pipe and conduct the unrestrained hydrostatic joint test.

7.2.2 The plain ends of the pipe to be used shall be machined to the correct nominal outside diameter of the types of pipe for which the coupling is intended to join. Plain ends shall have 0.015 in. [2 mm] deep grooves machined circumferentially around them at 0.125 in. [3.2 mm] intervals down the pipe section for a distance equal to that covered by the elastomeric sleeve. The tool used to machine the grooves shall have a 60° included angle and shall cut into the pipe from a perpendicular position. The surface between the grooves shall be a lathe turned surface of 125 RMS. The plain ends of the pipe are to be uncoated and shall be cleaned with acetone and thoroughly dried before each assembly.

7.2.3 Fill the pipe assembly with water, expelling all air and increase the hydrostatic pressure at a rate of 1 psi [6.9 kPa] every 30 s until the target test pressure is reached. The target test pressure shall be 20 psi [138 kPa] for 1½ through 5-in. pipe, 18 psi [124 kPa] for 6-in. pipe, 10 psi [69 kPa] for 8-in. pipe, and 6 psi [41.4 kPa] for 10-in. pipe. When the target pressure is reached, it shall be held for 10 min. Any leakage or axial joint movement of more than 0.150 in. [3.8 mm] shall mean failure.

7.2.4 Support the pipe assemblies in a manner that does not restrain joint movement as shown in Fig. 3.

8. Markings and Identification

8.1 Each clamp assembly and gasket shall be permanently marked with the manufacturer's name or U.S. registered trademark, country of origin, and the pipe size and class for which it is designed.

8.2 Each clamp assembly shall be labeled or permanently marked as to the material(s) for which it is intended. The label or marking shall be visible after installation.

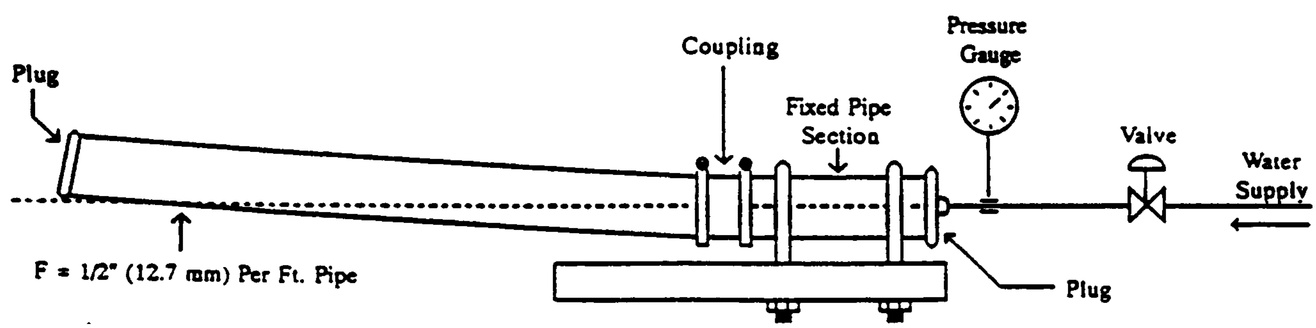


FIG. 1 Deflection Test

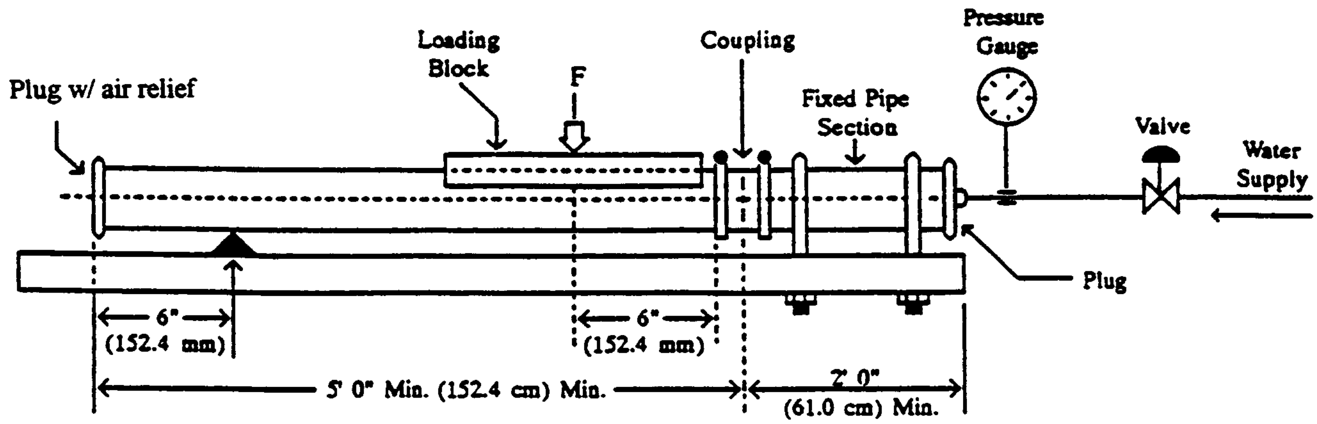
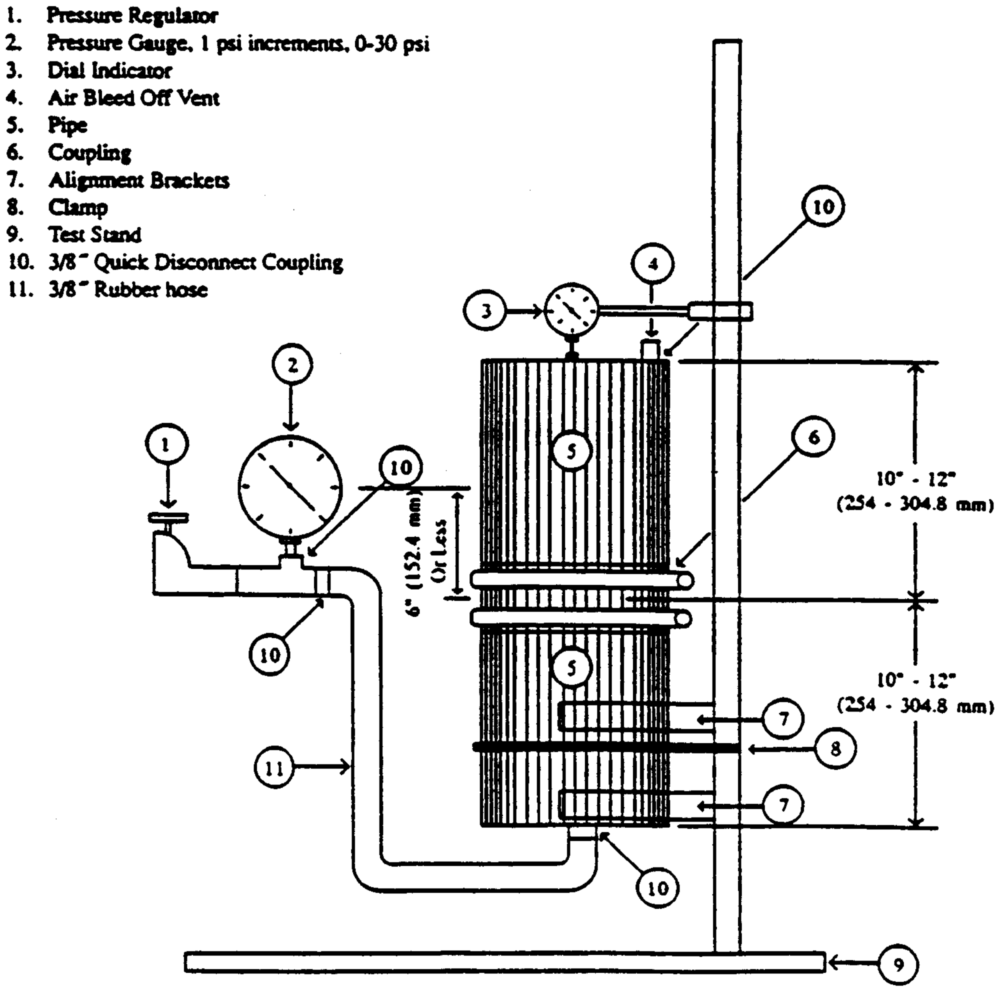


