Designation: D 4400 – 89a

27857e PDF

Standard Test Method for Sag Resistance of Paints Using a Multinotch Applicator[1]

This standard is issued under the fixed designation D 4400; 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.

NOTE—Paragraph 9.3.1.1 was editorially corrected and the year date was changed Oct. 6, 1989.

INTRODUCTION

The multinotch applicator used in this test method is a drawdown blade with a series of notches of successively higher clearance, referred to as the Anti-Sag Meter. See Figs. 1 and 2 for a representative diagram and photograph. The numerical value for sag resistance obtained with this instrument is referred to as the Anti-Sag Index.

Anti-Sag Meters are made with several clearance ranges for different types of coatings (see 5.1). In developing this test method the task group used an instrument with a range from 4 to 24 mils, but this test method is applicable to any clearance range, and results using instruments with overlapping ranges correlate and have equal validity.

This test method covers two procedures. Procedure A was developed in 1962[2,3] and is referenced in U.S. Federal specifications TT-E-508, TT-E-506, and TT-P-1511. Procedure B is a newer method that obviates concern about the effect of substrate wetting as a possible variable. Numerical values obtained with the two procedures are not necessarily equal, but their rank orders are essentially the same.

A preshear program is essential for a drawdown sag test to duplicate the breakdown in structure that occurs when thixotropic paints are applied by brushout or other practical application methods. The procedures therefore include the preshearing of paints just prior to making test applications.

1. Scope

1.1 This test method covers the laboratory determination of the sag resistance of aqueous and nonaqueous liquid coatings at any level of sag resistance.

1.2 Procedure A is applicable to coatings of any type or color.

1.3 Procedure B is applicable to any type of coating but does not work well with dark colors.

1.4 *This standard may involve hazardous materials, operations, and equipment. This standard does not purport to address all of the safety problems 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 2196 Test Methods for Rheological Properties of NonNewtonian Materials by Rotational (Brookfield) Viscometer[4]

D 3980 Practice for Interlaboratory Testing of Paint and Related Materials[4]

2.2 *U.S. Federal Standards:*[5]

Federal Test Method Standard 141, Method No. 494, Sag Test (Multinotch Blade)

2.3 *U.S. Federal Specifications:*[5]

Fed. Spec. TT-E-508 Alkyd semi-gloss enamel

Fed. Spec. TT-E-506 Alkyd gloss enamel

Fed. Spec. TT-P-1511 Interior latex gloss and semi-gloss finishes

3. Summary of Test Method

3.1 *Procedure A, Horizontal Stripes*—After preshearing, the coating is applied to a test chart with a multinotch applicator. The charts are immediately hung vertically with the drawdown stripes horizontal, similar to rungs of a ladder, with the thinnest stripe at the top. After drying in this position, the drawdown is examined and rated for sagging. A typical sag pattern obtained by this procedure is shown in Fig. 3.

3.2 *Procedure B, Vertical Stripes*—Two straight lines are

[1] This test method is under the jurisdiction of ASTM Committee D-1 on Paint and Related Coatings and Materials and is the direct responsibility of Subcommittee D01.42 on Architectural Finishes.

