

SSPC-PA 2

Procedure for Determining Conformance to Dry Coating Thickness Requirements

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Dry Film Thickness Measurement**



SSPC-PA 2

Procedure for Determining Conformance to Dry Coating Thickness Requirements

- Webinar Content

- Background of SSPC PA 2
- Overview and Purpose of SSPC-PA 2 (2012)
- Purpose of ASTM D 7091-12
- Definitions
- Gage Descriptions
- Calibration, Verification of Accuracy & Adjustment
- Measurement Procedures
- Frequency and Number of Measurements
- Conformance to Specified Thickness
- Content of Eight Appendices

Learning Objectives/Outcomes

- Completion of this webinar will enable the participant to:
 - Describe the purpose and content of SSPC-PA 2
 - Describe the differences between Type 1 and Type 2 gages
 - Describe the processes associated with calibration, verification of accuracy and adjustment
 - Explain Base Metal Reading acquisition
 - Describe the frequency and tolerance of measurements
 - Describe the procedure for determining the magnitude of a non-conforming area
 - Describe the basic content of eight appendices to the standard

Background of SSPC-PA 2

- Originally published in SSPC Volume 2 in 1973(T)
- Most recent update was 2004
- Editorial revision to an Appendix in 2009
- SSPC committee work on revisions initiated in 2007
- Current version dated May 1, 2012
- Standard re-balloted in August/September 2013



SSPC-PA 2-73T
September 1, 1973

SSPC METHOD

for

MEASUREMENT OF DRY PAINT THICKNESS WITH MAGNETIC GAGES

SSPC-PA 2-73T

1. SCOPE

This method describes the procedures and precautions required to measure the thickness of a dry film of a nonmagnetic coating applied on a magnetic base, using commercially available magnetic gages. These procedures are intended to supplement manufacturers' instructions for the manual operation of the gages. Magnetic gages of two types may be used:

Type 1 — Pull-Off Gages (such as Mikrotest, Inspector, and Tinsley Thickness Gages, and the Elcometer Pull-Off Gage)

Type 2 — Fixed Probe Gages (Such as Elcometer Thickness Gage, Mintitector, and the General Electric Type B Thickness Gage)

2. MEASUREMENT PROCEDURES

2.1 Access to Bare Substrate

To determine the effect of the substrate surface condition on the gage readings, access is required to some unpainted areas. Small representative areas may be masked-off during the painting. If the paint has already been applied to the entire surface, small areas of paint may be removed and later patched. An alternate procedure that may be specified is to provide separate unpainted reference panels of similar steel and surface condition representative of the substrates, to be measured with the same gages and at the same time as the painted surface, as in Section 2.3 and 2.4.

2.2 Repetition of Gage Readings: Spot Measurements.

Carefully note Appendices A.4, A.6, A.7, A.8, and A.9 before making any measurements.

Repeated gage readings, even at points close together, may differ considerably due to small surface irregularities. Three gage readings should therefore be made for each spot measurement of either the substrate or the paint. Move the probe a short distance for each new gage reading. Discard any unusually high or low gage reading that cannot be repeated consistently. Take

the average of the three gage readings as the spot measurement.

2.3 Measurement with Type 1 (Pull-Off) Gage

2.3.1 Measure (A), the bare substrate, at a number of spots to obtain a representative average value.

2.3.2 Measure (B), the dry paint film, at the specified number of spots. (See Section 3 for number.)

2.3.3 Correct the (A) and (B) gage readings or averages as determined by calibration of the gage, Section 4.1.

2.3.4 Subtract the corrected readings (A) from (B) to obtain the thickness of the paint above the original surface. On blast cleaned steel this would be above the peaks of the surface profile.

2.4 Measurement with Type 2 (Fixed Probe) Gage

2.4.1 Gage Adjustment or Setting

Place a standard shim of the expected paint thickness on the bare substrate that is to be painted. Adjust the gage in place on the shim so that it indicates the known thickness of the shim.

IMPORTANT — Confirm the gage setting by measuring the shim at several other areas of the bare substrate. Readjust the gage as needed to obtain an average setting representative of the substrate.