FIG. 2 Shear Test



1. Pressure Regulator
2. Pressure Gauge, 1 psi increments, 0-100 PSI
3. Dial indicator
4. Air Bleed Off Vent
5. Pipe
6. Coupling
7. Alignment Brackets
8. Clamp
9. Test Stand
10. 3⁄8 ″ Quick Disconnect Coupling
11. 3⁄8 ″ Rubber hose

FIG. 3 Unrestrained Hydrostatic Joint Testing Apparatus

Designation: C 1461 – 02

Standard Specification for Mechanical Couplings Using Thermoplastic Elastomeric (TPE) Gaskets for Joining Drain, Waste, and Vent (DWV), Sewer, Sanitary, and Storm Plumbing Systems for Above and Below Ground Use[1]

This standard is issued under the fixed designation C 1461; 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 describes the properties of devices or assemblies suitable for use as mechanical couplings using thermoplastic elastomeric (TPE) gaskets, hereinafter referred to as couplings, for joining drain, waste, and vent (DWV) sewer, sanitary, and storm plumbing systems for above and below ground use.

1.2 The pipe to be joined shall be of similar or dissimilar materials or size, or both.

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

1.4 The ASTM standards referenced herein shall be considered mandatory.

2. Referenced Documents

2.1 *ASTM Standards:*

A 240/A 240M Specification for Heat-Resisting Chromium and Chromium-Nickel Stainless Steel Plate, Sheet, and Strip for Pressure Vessels[2]

A 493 Specification for Stainless and Heat-Resisting Steel Wire and Wire Rods for Cold Heading and Cold Forging[2]

A 666 Specification for Annealed or Cold-Worked Austenitic Stainless Steel, Sheet, Strip, Plate and Flat Bar[2]

C 717 Terminology of Building Seals and Sealants[3]

C 1440 Specification for Thermoplastic Elastomeric (TPE) Gasket Materials for Drain, Waste and Vent (DWV), Sewer, Sanitary and Storm Plumbing Systems

D 2240 Test Method for Rubber Property—Durometer Hardness[4]

3. Terminology

3.1 *Definitions*—For definitions of terms used in this specification, see Terminology C 717.

3.2 *Definitions of Terms Specific to This Standard:*

3.2.1 *center stop*—an integral part of the gasket centered on its axial length intended to limit the insertion depth of the pipe to be coupled.

3.2.2 *fitting*—parts of a pipeline other than straight pipe, couplings, or valves.

3.2.3 *free torque*—the torque value expressed in lbf-in./(N-m) when the clamp is tightened four revolutions of the screw nut. While in the free state, this value does not include any breakaway effects due to staking method or passage of the band ends beyond the screw heads.

3.2.4 *inserts*—a bushing or ring placed into the coupling socket to accommodate pipe materials of differing outside diameters.

3.2.5 *joint*—the completed assembly of parts consisting of the flexible transition coupling and the joined pipes or fittings, or both.

3.2.6 *lot*—a specific quantity of similar material or collection of similar units from a common source; the quantity offered for inspection and acceptance at any one time. A lot might comprise a shipment, batch, or similar quantity.

3.2.7 *mechanical couplings*—devices used to join between sections of plain end pipe or fittings of the same or different materials, of the same or different size, or any combination of materials and pipe sizes.

3.2.8 *plain-end pipe*—any pipe that does not include any bell, hub, threaded area, or other means of joining.

3.2.9 *shear ring*—an interior or exterior element which is used to span the distance between the pipe ends within a coupling so as to provide increased resistance to axial displacement.

4. Classification

4.1 The couplings shall have a center stop unless telescoping of the pipe is necessary for special applications. The components shall be designed so that the elastomeric material is compressed to form a hydrostatic seal when the joint is assembled. The couplings shall be of the types described in 4.1.1-4.1.3.

4.1.1 *Unshielded*—A coupling consisting of an elastomeric

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[1] This specification is under the jurisdiction of ASTM Committee C24 on Building Seals and Sealants and is the direct responsibility of Subcommittee C24.75 on Gaskets and Couplings for Plumbing and Sewer Piping.

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[2] *Annual Book of ASTM Standards*, Vol 01.03.

[3] *Annual Book of ASTM Standards*, Vol 04.07.

[4] *Annual Book of ASTM Standards*, Vol 09.01.

sleeve incorporating corrosion-resistant tension bands and a tightening mechanism. Couplings shall be fabricated without shear rings. Couplings installed without metallic shear rings shall not be installed in fire-resistive construction.

4.1.2 *Shielded*—A coupling consisting of an elastomeric or rubber sleeve incorporating a metallic corrosion-resistant shear ring and tension bands or tightening mechanism, or both.

4.1.3 *Other*—A coupling (gasket) fabricated for elastomeric compression seals.

5. Materials and Manufacture

5.1 Elastomeric materials used in the manufacturing of couplings and inserts shall comply with the requirements in accordance with Specification C 1440.

5.2 The stainless steel tension band assembly shall be 300 series stainless steel, excluding copper bearing alloys, meeting the requirements of the appropriate ASTM standard for stainless steel.

5.3 Couplings with bushings or inserts, or both, of multipiece construction or with splices shall show no separation, peeling, or other defects when tested in accordance with Section 9.

5.4 The coupling shall be free from porosity and air pockets. Its surface shall be smooth and free from pitting, cracks, blisters, air marks, or any other imperfections that affect its performance in service. The flash extension shall not exceed 1⁄32 in. (0.8 mm) at any point where the presence of flash affects performance.

6. Requirements

6.1 In horizontal installations, unshielded couplings shall be supported on both sides of the coupling with suitable hangers or support necessary to support the pipe and fittings joined. The support must be located within 18 in. (mm) of the center of the coupling.

6.2 Couplings shall not be installed in locations where the expected internal or external temperatures are below 0°F (–18°C) or exceed 130°F (54°C).

6.3 Unshielded couplings shall not be installed in construction that has a fire rating that restricts the use of flammable materials through penetrations or plenums without additional fire-resistive protection.