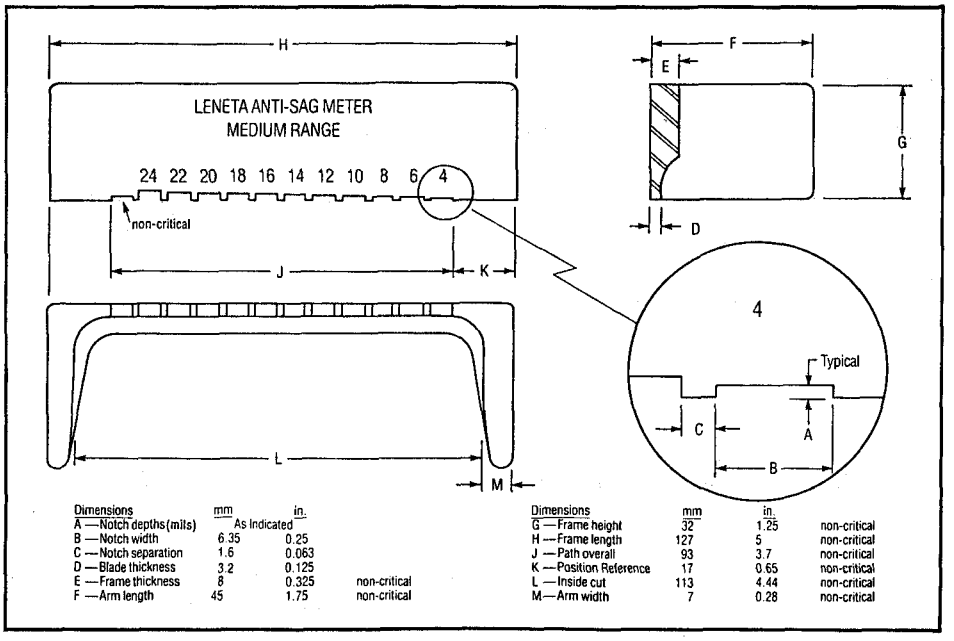
Current edition approved Oct. 6, 1989. Published December 1989. Originally published as D 4400 – 84. Last previous edition D 4400 – 89.

[2] "Design of an Improved Sag Tester," *Official Digest*, Vol 34, No. 453, October 1962.

[3] "Thixotropy . . . Trade Sales Paints," *Official Digest*, Vol 36, No. 468, January 1964.

[4] *Annual Book of ASTM Standards*, Vol 06.01.

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



Dimensions	mm	in.	
A —Notch depths (mils)	As Indicated		
B —Notch width	6.35	0.25	
C —Notch separation	1.6	0.063	
D —Blade thickness	3.2	0.125	
E —Frame thickness	8	0.325	non-critical
F —Arm length	45	1.75	non-critical

Dimensions	mm	in.	
G —Frame height	32	1.25	non-critical
H —Frame length	127	5	non-critical
J —Path overall	93	3.7	non-critical
K —Position Reference	17	0.65	non-critical
L —Inside cut	113	4.44	non-critical
M—Arm width	7	0.28	non-critical

FIG. 1 Diagram of the Medium Range Anti-Sag Meter

FIG. 2 Medium Range Anti-Sag Meter

drawn across a test chart using a suitable marker pen. After preshearing, the coating is applied with a multinotch applicator so that the stripes are perpendicular to the lines. After waiting briefly for the marker ink to migrate through the wet film, the charts are hung vertically with the stripes vertical, similar to the slats of a picket fence, with the thinnest stripe on the left. After drying in this position, the ink lines are examined and rated for sagging. A typical sag pattern obtained by this procedure is shown in Fig. 4.

4. Significance and Use

4.1 Evaluation of sag resistance is essential in quality control for both producers and purchasers of coatings. Practical application tests are poor in reproducibility while viscometric methods, for example Test Methods D 2196, are time-consuming and lack the convincing aspect of actual sagging. This method provides simple and rapid tests, whereby sag resistance is demonstrated by a visible sag pattern, and is rated objectively in terms of numerical values that correlate with brushout test observations.

5. Apparatus

5.1 *Multinotch Applicator,* Anti-Sag Meter[6], a drawdown blade with a series of notches of successively higher clearance. Select a clearance range suitable for the type of coating under test in accordance with Table 1.

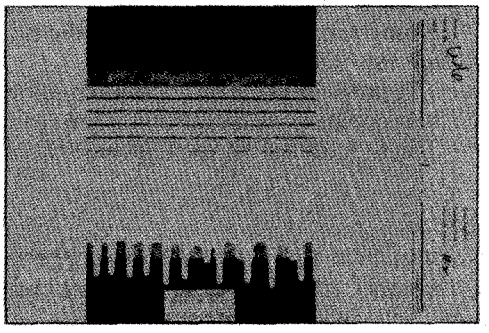


FIG. 3 Typical Sag Pattern—Procedure A

5.2 *Test Surfaces,* sealed, smooth-surfaced paper test charts, with sizes and designs as follows:

5.2.1 *Black and White Charts,*[7] about 7⅝ by 11⅜ in. (193 by 288 mm), the black area comprising about 5½ in. (140 mm) centered on the drawdown path. A chart of this design is shown in Figs. 3 and 5.