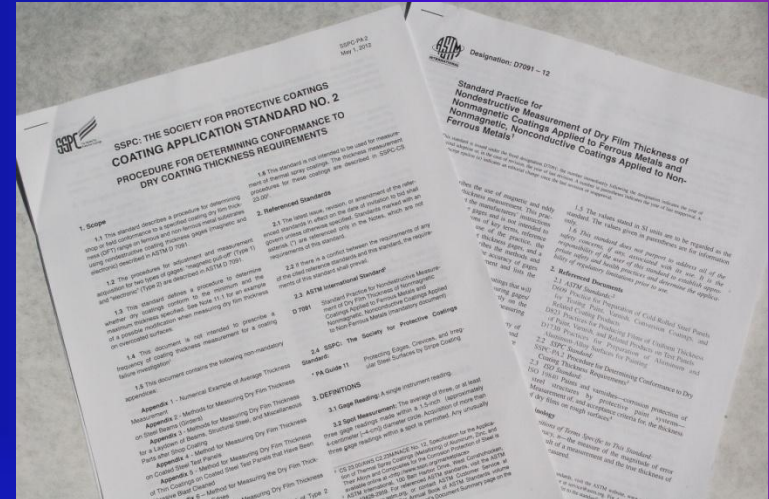
2.4.2 Spot Measurement of Paint

With the gage adjusted as above, measure the dry paint film at three points. The gage readings indicate the paint thickness above the surface on which the gage was "set". On blast cleaned steel, it is the paint thickness above the peaks of the surface profile.

Re-check the gage setting at frequent intervals during a long series of measurements.

Background of SSPC-PA 2

- Update to ASTM D 7091-05 concurrent with revisions to SSPC-PA 2
- ASTM D7091-12 focuses on gage use
- SSPC-PA 2 (2012) focuses on acceptability of acquired measurements
- Both address ferrous and non-ferrous metal surfaces



Scope of SSPC-PA 2

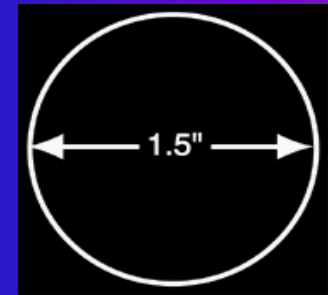
- Describes a procedure for determining shop/field conformance to a specified DFT range on ferrous and non-ferrous metals
- Measurements are acquired using commercially available gages (two “types”)
- Procedures for gage calibration, verification of accuracy and adjustment are described
- Procedure for determining conformance to specified thickness range over extended areas is described

Scope of SSPC-PA 2

- Standard contains 8 non-mandatory appendices (described later)
- 9th appendix was recently balloted (precautions regarding the use of the standard for coating failure investigations)
- Standard is not intended to be used for measurement of thermal spray coatings (procedure described in SSPC-CS 23.00)

Definitions in SSPC-PA 2

- **Gage Reading:** A single instrument reading
- **Spot Measurement:** The average of three or at least three gage readings made within a 1 1/2" (4 cm) diameter circle



- **Area Measurement:** The average of five spot measurements over each 100 square feet of coated surface

Gage Descriptions

- Gage type is determined by magnetic properties employed to measure thickness (not the read-out mode)
 - Type 1 – Magnetic Pull-off Gages
 - Type 2 – Electronic Gages

Gage Types

Type 1 – Magnetic Pull-off Gages



Type 2 – Electronic Gages



Gage Types, continued

- Type 1 – Magnetic Pull-off Gages
 - Permanent magnet contacts coated surface
 - Force required to detach magnet is measured
 - Force interpreted as the coating thickness on scale or display
 - Scale is nonlinear



Gage Types, continued

- Type 2 – Electronic Gages
 - Electronic circuitry converts reference signal to coating thickness



Calibration & Verification of Accuracy

- ASTM D7091 describes 3 operational steps to ensure accurate measurement:
 - Calibration
 - Verification of Accuracy
 - Adjustment
- Steps are required to be completed before coating thickness data acquisition to determine conformance to a specification

Gage Calibration

- Performed by the gage manufacturer or an accredited calibration laboratory
- Test certificate traceable to a National Metrology institution required
- No standard calibration interval (established based on experience & work environment)
- One year interval is common

Verification of Type 1 Gage Accuracy

- Performed as described in ASTM D7091
 - Beginning and end of each work shift (minimum)
 - During (e.g., hourly), if:
 - Obtaining a large no. of readings
 - Gage is dropped or readings are suspect
- Record:
 - Serial no. of gage & standard
 - Stated & measured thickness
 - Method used to verify accuracy

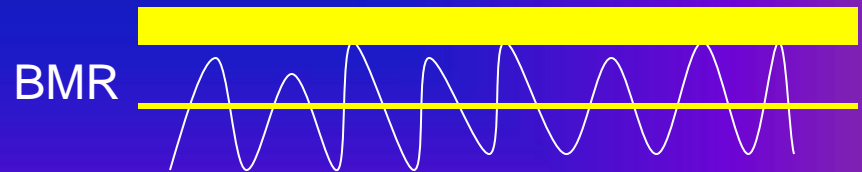


Verification of Type 1 Gage Accuracy

- Type 1 gages should not be “adjusted”
- Adjustments to the helical spring may void the gage warranty
- Combined tolerance of gage and coated standard determines gage accuracy
 - E.g., if gage accuracy is 5% and reference standard accuracy is 3%, combined tolerance is ~ 6%, calculated as: $\sqrt{5^2 + 3^2}$
 - On a 10 mil reference standard, the gage reading can range from 9.4-10.6 mils