7. Dimensions, Mass, and Permissible Variations

7.1 Coupling and bushing dimensions shall be compatible with the dimensions and tolerances of the specific piping material which it is designed to join.

8. Sampling, Tests, and Retests

8.1 Test specimens representative of the couplings to be used shall be randomly selected from the manufactured lot for testing.

8.2 Not less than two couplings for each size or type shall be tested, unless otherwise specified or waived by the purchaser.

8.3 Where there is a failure in the original test, the entire test shall be rerun with twice the number of samples and any failure shall be cause for rejection.

9. Test Methods

9.1 *Elastomeric Materials*—Physical properties of gaskets shall be in accordance with specification ASTM C 1440. Many thermoplastic elastomeric gaskets are temperature-sensitive. Refer to Specification C 1440 for the allowable temperature range of materials.

9.2 *Tension Band Performance*:

9.2.1 *Torque Resistance*—Stainless steel tension bands shall be tested to withstand 150 % of the manufacturer's specified installation torque without visible signs of failure. The band shall be tested over a steel mandrel of the appropriate coupling diameter and torqued as required.

9.2.2 The maximum free running torque shall be 4 lbf-in. (0.45 N-m).

9.2.2.1 Stainless steel tension bands with torque resistance in excess of 100 lbf-in. shall have a maximum free running torque of 8 lbf-in.

9.2.3 *Test Procedure for Free Running Torque*:

9.2.3.1 With the nonstressed clamp hand-held and the slotted band fully engaged, the screw shall be rotated clockwise four revolutions with the maximum value of the torque meter recorded.

9.2.3.2 The equipment required shall be a hand-held torque meter with a 0 to 15-lbf-in. range.

9.3 *Joint Assemblies Test Methods*:

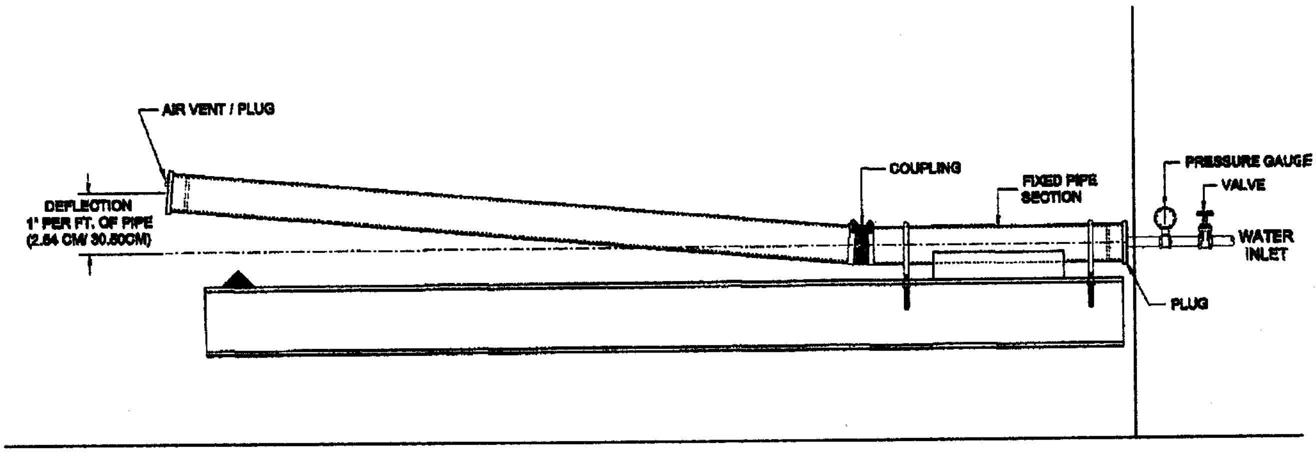
9.3.1 *Deflection Sealing Resistance Test*—The joint shall have sufficient flexibility to permit deflection in any direction as defined by Table 1 and shall show no visible leakage when so deflected while under an internal hydrostatic pressure of 4.3 psi (30 kPa). The ends of the test pipe shall be restrained only by an amount necessary to prevent longitudinal movement. The deflection shall be measured as the distance the free end of the one pipe has moved away from the center line of the fixed pipe. See Fig. 1.

9.3.2 *Shear Loading Resistance*—The joint shall have sufficient resistance to shear loading to meet the requirements of the following test. Two lengths of randomly selected pipe shall be joined by a coupling with the two joined lengths of pipe supported on blocks at three locations. One length of pipe shall be supported on two blocks, one near the unjoined end, and the other immediately adjacent to the joint. This length shall then be firmly restrained in position. The other length of pipe shall be supported by a single block located 36 in. (0.9 m) from the centerline of the joint. A load of 50 lbf-in. (220 N/25 mm) of nominal pipe diameter adjusted by the weight of pipe extending beyond the support times its moment arm divided by the moment arm to the test load, shall be uniformly applied over an arc of 120° and along a longitudinal length of 24 in. (0.6 m) immediately adjacent to the joint of the pipe having one support (see Fig. 2). While thus loaded, an internal hydrostatic pressure of 4.3 psi (30 KPa) shall be maintained for a period of 1 h with the temperature of water, pipe, and atmosphere within the range between 60°F and 75°F (15.5 and 23.8°C) and shall show no visible leakage.

9.4 *Unrestrained Hydrostatic Joint Test*:

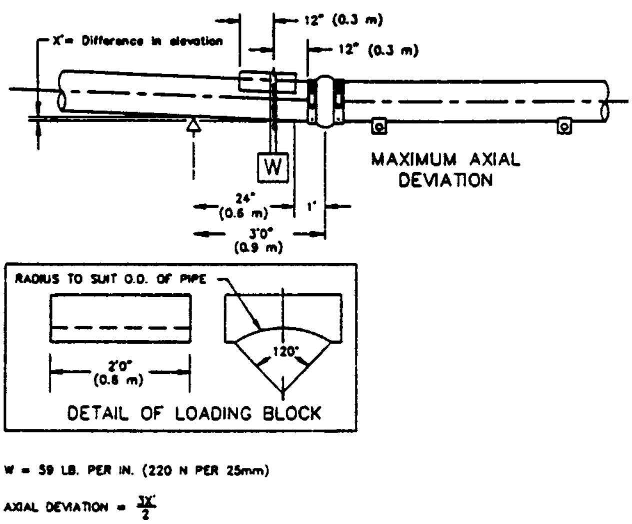
TABLE 1 Requirements - Deflection per Foot of Pipe Length

Nominal ID, in. (mm), incl.	Offset in./linear ft (mm/linear m)
1 ½-4	½ in.



NOTE 1—Deflection (in.(mm)) = L(ft(m)) × offset (in./linear ft (mm/linear m)). See Table 2.

FIG. 1 Deflection Test (Plan View)



NOTE 1—For maximum axial deviation values, see Table 3.

FIG. 2 Shear Test

9.4.1 Assemble each coupling tested according to the manufacturer's instruction between two sections of machined steel pipe and conduct the unrestrained hydrostatic joint test.