5.2.2 *Plain White Charts,*[7] about 7⅝ by 11¼ in. (193 by 285 mm).

5.2.3 *Plain White Charts,*[7] about 5½ by 11¼ in. (140 by 285 mm). The use of a chart of this description is shown in Fig. 4.

5.3 *Glass Drawndown Plate,* plus straightedge guide for attachment thereto.

[6] Available from The Leneta Co., P.O. Box 86, Ho-Ho-Kus, NJ 07423. An equivalent may be used.

[7] The following are available from The Leneta Co.:
Black and White Charts, Form 7B.
Plain White Charts, 7⅜ by 11¼ in., Form WB.
Plain White Charts, 5½ by 11¼, Form WM.
Catch-Papers, Form CP-2.

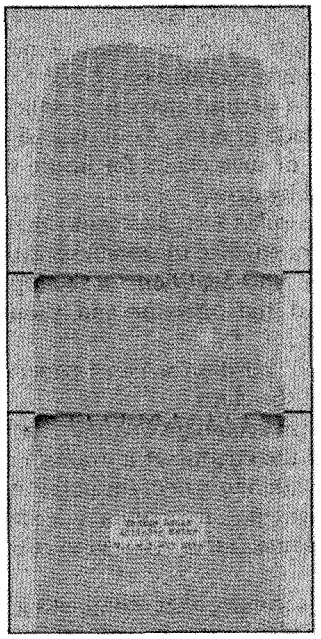


FIG. 4 Typical Sag Pattern—Procedure B

5.4 *Catch-papers*,[7] thin sheets of sealed paper, for catching surplus paint at the completion of a drawdown.

5.5 *Fine-Line Marker Pens*—The ink shall be a solvent-based type that wets readily and dries quickly on smooth nonporous surfaces, specifically:

5.5.1 A pen[8] that applies a hydrophilic ink line for use with water-dispersed coatings.

5.5.2 A pen[9] that applies an oleophilic ink line for use with solvent-dispersed coatings.

5.6 *Equipment for the Preshearing of Aqueous Coatings:*

5.6.1 *Syringe*, 10-mL, Becton-Dickinson, Luer-Lok disposable plastic type.[10]

5.6.2 *Syringe Needle*, 15 g by 1½ in. (40 mm) to fit syringe.

5.6.3 *Syringe Extension Tubing*, clear vinyl, inside diameter ⅛ in. (3.2 mm), outside diameter ⅜ in. (5 mm).

5.7 *Equipment for the Preshearing of Nonaqueous Coatings:*

5.7.1 *Rotary Mechanical Stirrer*, variable speed.

5.7.2 *Circular Mixing Paddle*,[11] diameter approximately 1⅞ in. (48 mm).

5.7.3 *Mixing Container*, cylindrical jar or can with capacity of up to 1 pt (500 mL).

6. Procedure A—Horizontal Stripes

6.1 *Preparation of Sample:*

[8] "Vis-A-Vis" pens, manufactured by Sanford Pen Company, Bellwood, IL 60104, have been found satisfactory. These are sold at commercial stationers.

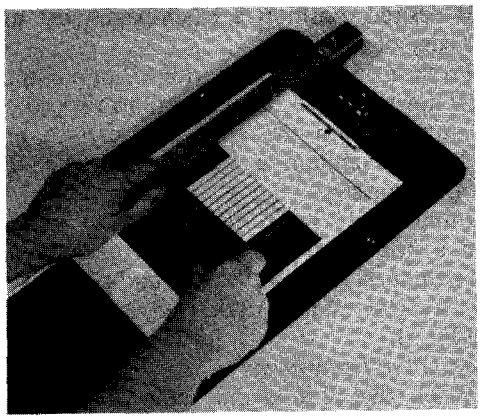
[9] A "Flow Master" refillable pen with a fine line adapter and red Flow Master ink have been found satisfactory. The pen and the ink are sold separately. Both are manufactured by Faber-Castell Pen Corp. Newark, NJ 07107, and are available at commercial stationers.