Correction for Surface Roughness

- Base Metal Reading (BMR)
- Effect of surface roughness on coating thickness gage
- NOT surface profile
- Measure the prepared, uncoated substrate; calculate average BMR
- Deduct BMR from measured coating thickness



Correction for Surface Roughness

| Area | BMR |
|------|-----------------------------|
| 1 | 30 μm (1.2 mils) |
| 2 | 25 μm (1.0 mils) |
| 3 | 18 μm (0.7 mil) |
| 4 | 13 μm (0.5 mil) |
| 5 | 20 μm (0.8 mil) |
| 6 | 8 μm (0.3 mil) |
| 7 | 25 μm (1.0 mil) |
| 8 | 28 μm (1.1 mils) |
| 9 | 23 μm (0.9 mil) |
| 10 | 13 μm (0.5 mil) |



Measuring Base Metal Effect with Type 1 DFT Gage

Average BMR: 21 μm (0.8 mil)

BMR Correction for Multiple Coat Systems

| | |
|-------------------------------------|------------------------------|
| Measured Primer Thickness: | 102 μm (4.0 mils) |
| BMR: | 13 μm (0.5 mils) |
| Actual Primer Thickness: | 89 μm (3.5 mils) |
| Measured Primer + Finish Thickness: | 178 μm (7.0 mils) |
| BMR: | 13 μm (0.5 mils) |
| Actual Total System Thickness: | 165 μm (6.5 mils) |

Correction for Surface Roughness

- What if access to blast cleaned steel is not available (already coated)?
- Appendix A8.3 addresses smooth surface adjustment
 - Verify gage accuracy on a smooth surface (per gage manufacturer instructions)
 - Deduct “assumed” approximate correction value from each gage reading

Correction for Surface Roughness

Table A8

Typical Gage Correction Values Using ISO 8503 Profile Grades

| ISO 8503 Profile Grade | Correction Value (μm) | Correction value (mils) |
|-------------------------------|------------------------------|--------------------------------|
| Fine | 10 | 0.4 |
| Medium | 25 | 1.0 |
| Coarse | 40 | 1.6 |

Verification of Type 2 Gage Accuracy

- Verify accuracy per manufacturer instructions (use coated standards)
- Performed as described in ASTM D7091
 - Beginning and end of each work shift (minimum)
 - During (e.g., hourly), if:
 - Obtaining a large no. of readings
 - Gage is dropped or readings are suspect
- Record:
 - Serial no. of gage & standard
 - Stated & measured thickness



Verification of Type 2 Gage Accuracy

- Single Point Verification

- Select one reference coated standard representing the mid-range of the anticipated coating thickness
- E.g., 4-6 mils (100-150 μm), select 5 mil (125 μm) reference standard

- Two Point Verification

- Select reference coated standards below and above the median anticipated coating thickness
- E.g., 5 mils (125 μm), select 3 mil (75 μm) and 7 mil (175 μm) coated standards

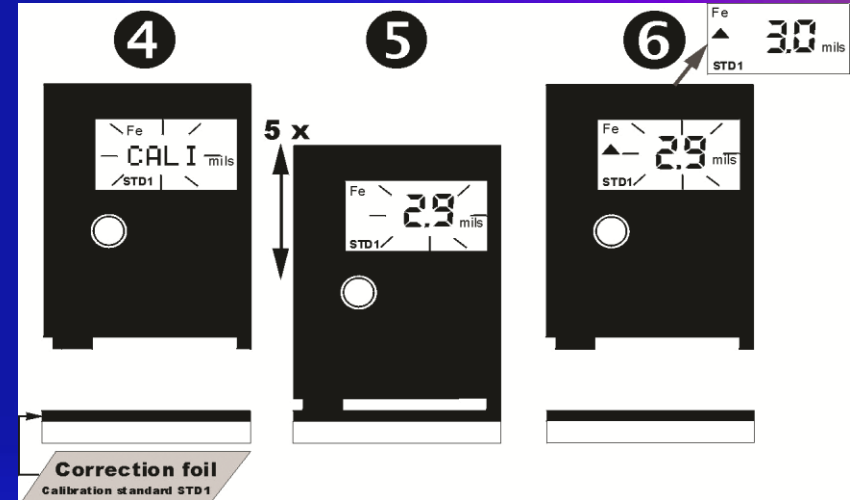
Adjustment of Type 2 Gages

- Aligning a gage's thickness readings to those of a known thickness value to improve gage accuracy on a specific surface or within a measuring range
- Corrects for:
 - Surface Roughness
 - Substrate Properties (metallurgy)
 - Curvature
 - Etc.
- Use Certified or Measured shims