9.4.2 The assembly shall consist of a maximum outside diameter pipe connected to a minimum outside diameter pipe with diameters as referenced in the appropriate pipe standards and lengths as shown in Fig. 3. Machine the plain ends of the pipe to be used for the unrestrained hydrostatic joint test to the correct diameters. Plain ends shall have 0.015 in. (0.38 mm) deep grooves machined circumferentially around them at .125 in. (2 mm) intervals down the pipe section for a distance equal to that covered by the elastomeric sleeve of the coupling being tested. The tool used to machine the grooves shall have a 60° included angle and cut into the pipe from a perpendicular position. The surface between the grooves shall be a lathe turned surface finish of 125 RMS.

9.4.3 The plain ends of the pipe for the unrestrained hydrostatic joint test shall be uncoated, cleaned, and thoroughly dried before each assembly.

9.4.4 *Test Method*:

9.4.4.1 Support the pipe assemblies in a manner that does not restrain joint movement as shown in Fig. 3.

9.4.4.2 Fill the pipe assembly with water, expelling all air. Increase the hydrostatic pressure at a rate of 1 psi (6.9 kPa) every 30 s until the specified test pressure is reached. The specified test pressure shall be 20 psi (137.9 kPa) for 1 ½in. (38.1 mm) through 4 in. (100 mm), When the specified test pressure is reached, hold it for 10 min. Any leakage or axial joint movement of more than 0.150 in. (3.81 mm) shall mean failure.

10. Product Marking

10.1 Each coupling shall be permanently marked with the manufacturers name and country of origin. It shall have adequate marking of such manufacturer's name if the marking readily identifies the manufacturer to the end user of the product.

10.2 The type, class, and size of pipe for which the coupling is intended shall be marked on or attached to each coupling and shall be visible after installation.

10.3 All couplings shall be marked with the designation ASTM _____ showing compliance to this standard.

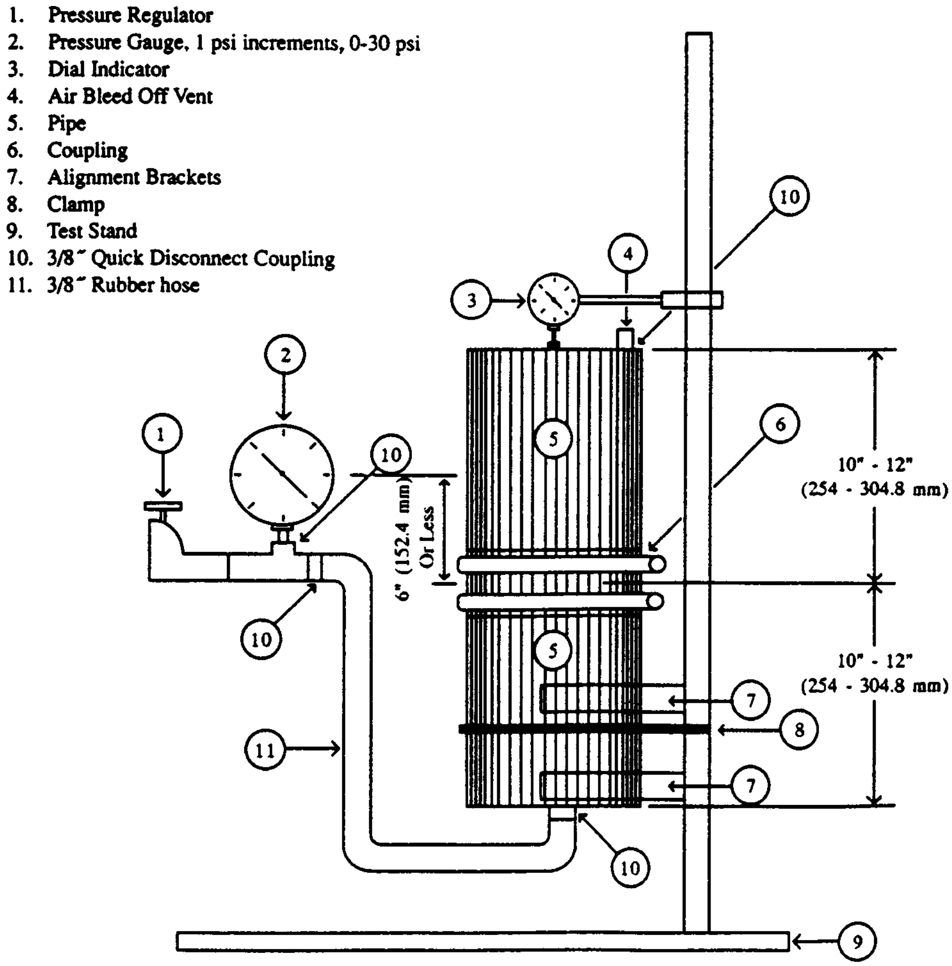


FIG. 3 Unrestrained Hydrostatic Joint Test

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.

Designation: C 1540 – 02

Standard Specification for Heavy Duty Shielded Couplings Joining Hubless Cast Iron Soil Pipe and Fittings[1]

This standard is issued under the fixed designation C 1540; 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 evaluating of the performance of heavy duty shielded couplings to join hubless cast iron soil pipe and fittings.

1.2 Couplings covered by this standard shall have minimum dimensions as found in Table 1 and Fig. 1 of this standard.

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

1.4 The committee with jurisdiction over this standard is aware of comparable standards published by other organizations, namely Cast Iron Soil Pipe Institute specification CISPI 310 and Factory Mutual Research standard FM 1680.

1.5 The following precautionary caveat pertains only to the test method portion, Section 7, 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 240 Specification for Stainless and Heat-Resisting Chromium-Nickel Steel Plate, Sheet, and Strip[2]

A 493 Specification for Stainless Wire and Wire Rods for Cold Heating and Cold Forging[2]

A 888 Specification for Hubless Cast Iron Soil Pipe and Fittings for Sanitary, Storm and Drain, Waste, and Vent Piping Applications[2]

C 564 Specification for Rubber Gaskets for Cast Iron Soil Pipe and Fittings[2]

C 717 Terminology of Building Seals and Sealants[2]

2.2 *CISPI Standards:*

CISPI-301 Specification for Hubless Cast Iron Soil Pipe and Fittings for Sanitary and Storm Drain, Waste and Vent Piping Applications

CISPI-310 Specification for coupling for use in Connection with Hubless Cast Iron Soil Pipe and Fittings for Sanitary and Storm Drain, Waste and Vent Piping Applications

FM 1680 Approval Standard Couplings used in Hubless Cast Iron Systems for Drain, Waste or Vent Systems above or below ground Industrial, Commercial, and Residential

TABLE 1

Nominal Pipe Size	Coupling Width
1½ to 4 in. (38 to 100 mm)	3 in. (76 mm) Minimum Width
5 to 10 in. (127 to 254 mm)	4 in. (100 mm) Minimum Width
12 to 15 in. (305 to 381 mm)	5½ in. (140 mm) Minimum Width

3. Terminology

3.1 *Definitions:*

3.1.1 Definitions of the following terms used in this specification are found in Terminology C 717.

3.2 *Definitions of Terms Specific to This Standard:*

3.2.1 *center stop*, *n*—an integral part of the gasket centered on the axial length of the gasket intended to limit the insertion depth of the pipe to be coupled.

3.2.2 *clamp assembly*, *n*—that portion of the coupling excluding the gasket.