[10] Luer-Lok is a trademark of Becton-Dickinson, Beaver Brook Rd., Lincoln Park, NJ 07035. Available from distributors of general laboratory supplies.

[11] A mixing paddle (Catalog Number PM-70) with a diameter of 1⅞ in. (48 mm) made by Shur-Line Mfg. Co., 2200 Commerce Rd., Lancaster, NY 14086 has been found satisfactory for this purpose. This or equivalent paddles may be purchased at most hardware stores.

TABLE 1 Anti-Sag Meter Types

Type of Coating Under Test	Clearance Range, mils	Range Reference	Number of Clearances
Architectural	3–12	Standard	10
Industrial—OEM.	1–6	Low	11
High build	14–60	High	11
Architectural	4–24	Medium	11



NOTE—Note use of straightedge guide.

FIG. 5 Drawing Down with the Anti-Sag Meter

6.1.1 Stir thoroughly with a spatula in the original container.

6.1.2 Strain if necessary to remove large particles or skins.

6.1.3 Adjust the temperature of the coating to 73.5 ± 3.5°F (23 ± 2°C).

6.2 *Preshearing with Syringe and Needle (Aqueous Coatings):*

6.2.1 Prepare the paint as described in 6.1.

6.2.2 Cut a 2½-in. (60-mm) length of syringe extension tubing and attach it to the syringe.

6.2.3 Press the syringe barrel firmly to expel air, dip the end of the syringe into the coating, pump slightly to expel remaining air, then withdraw 8 mL of coating.

6.2.4 Remove and discard the extension tubing and then attach a syringe needle.

6.2.5 Eject the contents of the syringe in front of the applicator as rapidly as possible, with firm, steady pressure.

6.3 *Preshearing with a Rotary Mechanical Mixer (Nonaqueous Coatings):*

6.3.1 Prepare the paint as described in 6.1 and fill the mixing container slightly more than half. Set the container under the stirrer so that the paddle is about ¼ in. (5 mm) from the bottom.

6.3.2 Mix vigorously for 1 min at a speed sufficient to form a moderate vortex, with the entire contents of the can in rapid circular motion. Rotor speeds of 1300 to 3600 r/min have been found satisfactory, the optimum speed depending on the relative diameters of the mixing paddle and container. For referee tests the operators should agree upon the specific container, paddle, and mixing speed.

6.3.3 Immediately after mixing place about 8 mL of paint in front of the applicator and draw down in accordance with 6.4 (Procedure A) or 7.4 (Procedure B).

6.4 *Application of the Test Coating:*

6.4.1 Affix a suitable test chart onto the drawdown plate. Use black and white charts in accordance with 5.2.1 for light or moderately dark colored coatings and white charts in accordance with 5.2.2 for very dark coatings.

6.4.2 Fasten the straightedge onto the drawdown plate in a suitable position.

6.4.3 Place the Anti-Sag Meter at the far end of the chart, the open side toward the operator and shoulder against the straightedge guide.

6.4.4 If desired, position a catch-paper just underneath the lower edge of the chart.

6.4.5 Preshear in accordance with 6.2 or 6.3 and immediately draw down the coating at a uniform speed of about 6 in. (150 mm)/s, with the applicator pressed against the straightedge to maintain a straight path. See Fig. 5 for illustration of this step.

6.4.6 Immediately hang the chart with the drawdown stripes in a horizontal position like rungs in a standing ladder, the thinnest stripe at the top, and allow to dry in that position. A typical test pattern derived using this procedure is shown in Fig. 3.

6.5 *Rating the Drawdown:*

6.5.1 When the film is dry, note the notch numbers marked on the Anti-Sag Meter and identify the corresponding stripes accordingly.

6.5.2 Observe the sag pattern, ignoring the bottom stripe, which serves only as a position reference for the stripe above it, and the leading and trailing edges of the drawdown, considering only the central 5½ in. (140 mm) of the blade path. This corresponds to the black area of the black and white chart described in 5.2.1. (See Fig. 3 for a typical sag pattern of this type.)