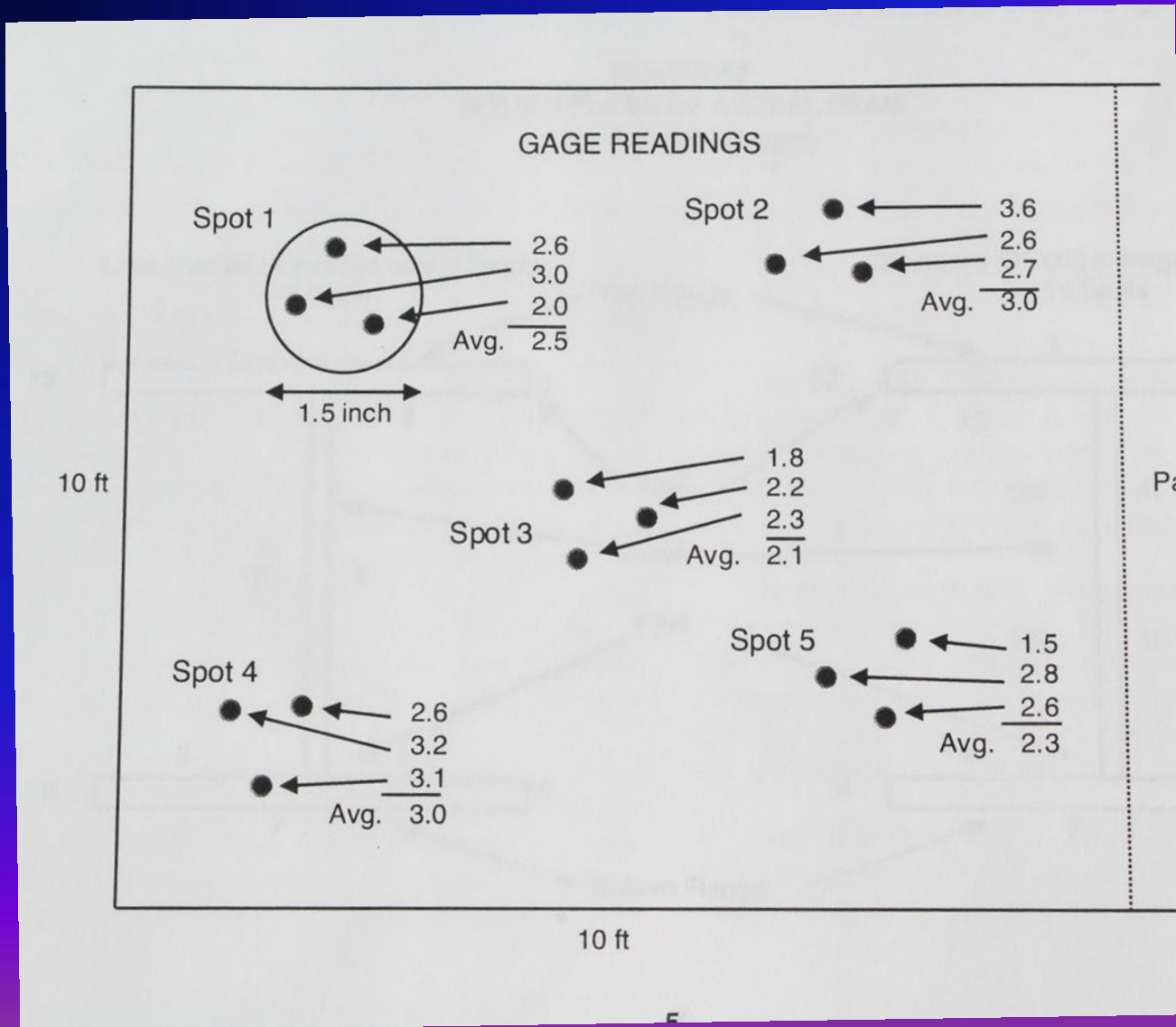


Adjustment of Type 2 Gages

- Addressed in Appendix 8
- Follow the gage manufacturers step-by-step procedures for gage adjustment
- Instructions vary by gage manufacturer
- Adjustment is performed using certified or measured plastic shims (foils)