3.2.3 *coupling*, *n*—the complete assembly.

3.2.4 *fitting*, *n*—parts of a pipeline other than straight pipes, valves, or couplings.

3.2.5 *gasket*, *n*—the elastomeric portion of the coupling.

3.2.6 *heavy duty coupling*, *n*—a shielded coupling that has dimensions not less than those detailed in Table 1 and Fig. 1.

3.2.7 *joint*, *n*—the point of assembly consisting of the coupling and the joined pipes or fittings, or both.

3.2.8 *shield*, *n*—an external metallic protective device designed to protect the sealing gasket from external elements that could cause failure of the sealing assembly.

4. Materials and Manufacture

4.1 Physical properties of gaskets shall comply with Specification C 564 using the applicable durometer hardness requirement of the column of Table 2 of that document as specified by the manufacturer.

4.2 Clamp assembly screws or bolts shall not have screwdriver slots.

4.3 All stainless steel shall meet the physical requirements of Specification A 240.

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[1] This specification is under the jurisdiction of ASTM Committee C24 on Building Seals and Sealants and is the direct responsibility of Subcommittee C24.75 on Gaskets and Couplings for Plumbing and Sewer Piping.

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[2] *Annual Book of ASTM Standards*, Vol

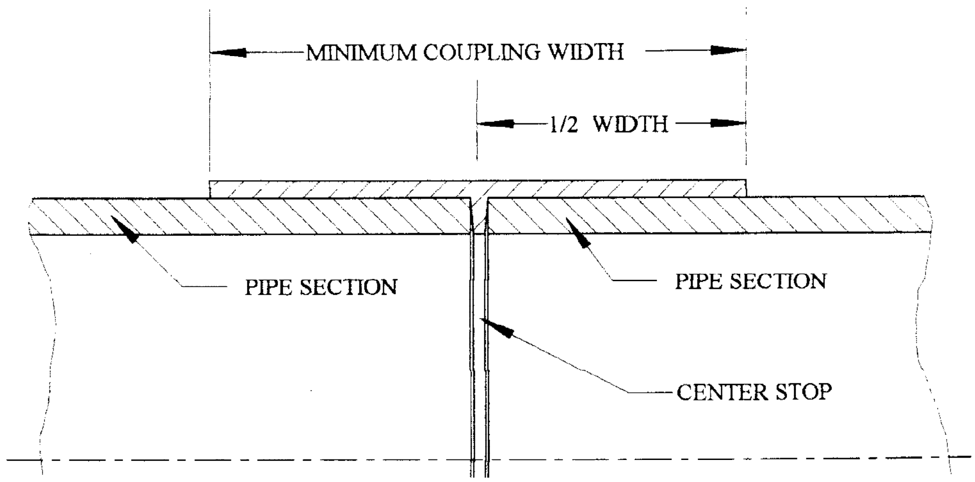

FIG. 1 Typical Center Stop Detail

TABLE 2 Dimensions and Tolerances for Hubless Pipe and Fittings

Size, in. (mm)	Outside Diameter, in. (mm)
1½ (38)	1.90 ± 0.06 (48.26 ± 1.52)
2 (51)	2.35 ± 0.09 (59.69 ± 2.29)
3 (76)	3.35 ± 0.09 (85.09 ± 2.29)
4 (102)	4.38+0.09-0.05 (111.25+2.29/-1.27)
5 (127)	5.30+0.09-0.05 (134.63+2.29/-1.27)
6 (152)	6.30+0.09-0.05 (160.02+2.29/-1.27)
8 (203)	8.38+0.13-0.09 (212.85+3.30/-2.29)
10 (254)	10.56 ± 0.09 (268.22 ± 2.29)
12 (305)	12.50 ± 0.09 (317.5 ± 2.29)
15 (381)	15.83 ± 0.09 (402.08 ± 2.29)

5. Elastomeric Gasket Requirements

5.1 The elastomeric gasket shall consist of one piece polychloroprene construction conforming to the physical requirements of Specification C 564.

5.1.1 The elastomeric gasket shall have an inside center stop that does not create an enlargement chamber or recess with a ledge, shoulder, or reduction of pipe area or offer an obstruction to flow.

5.1.2 The elastomeric gasket shall be free of defects that affect the use and serviceability.

6. Clamp Assembly Requirements

6.1 The clamp assembly shall be made of material conforming to the requirements as outlined in Sections 4 and 6.

6.1.1 All metallic parts shall be of 300 series stainless steel and shall conform to the requirements of Specification A 240. All metallic parts made from round stock shall be of 300 series stainless steel and shall conform to the requirements of Specification A 493 (excluding copper bearing alloys).

6.1.2 Clamp assemblies shall be tested to withstand no less than 125 % of the manufacturers stated installation torque without visible signs of failure. The clamp assembly shall be tested over a steel mandrel of the appropriate diameter and torqued as required.

7. Couplings Requirements and Test Methods

7.1 Assemble each coupling to be tested according to the manufacturer's instructions between two sections of randomly selected hubless cast iron soil pipe meeting the requirements of CISPI 301 or Specification A 888 and conduct deflection and shear tests. In addition, unrestrained hydrostatic tests shall be performed as detailed in 7.2.

7.1.1 *Deflection Test*:

7.1.1.1 A test apparatus such as the one shown in Fig. 2 is suggested. Other testing apparatus that provide restraint to the assembly shall also be permitted. Close the outboard ends of the pipe with test plugs.

7.1.1.2 Fill the assembly with water, expel all air, and hydrostatically pressurize to 8.6 psi (59.3 kPa) for the duration

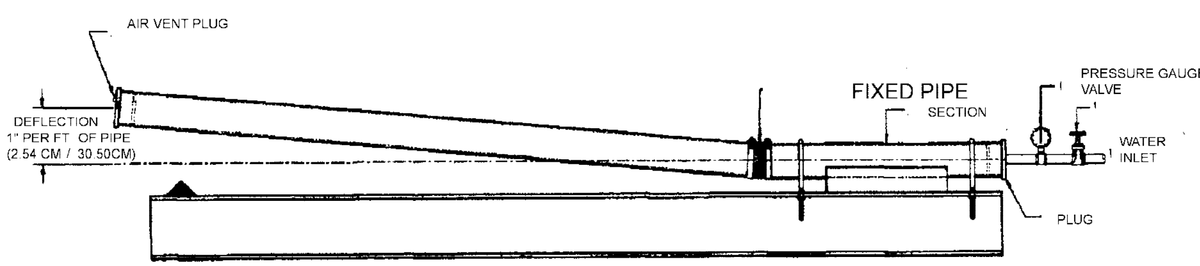

FIG. 2 Deflection Test

of the test. One pipe shall be rigidly supported and while the assembly is under pressure, raise the opposite end of the other pipe 1 in. (25 mm) per lineal foot of pipe. Maintain the pressure for 15 min. Any leakage shall mean failure.