6.5.3 Select the lowest (thickest) stripe that has resisted crossing the gap to touch the next lower stripe. This is referred to as the index stripe.

6.5.4 Estimate the degree to which the next lower stripe (the post-index stripe) has merged with the one below it, and determine the corresponding addendum fraction, as specified in Table 2.

6.5.5 Multiply the fraction from 6.5.4 by the difference between the index and post-index stripe number to obtain the index addendum.

6.5.6 Add the index addendum to the index stripe number to obtain the Horizontal Anti-Sag Index and record same.

7. Procedure B—Vertical Stripes

7.1 *Preparation of Sample*—Follow procedure in 6.1.

7.2 *Preshearing with Syringe and Needle (Aqueous Coatings)*—Follow procedure in 6.2.

7.3 *Preshearing with a Rotary Mechanical Mixer (Non-Aqueous Coatings)*—Follow procedure in 6.3.

TABLE 2 Intermediate Ratings

Degree of Merger of Post-Index Stripe	Addendum Fraction
Complete	0.0
Almost complete	0.2
Somewhat more than half	0.4
Half	0.5
Somewhat less than half	0.6
Slight (just touching)	0.8

7.4 *Application of Test Coating:*

7.4.1 On a plain white test chart as described in 5.2.3, using the appropriate pen described in 5.5, rule two parallel lines about 1½ in. (40 mm) apart, across the intended path of the drawdown blade (see Fig. 4). If desired the operator can prepare a supply of such charts for future use, since the ink line is unaffected by aging.[12]

7.4.2 Affix the ruled test chart onto the drawdown plate and fasten the straightedge in suitable position.

7.4.3 Place the Anti-Sag Meter at the top of the chart, the open side toward the operator and shoulder against the straightedge guide.

7.4.4 If desired, position a catch-paper just underneath the lower edge of the chart.

7.4.5 Preshear in accordance with 6.2 or 6.3 and immediately draw down the coating at a uniform speed of about 6 in. (150 mm)/s, with one arm of the applicator pressed gently against the straightedge to maintain a straight path. This procedure is the same as that referred to in 6.4 and illustrated in Fig. 5.

7.4.6 Fifteen seconds after completing the drawdown, hang the chart with the stripes vertical (like fence pickets), thinnest stripe to the left, and allow to dry in that position. A typical test pattern obtained using this procedure is shown in Fig. 4.

7.5 *Rating the Drawdown:*

7.5.1 When the film is dry, note the notch numbers marked on the Anti-Sag Meter and identify the corresponding stripes and sag loops accordingly.

7.5.2 Examine Fig. 6 and note the "reference loop," which was selected because it indicates a limited but unambiguous sag movement. By actual measurement this loop represents 1/16 in. (1.5 mm) of sagging, which amount can be considered as defining the reference loop.

7.5.3 For each of the two ink lines on the test drawdown, note the loop that shows the same or almost as much sag as the reference loop. This is referred to as the "index" loop. The loop to its immediate right is the "post-index" loop and the corresponding stripes are the "index" and "post-index" stripes.

7.5.4 Estimate the visual difference between the index and reference loops as a fraction (to the nearest fifth or half) of the difference between the index and post-index loops. This is the addendum fraction, permissible values being 0, 0.2, 0.4, 0.5, 0.6, or 0.8.

7.5.5 Multiply the addendum fraction from 7.5.4 by the difference between the index and post-index stripes to obtain the index addendum.

7.5.6 For each ink line, add the index addendum to the index stripe number to obtain the Vertical Anti-Sag Index and record the mean value.

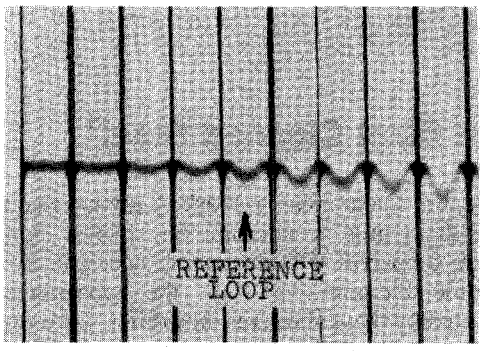
8. Report

8.1 Report the following information:

8.1.1 *Procedure A*—The Horizontal Anti-Sag Index (HASI) of the coating as recorded in 6.5.6.