Measurement Frequency



Measurement Frequency

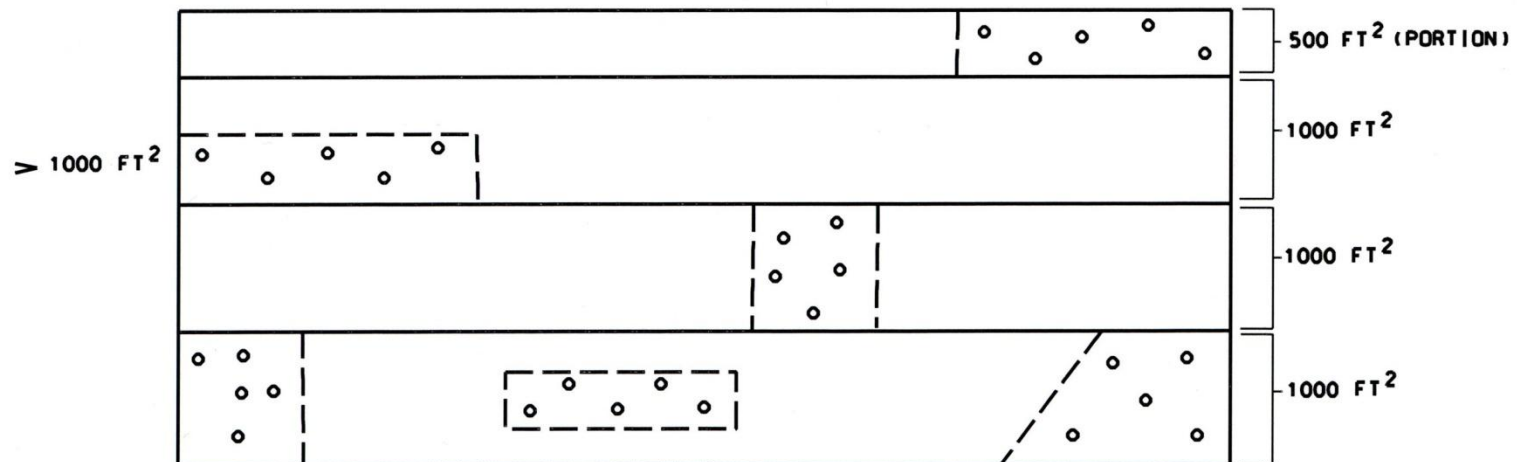
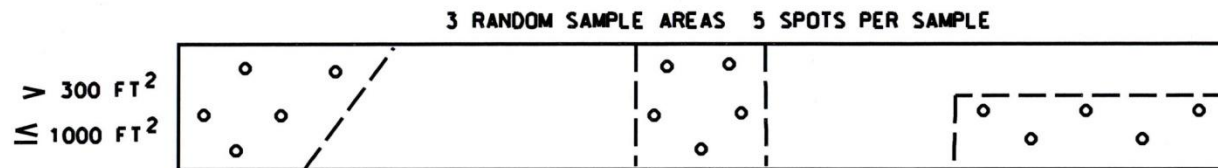
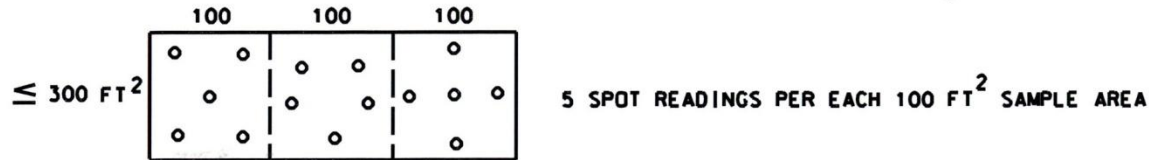
- For areas of coating not exceeding 300 square feet, (~30 square meters) each 100 square feet (~10 square meters) is measured
- For areas of coating exceeding 300 square feet and not exceeding 1000 square feet, arbitrarily select 3 random 100 square foot (~10 square meter) areas and measure

Measurement Frequency

- For areas of coating exceeding 1000 square feet (~100 square meters), arbitrarily select 3 - 100 square feet (~10 square meter) areas for the first 1000 square feet (~100 square meters), and 1 additional 100 square foot (~10 square meter) area for each additional 1000 square feet (100 square meters), or portion thereof

Measurement Frequency

SSPC GUIDELINES FOR MEASURING DFT LARGE STEEL PLATE SURFACES (e.g., TANK WALLS)



3 SAMPLE AREAS FOR FIRST 1000 FT²

1 SAMPLE AREA FOR EACH REMAINING 1000 FT² OR PORTION THEREOF.

Measurement Frequency Example 1 (US Standard)

Size of Coated Area: 900 square feet

No. of Areas: 3 areas

No. of Spots: $3 \text{ Areas} \times 5 \text{ Spots/Area} = 15$
Spots

Minimum No. of Gage

Readings: $15 \text{ Spots} \times 3 \text{ Readings/Spot} =$
45 Gage Readings

Measurement Frequency Example 2 (US Standard)