7.1.2 *Shear Test*:

7.1.2.1 Support two joined lengths of randomly selected hubless cast iron soil pipe on blocks, a minimum of 1½ in. (38.1 mm) high, at three locations. One length shall be a minimum of 24 in. (609.6 mm) in length, supported on blocks, one near the uncoupled end, and the other immediately adjacent to the couplings. Firmly restrain this length in position as shown in Fig. 3. The other coupled length shall be a minimum of 5 ft (1.52 m) in length and supported by a single block 6 in. (152.4 mm) from the end of the pipe.

7.1.2.2 Fill the assembly with water and expel all air. Apply a load of 50 lb per in. (22.7 kg) of nominal diameter at a point 6 in. (152.4 mm) from the edge of the coupling upon a 12 in. (304.8 mm) length of 3 by 3 in. (76.2 by 76.2 mm) angle iron or load distribution pad located on the top of the pipe immediately adjacent to the coupling of the pipe having one support only. Under this loading there shall be no visible leakage or displacement of more than ⅜ in. (9.53 mm) from true alignment adjacent to the coupling, when an internal pressure equivalent to a 20 ft (6.10 m) head of water 8.6 psi (59.3 kPa) is applied. Maintain the load and internal pressure for 15 min.

7.2 *Unrestrained Hydrostatic Joint Test*:

7.2.1 Assemble each coupling to be tested according to the manufacturer's instruction between two sections of machined steel pipe and conduct the unrestrained hydrostatic joint test.

7.2.2 The assembly shall consist of a maximum outside diameter pipe connected to a minimum outside diameter pipe with diameters as referenced in Table 2 and lengths as shown in Fig. 4. Machine the plain ends of the pipe to be used for the thrust test to the correct diameters. Plain ends shall have 0.015 in. (0.38 mm) deep grooves machined circumferentially around them at ⅛ in. (3.18 mm) intervals down the pipe section for a distance equal to that covered by the elastomeric sleeve of the coupling being tested. The tool used to machine the grooves shall have a 60° included angle and cut into the pipe from a perpendicular position. The surface between the grooves shall be a lathe turned surface of 125 RMS.

7.2.3 The plain ends of the pipe for the thrust test shall be uncoated and cleaned with acetone and thoroughly dried before each assembly.

7.2.4 *Test Method*:

7.2.4.1 Support the pipe assemblies in a manner that does not restrain joint movement as shown in Fig. 4.

7.2.4.2 Fill the pipe assembly (as required in 7.2) with water, expelling all air. Increase the hydrostatic pressure at a rate of 1 psi (6.9 kPa) every 30 s until the specified test pressure is reached. The specified test pressure shall be 30 psi (206.8 kPa) for 1½ in. (38.1 mm) through 5 in. (127 mm), 27 psi (186 kPa) for 6 in. (152.4 mm), 15 psi (103.4 kPa) for 8 in. (203.2 mm), 9 psi (62 kPa) for 10 in. (254 mm), and 6 psi (31.3 kPa) for 12 and 15 in. pipe. When the specified test pressure is reached, hold it for 15 min. Any leakage or axial joint movement of more than 0.150 in. (3.81 mm) shall mean failure.

8. Markings and Identification

8.1 Permanently mark each clamp assembly with the manufacturer's name or U.S. registered trademark, country of origin, all stainless and the pipe size for which it is designed. Marking shall be visible after installation.

8.2 Gasket markings shall conform to Specification C 564.

8.3 The product shall also have any other markings required by law and shall have the option to include this designation (Specification C 1540).