8.1.2 *Procedure B:*

[12] Charts with suitable ink lines are available from The Leneta Co. Refer to Form WM-BL (Blue Line) and Form WM-RL (Red Line) for hydrophilic and oleophilic ink lines respectively.



NOTE—The "reference loop" is 1.5 mm (1/16 in.) deep.

FIG. 6 Sag Loops Obtained with Procedure B

8.1.2.1 The Vertical Anti-Sag Index (VASI) of the coating as recorded in 7.5.6.

9. Precision[13]

9.1 *Correlation*—In an interlaboratory study in which operators in seven laboratories tested six water-reducible paints covering a wide range of sag resistance and in five laboratories tested four solvent-reducible paints covering a wide range of sag resistance, the Spearman Rank Correlation Coefficient was 0.92 for Procedure A and 0.96 for Procedure B versus brushouts (a coefficient of 1.0 indicates perfect agreement in ranking).

9.2 *Sensitivity*—In the interlaboratory study described in 9.1, the sensitivity criterion values have been computed to be 4 for brushouts, 11 for Procedure A, and 13 for Procedure B. Thus, Procedures A and B are approximately three times more sensitive to differences in sag resistance than brushouts.

9.3 *Precision:*

9.3.1 Two interlaboratory tests were conducted to establish the precision of this test method. The first test was that described in 9.1. The second test consisted of operators in five laboratories performing three tests on each of three paints. On the basis of the second interlaboratory test, the within-laboratory pooled coefficients of variations for both water- and solvent-reducible paints were 4.4 % for Procedure A and 5.0 % for Procedure B. On the basis of the first interlaboratory test, the between-laboratory pooled coefficient of variation for Procedure A was found to be 12.4 % for water-reducible paints and 8.8 % for solvent-reducible paints. The between-laboratory pooled coefficient of variation for Procedure B was found to be 8.0 % for water-reducible paints and 6.6 % for solvent-reducible paints. Based on these coefficients of variation, the following criteria should be used for judging the acceptability of results at the 95 % confidence level:

9.3.1.1 *Repeatability*—Two results obtained by the same operator for either water-reducible or solvent-reducible paints should be considered suspect if they differ by more than 10.7 % using Procedure A and by more than 13.6 % using Procedure B.

9.3.1.2 *Reproducibility*—Two results obtained by operators in different laboratories using Procedure A should be suspect if they differ by more than 34.4 % for water-reducible paints and 23.4 % for solvent-reducible paints. Two results obtained by operators in different laboratories using Procedure B should be suspect if they differ by more than 23.1 % for water-reducible paints and 19.8 % for solvent-reducible paints.

10. Keywords

10.1 Anti-Sag Index; rheological properties; sag-resistance

[13] Supporting data are available from ASTM Headquarters. Request RR: D01-1040.

Designation: D 4417 - 84

Standard Test Methods for Field Measurement of Surface Profile of Blast Cleaned Steel[1]

1. Scope

1.1 These test methods cover the description of techniques for measuring the profile of abrasive blast cleaned surfaces in the laboratory, field, or in the fabricating shop. There are additional techniques suitable for laboratory use not covered by these test methods.

1.2 *This standard may involve hazardous materials, operations, and equipment. This standard does not purport to address all of the safety problems associated with its use. It is the responsibility of whoever uses this standard to consult and establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

2. Summary of Method

2.1 The methods are:

2.1.1 *Method A*—The blasted surface is visually compared to standards prepared with various surface profile depths and the mode determined.

2.1.2 *Method B*—The depth of profile is measured using a fine pointed probe at a number of locations and the arithmetic mean determined.

2.1.3 *Method C*—A composite plastic tape is impressed into the blast cleaned surface forming a reverse image of the profile, and the peak to valley height on the tape measured with a micrometer.

3. Significance and Use

3.1 The height of surface profile has been shown to be a factor in the performance of various coatings applied to steel. For this reason, surface profile should be measured prior to coating application to ensure that it meets the specification. The instruments described are readily portable and sufficiently sturdy for use in the field.