Size of Coated Area : 12,500 square feet

No. of Areas: $3 + 12 = 15$ areas

No. of Spots: $15 \text{ Areas} \times 5 \text{ Spots/Area} = 75$
Spots

Minimum No. of Gage

Readings: $75 \text{ Spots} \times 3 \text{ Readings/Spot} =$
225 Gage Readings

Conformance to Specified Coating Thickness

- Specifications normally indicate the range of coating thickness (e.g., 5-7 mils), not as a single value (e.g., 5 mils)
- When a single thickness value is specified and no range is indicated by manufacturer:
 - Range established at +/-20% of stated thickness value
 - E.g., 7 mils is 5.6-8.4 mils



Table 1

Coating Thickness Restriction Levels

| Thickness | Gage Reading | Spot Reading | Area Measurement |
|----------------|--------------|-----------------|------------------|
| Level 1 | | | |
| Minimum | Unrestricted | As specified | As specified |
| Maximum | Unrestricted | As specified | As specified |
| Level 2 | | | |
| Minimum | Unrestricted | As specified | As specified |
| Maximum | Unrestricted | 120% of maximum | As specified |
| Level 3 | | | |
| Minimum | Unrestricted | 80% of minimum | As specified |
| Maximum | Unrestricted | 120% of maximum | As specified |
| Level 4 | | | |
| Minimum | Unrestricted | 80% of minimum | As specified |
| Maximum | Unrestricted | 150% of maximum | As specified |
| Level 5 | | | |
| Minimum | Unrestricted | 80% of minimum | As specified |
| Maximum | Unrestricted | Unrestricted | Unrestricted |

Note: If unspecified, Level 3 is the default

Measurement Tolerance

EXAMPLE 1:

- Target DFT: 4-6 mils
- Coating Thickness Restriction Level 3 (default)
- Individual gage readings unrestricted
- Spot measurements must be between 3.2 mils and 7.2 mils
- Area measurement must be between 4 and 6 mils
- If spot or area measurements are out of tolerance, the magnitude of the nonconforming thickness must be determined and demarcated.

Measurement Tolerance

EXAMPLE 2:

- Target DFT: 4-6 mils
- Coating Thickness Restriction Level 2
- Individual gage readings unrestricted
- Spot measurements must be between 4 mils and 7.2 mils
- Area measurement must be between 4 and 6 mils
- If spot or area measurements are out of tolerance, the magnitude of the nonconforming thickness must be determined and demarcated.

SSPC-PA 2 Measurement Specifications

Built Into Type 2 Gages

SSPC-PA 2

No. of readings:
3

Number of spots:
5

Number of areas:
unlimited

OK: ENTER

SSPC-PA 2

Lower sp. limit
8.00 mils

80%: 6.40 mils

Upper sp. limit
12.0 mils


120%: 14.4 mils

OK: ENTER

SSPC-PA 2 mils

↑ 30.9

Aft Bkhd

Ap:16 th.= 23.85 

Sp: 5 Area: 1

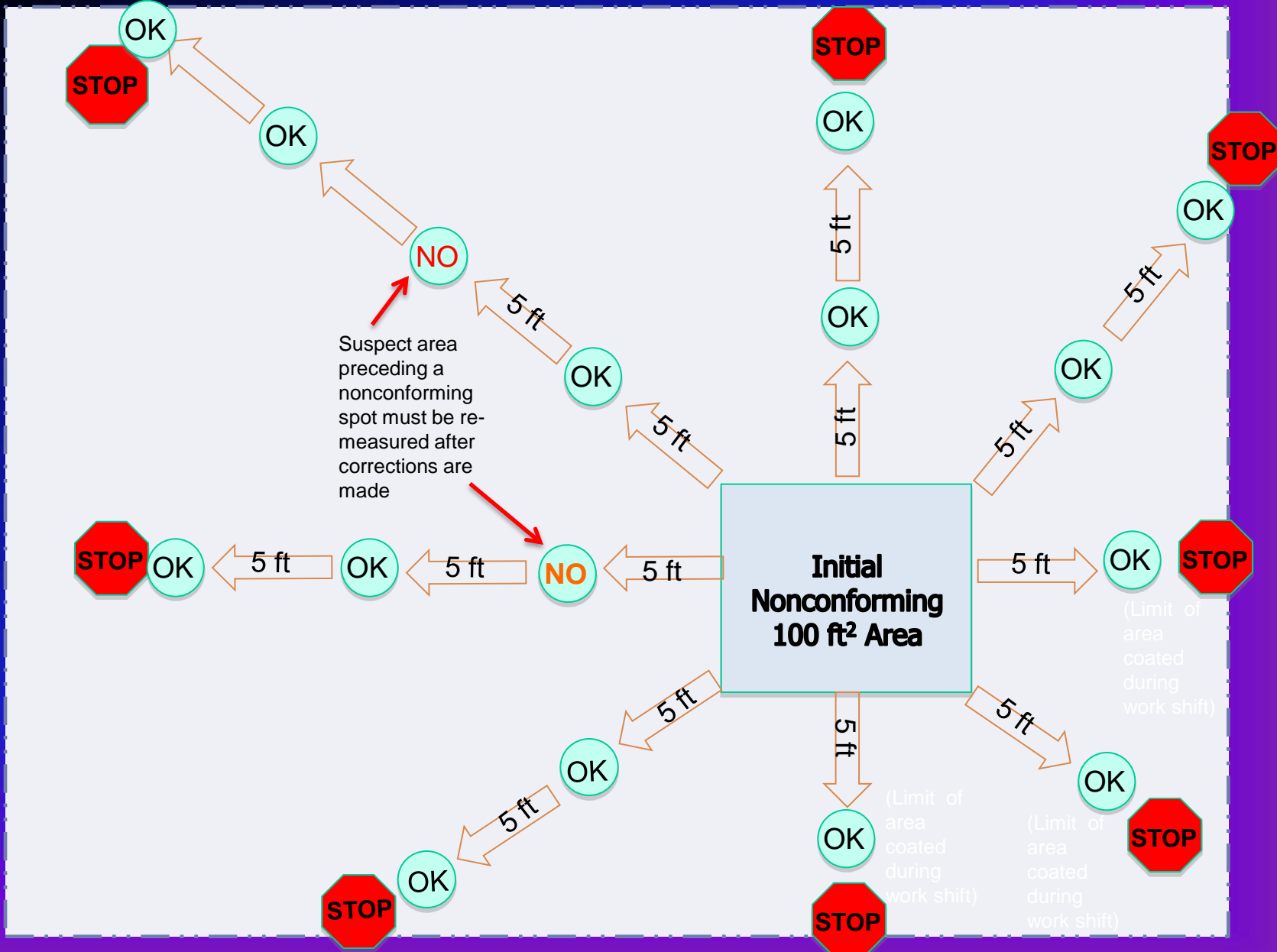
Audible and/or visual indicators if spot readings are out of tolerance