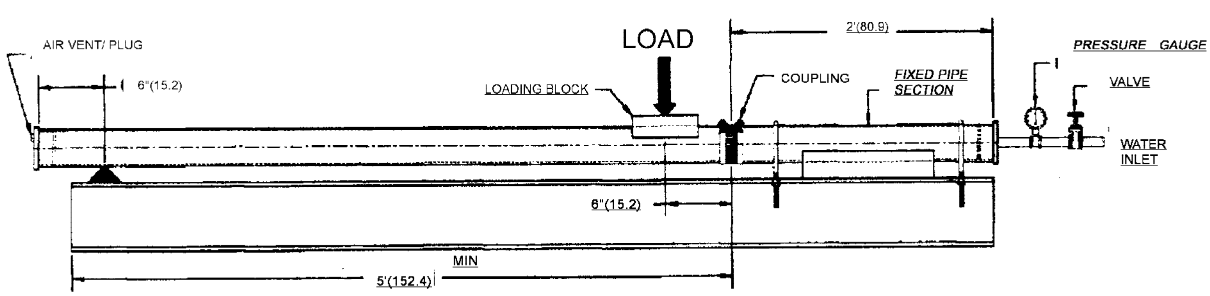

FIG. 3 Shear Test

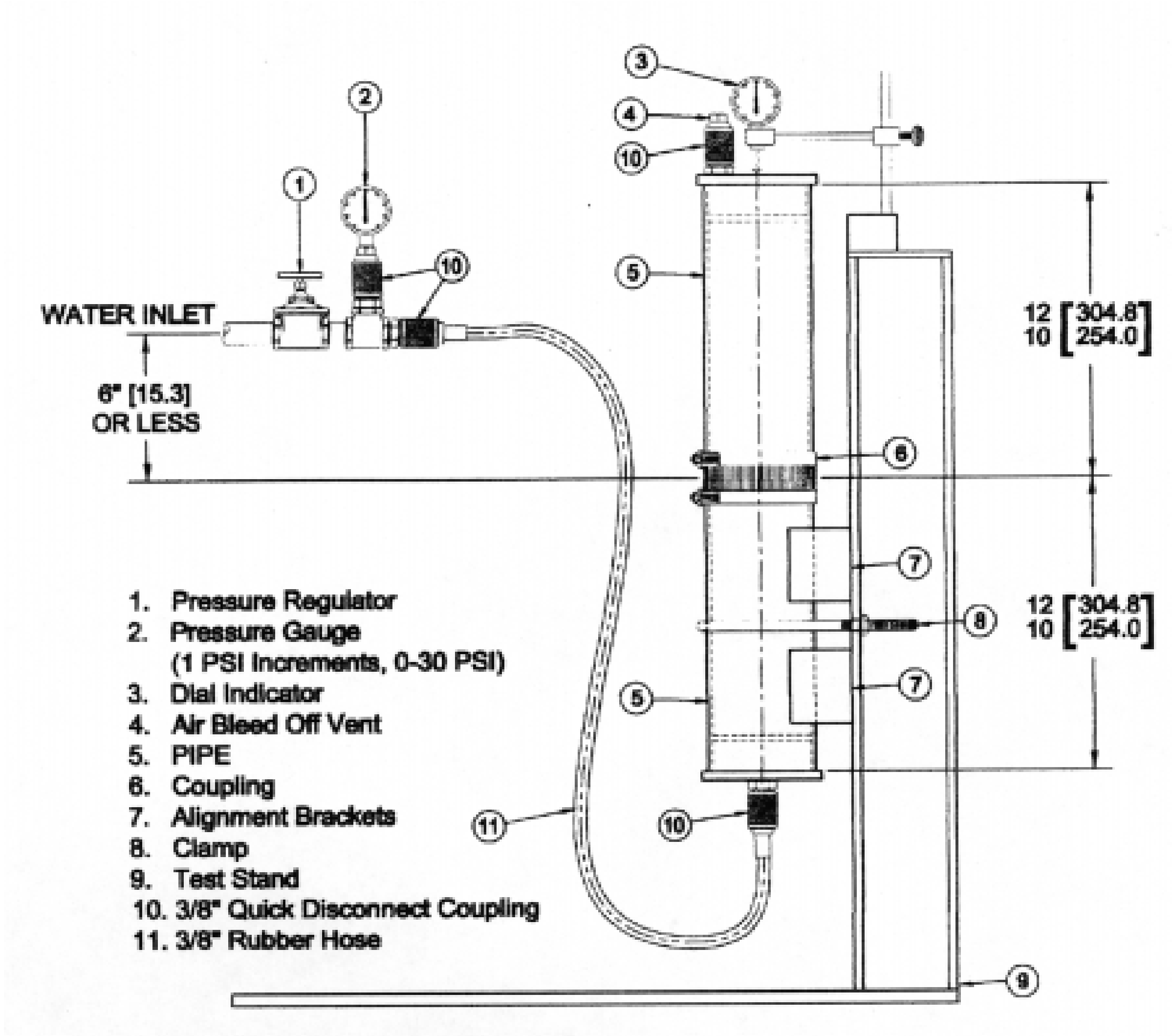

FIG. 4 Unrestrained Hydrostatic Joint Testing Apparatus

Designation: C 1541 – 04

Standard Specification for Shielded Transition Couplings Using Flexible Poly Vinyl Chloride (PVC) Gaskets to Connect Dissimilar DWV Pipe and Fittings[1]

This standard is issued under the fixed designation C 1541; 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 performance of shielded transition couplings using flexible PVC gaskets to join dissimilar DWV pipe and fittings above and below ground up to and including 10-in. pipe and fittings.

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.

1.3 The committee with jurisdiction over this standard is not aware of any comparable standards of any other organization.

1.4 The following precaution pertains only to the test method portion, Sections 7 and 8 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 requirements prior to use.*

2. Referenced Documents

2.1 *ASTM Standards:* [2]

A 493 Specification for Stainless Steel Wire and Wire Rods for Cold Heading and Cold Forging

C 717 Terminology of Building Seals and Sealants

D 5926 Specification for Poly Vinyl Chloride (PVC) Gaskets for Drain Waste and Vent (DWV), Sewer, Sanitary, and Storm Plumbing Systems

3. Terminology

3.1 *Definitions:*

3.1.1 Definitions of the following terms used in this specification are found in Terminology C 717.

3.2 *Definitions of Terms Specific to This Standard:*

3.2.1 *center stop*, *n*—an integral part of the gasket centered on the axial length of the gasket intended to limit the insertion depth of the pipe to be coupled.

3.2.2 *clamp assembly*, *n*—that portion of the coupling excluding the gasket.

3.2.3 *coupling*, *n*—the complete assembly.

3.2.4 *dissimilar DWV pipe and fittings*, *n*—pipe and fittings made of different materials or different outside diameters, or both.

3.2.5 *fitting*, *n*—parts of a pipeline other than straight pipes, valves, or couplings.

3.2.6 *gasket*, *n*—the elastomeric portion of the coupling.

3.2.7 *joint*, *n*—the point of assembly consisting of the coupling and the joined pipes or fittings, or both.

3.2.8 *shield*, *n*—an external metallic protective device designed to protect the sealing gasket from external elements that could cause failure of the sealing assembly.

TABLE 1 Unrestrained Hydrostatic Joint Test

Pipe Size	Test Pressure
1½ to 5 in. [38 to 76 mm]	20 psi [138 kPa]
6 in. [152.4 mm]	18 psi [124 kPa]
8 in. [203.2 mm]	10 psi [69 kPa]
10 in. [254 mm]	6 psi [41.4 kPa]

4. Materials and Manufacture

4.1 Physical properties of Flexible PVC (Poly Vinyl Chloride) gaskets shall comply with Specification D 5926. The gaskets shall be permitted to be spliced or molded.

4.2 All steel parts shall be 300 series stainless steel meeting the requirements of Specification A 493 excluding copper bearing alloys.

5. Requirements

5.1 Couplings shall be supported with suitable hangers or support necessary to support the pipe, fitting, and contents. The support must be located within 18 in. of the center of the coupling.

5.2 The coupling shall not be installed in a location where the expected internal or external temperatures are below -30°F [-34°C] or exceed 130°F [54°C].

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[1] This specification is under the jurisdiction of ASTM Committee C24 on Building Seals and Sealants and is the direct responsibility of Subcommittee C24.75 on Gaskets and Couplings for Plumbing and Sewer Piping.

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[2] 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.

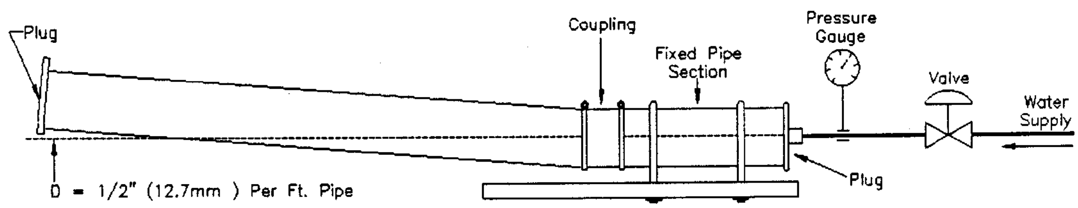


FIG. 1 Deflection Test

5.3 Couplings shall not be installed in construction that has a fire rating that restricts the use of flammable materials through penetrations or plenums without additional fire-resistive protection.

6. Elastomeric Gasket Requirements

6.1 The elastomeric gasket shall consist of one piece conforming to the physical requirements of 4.1.

6.2 The elastomeric gasket shall have an inside center stop-ring spaced an equal distance from the ends to serve as a stop between the pipe/fitting ends. The center stop ring shall not create an enlargement chamber or recess with a ledge, shoulder or reduction of pipe area or offer an obstruction to flow. A gasket without an inside center stop shall be permitted in tubular transition applications.

6.3 The elastomeric gasket shall be free from imperfections and porosity that affects its use and serviceability.

7. Clamp Assembly Requirements

7.1 Stainless steel tension bands shall be tested to withstand 125 % of the manufacturer's installation torque or a minimum of 60 in.-lbf of applied torque whichever is greater without visible signs of failure. The band shall be tested over a steel mandrel of the appropriate coupling diameter and torque as required.

7.2 Clamp assembly screws or bolts shall not have screw-driver slots.

8. Coupling Requirements and Test Methods

8.1 Assemble each coupling tested in accordance with the manufacturer's instructions between two sections of randomly selected pipe manufactured to appropriate standards for the type of pipe the couplings are expected to join. The pipe section will not exceed a length of 20 ft [6.1 m]. Conduct the following tests:

8.2 *Deflection Test*—Each coupling tested shall be mounted between two pieces of pipe as provided in 8.1. The out bound ends of the pipe shall be closed with test plugs. The assembly shall be filled with water, all air expelled, and hydrostatically pressurized to 4.3 psi [29.6 kPa] for the duration of the test. One pipe shall be rigidly supported and while the assembly is under pressure, the opposite end of the other pipe shall be raised ½ in. [12.7 mm] per linear foot of pipe. The pressure shall be maintained for 15 min and leakage shall not be permitted. A test apparatus such as the one shown in Fig. 1 is suggested.

8.3 *Shear Test*—The assembly shall be filled with water, all air expelled, and hydrostatically pressurized to 4.3 psi [29.6 kPa] for the duration of the test. Two joined lengths of pipe selected as provided in 8.1 shall be supported on blocks at three locations. One length shall be supported on two blocks, one near the uncoupled end and the other immediately adjacent to the coupling. This length shall be firmly restrained in position (refer to Fig. 2). The other coupled length shall be supported by a single block 6 in. from [152.4 mm] the end of the pipe. A load of 50 lb [22.7 kg] per inch of nominal diameter shall be applied at a point 6 in. [152.4 mm] from the edge of the coupling upon a 12 in. [304.8 mm] length of 3 by 3 [76.2 by 76.2 mm] angle iron or load distributing pad located on the top of the pipe immediately adjacent to the coupling of the pipe having one support only. When testing reducing couplings the load shall be applied to the reduced size. Under this loading there shall be no visible leakage or displacement of more than ⅜ in. [9.5 mm] from true alignment when an internal pressure equivalent to a

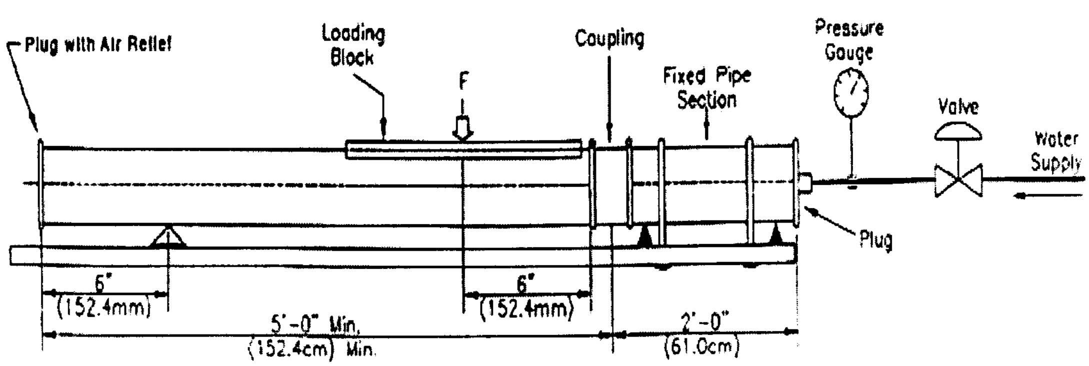


FIG. 2 Shear Testing Apparatus

10 ft [3 m] head of water 4.3 psi [29.6 kPa] is applied. The load and internal pressure shall be maintained for 15 min and leakage shall not be permitted.

8.4 *Unrestrained Hydrostatic Joint Test*:

8.4.1 Each coupling tested shall be assembled in accordance with the manufacturer's instructions between two sections of machined steel pipe and conduct the unrestrained hydrostatic joint test.

8.4.2 The plain ends of the pipe to be used shall be machined to the correct nominal outside diameter of the types of pipe for which the coupling is intended to join. Plain ends shall have 0.015 in. [2 mm] deep grooves machined circumferentially around them at 0.125 in. [3.2 mm] intervals down the pipe section for a distance equal to that covered by the elastomeric sleeve. The tool used to machine the grooves shall have a 60° included angle and shall cut into the pipe from a perpendicular position. The surface between the grooves shall be a lathe turned surface of 125 RMS. The plain ends of the pipe are to be uncoated and shall be cleaned with acetone and thoroughly dried before each assembly.

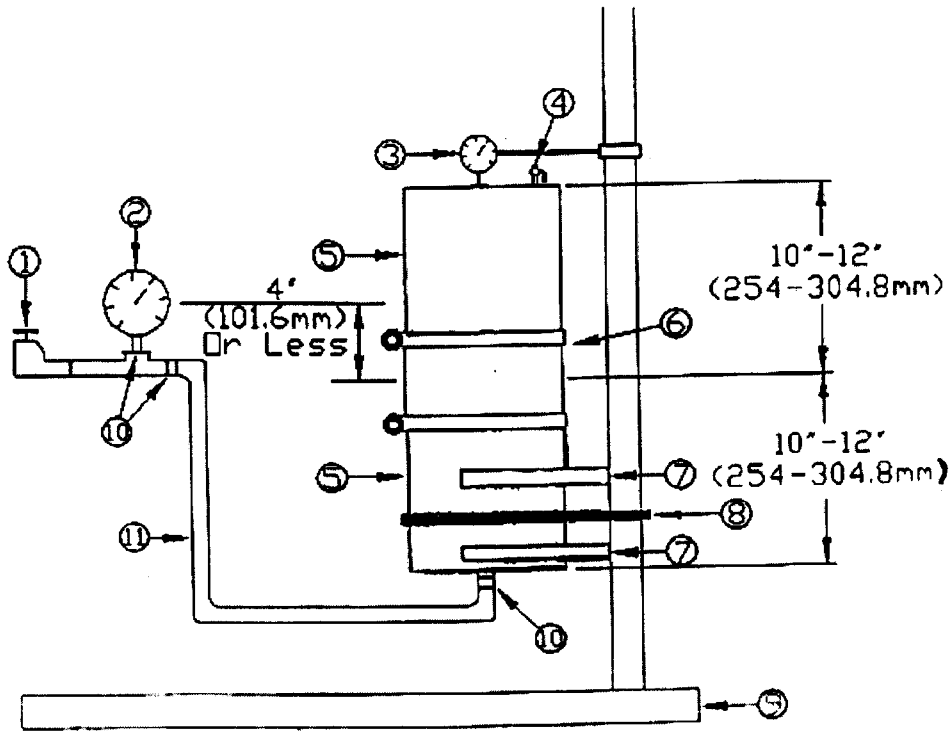
8.4.3 Fill the pipe assembly with water, expelling all air and increase the hydrostatic pressure at a rate of 1 psi [6.9 kPa] every 30 s to the target test pressure shown in Table 1. When the target pressure is reached, it shall be held for 10 min. Any leakage or axial joint movement of more than 0.150 in. [3.8 mm] shall mean failure.

8.4.4 The pipe assemblies are to be supported in a manner that does not restrain joint movement as shown in Fig. 3.

9. Markings and Identification

9.1 Each gasket shall be permanently marked with the manufacturer's name or US registered trademark, country of origin, pipe size for which it is designed, and the designation Specification D 5926.

9.2 Each coupling shall be labeled as to the size(s), material(s), class for which it is intended, operating temperature range, and the designation ASTM showing compliance to this standard. The marking shall be visible after installation.



1. Pressure Regulator
2. Pressure Gauge, 1-PSI increments, 0-30 PSI
3. Dial indicator
4. Air Bleed Off Vent
5. Pipe
6. Coupling
7. Alignment Brackets
8. Clamp
9. Test Stand
10. 3/8" Quick Disconnect Coupling
11. 3/8" Rubber Hose

FIG. 3 Unrestrained Hydrostatic Joint Testing Apparatus