Determining the Magnitude of a Nonconforming Area

- Obtain spot measurements at 5 foot intervals in 8 equally spaced directions radiating out from the nonconforming area up to the limit of area coated during the work shift
 - Each spot must conform to requirements
 - When 2 consecutive spots conform to requirements, measuring can stop
- Area within 5 feet of any nonconforming measurement is suspect and must be re-inspected after correction
- Repeating structural units or parts – 1 spot measurement on each unit
 - Repeat until spot readings on 2 consecutive units conform

Dashed line indicates boundary of area painted during work shift

Dashed line indicates boundary of area painted during work shift



Dashed line indicates boundary of area painted during work shift

Dashed line indicates boundary of area painted during work shift

SSPC-PA 2 Appendices

1. Numerical Example of Average Thickness Measurement
2. Methods for Measuring DFT on Steel Beams (Girders)
3. Methods for Measuring DFT for a Laydown of Beams, Structural Steel & Misc. Parts after Shop Cleaning
4. Method for Measuring DFT on Coated Steel Test Panels

SSPC-PA 2 Appendices, cont.

5. Method for Measuring the DFT of Thin Coatings on Coated Steel Test Panels that Have Been Abrasive Blast Cleaned
6. Method for Measuring the DFT of Coatings on Edges
7. Method for Measuring the DFT of Coated Steel Pipe Exterior
8. Examples of the Adjustment of Type 2 Gages Using Shims



New

Appendix 2: Measuring Coating Thickness on Steel Beams (Girders)

- Full Determination
- Sample Determination
 - Beams < 20 ft (<6 m)
 - Beams 20 ft - 60 ft (6 m-18 m)
 - Beams > 60 ft (> 18 m)
- Coating Thickness Restriction Level 3 (default)
- The average of all spot measurements (per area) must conform to specified range
- Measurement locations on stiffeners arbitrarily selected



Stiffener

Appendix 2: Measuring Coating Thickness on Steel Beams (Girders)

- Full Determination
 - Divide beam into 5 equal sections along the length
 - Web $\geq 36''$: Obtain one spot measurement in 14 areas, per section (total of 70 spot measurements)
 - Web $< 36''$: Obtain one spot measurement in 12 areas, per section (total of 60 spot measurements)

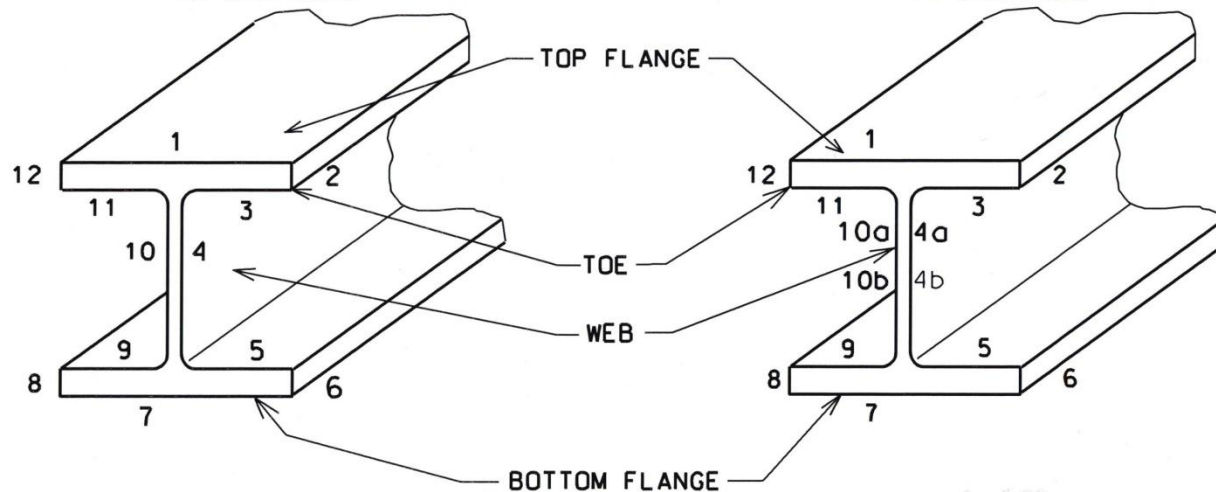


Full Determination

SSPC PA2 GUIDELINES FOR MEASURING DFT SURFACES OF STEEL BEAMS

LESS THAN 91cm (36 inches) IN HEIGHT
12 SURFACES

91cm (36 inches) IN HEIGHT OR GREATER
14 SURFACES



*Note: Areas 2, 6, 8 and 12 (Toe) may not be measured.
The top of the top flange may not be accessible*

Appendix 2: Measuring Coating Thickness on Steel Beams (Girders)

- Sample Determination
 - Beam length < 20 ft: Obtain **2** spot measurements randomly distributed in all 12 areas (total of 24 spot measurements)
 - Beam length 20-60 ft: Obtain **3** spot measurements randomly distributed in all 12 areas (total of 36 spot measurements)



Note: If toe areas are not included, measure in 8 areas (16 or 24 spot measurements)

Appendix 3: Measuring Coating Thickness on Laydown of Beams

- Laydown: Group of steel members laid down to be painted in one shift by one applicator
- Full DFT Determination
 - Beams (girders)
 - Miscellaneous parts
- Sample DFT Determination
 - Beams < 20 ft (6 m)
 - Beams 20 ft - 60 ft (6 m-18 m)



Appendix 4: Measuring Coating Thickness on Test Panels

- Minimum panel size:
3" x 6" (7.5 x 15 cm)
- Maximum panel size:
12" x 12" (30 x 30 cm)
- Use Type 2 gage
- Two gage readings from top, middle and bottom third
- At least 0.5" from edge and 1" from other readings
- 80% min. & 120% max. applies to gage readings



Appendix 5: Measuring Thickness of **Thin** Coatings on Abrasive Blast Cleaned Test Panels

- “**Thin**” is considered 1 mil (25.4 μm) or less
- Obtain 10 gage readings from each of three “zones”
- Calculate the mean and standard deviation in each zone
- The mean of all three zones is the coating thickness



Appendix 6: Measuring Thickness on Edges (Type 2 Gages Only)

- Gage probe configurations less affected by edge proximity
- Consult gage manufacturer
- SSPC Guide 11 (discusses edge retentive coatings)
- Verify probe will measure using shim placed on edge
- Minimum 3 readings within 1.5 linear inches along edge (“spot”)
- Number of “spots” will vary



Appendix 7: Measuring Thickness on Coated Steel Pipe Exterior

- Pipe sections on cart or rack considered a complete unit
- Area = (length of each pipe x circumference) x no. of pipe sections on cart
- Alternative: Pipe DFT Frequency Factors (FF) 1 through 5
- EXAMPLE:
 - Total coated area exceeds 100 sq. ft.
 - FF 2 invoked
 - 175 sq. feet of coated pipe
 - 10 spot measurements
 - FF 2 results in 20 spot measurements



Appendix 7: Measuring Thickness on Coated Steel Pipe Exterior

- Pipe spools measured individually
- Table A7 describes frequency
- Pipe spools < 10 ft: 3 sets of circumferential spot measurements



Table A7

| Pipe Diameter | Circumferential Spot Measurements | Interval Spacing |
|-------------------------|-----------------------------------|-------------------|
| Up to 12 inch (30 cm) | 4 evenly spaced | 10 ft (3 m) apart |
| 14-24 inches (36-60 cm) | 6 evenly spaced | 10 ft (3 m) apart |
| > 24 inches (60 cm) | 8 evenly spaced | 10 ft (3 m) apart |

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