NOTE—Optical microscope methods serve as a referee method for surface profile measurement. Profile depth designations are based on the concept of average maximum profile ($\bar{h}$ max); this value is determined by averaging a given number (usually 20) of the highest peak to lowest valley measurements made in the field of view of a standard measuring microscope. This is done because of evidence that coatings performance in any one small area is primarily influenced by the highest surface features in that area and not by the average roughness.[2]

4. Apparatus

4.1 *Method A*—A profile comparator[3] consisting of a number of areas (each approximately one square inch in size), usually side by side, with a different profile or anchor pattern depth. Each area is marked giving the nominal profile depth in mils or micrometres. Typical comparator surfaces are prepared with steel shot, steel grit, or sand or other nonmetallic abrasive, since the appearance of the profile created by these abrasives may differ. The comparator areas are used with or without magnification of 5 to 10×.

4.2 *Method B*—A dial gage[4] depth micrometer fitted with a pointed probe. The probe is machined at a 60° angle with a nominal radius of 50 μm. The base of the instrument rests on the tops of the peaks of the surface profile while the spring loaded tip projects into the valleys.

4.3 *Method C*—A special tape containing a compressible foam attached to a noncompressible uniform plastic film. A burnishing tool is used to impress the foam face of the tape into the surface to create a reverse replica of the profile that is measured using a spring-loaded micrometer.[5]

5. Test Specimens

5.1 Use any metal surface that, after blast cleaning, is free of loose surface interference material, dirt, dust, and abrasive residue.

6. Procedure

6.1 *Method A:*

6.1.1 Select the comparator standard appropriate for the abrasive used for blast cleaning.

6.1.2 Place the comparator standard directly on the surface to be measured and compare the roughness of the prepared surface with the roughness on the comparator segments. This can be done with the unaided eye, under 5 to 10× magnification, or by touch. When using magnification, the magnifier should be brought into intimate contact with the standard, and the depth of focus must be sufficient so that the standard and surface are in focus simultaneously.

6.1.3 Select the comparator segment that most closely approximates the roughness of the surface being evaluated or, if necessary, the two segments to which it is intermediate.

6.1.4 Evaluate the roughness at a sufficient number of locations to characterize the surface as specified or agreed upon between the interested parties. At each location make three evaluations against the comparator and determine the mode. The mode of the three evaluations represents the profile at the specific location, with the mode of all locations representing the profile of the entire surface.

6.2 *Method B:*

6.2.1 Prior to use set the gage to zero by placing it on a piece of plate glass. Hold the gage by its base and press firmly against the glass. Adjust the instrument to zero.

6.2.2 To take readings, hold the gage firmly against the prepared substrate. Do not drag the instrument across the

---

[1] These test methods are under the jurisdiction of ASTM Committee D-1 on Paint and Related Coatings and Materials and are the direct responsibility of Subcommittee D01.46 on Industrial Protective Painting.

Current edition approved Nov. 14, 1984. Published January 1985.

[2] John D. Keane, Joseph A. Bruno, Jr., Raymond E. F. Weaver, "Surface Profile for Anti-Corrosion Paints," Oct. 25, 1976, Steel Structures Painting Council, 4400 Fifth Ave., Pittsburgh, PA 15213.

[3] Suitable comparators include Keane-Tator Surface Profile Comparator and Clemtex coupons.

[4] Suitable depth micrometers include the Elcometer Model 123 Surface Profile Gage.

[5] Suitable replica tape and micrometers include Testex "Press-O-Film" tape and Mitutoyo Model 7326 Spring Micrometer.

surface between readings, otherwise the spring-loaded tip may become rounded.

6.2.3 Measure the profile at a sufficient number of locations to characterize the surface, as specified or agreed upon between the interested parties. At each location make ten readings and determine the mean. Then determine the mean for all the locations and report it as the profile of the surface.

6.3 *Method C:*

6.3.1 Select the correct tape range for the profile to be measured: coarse, 0 to 2 mils (0 to 50 μm) and extra coarse, 1.5 to 4.5 mils (40 to 115 μm).

6.3.2 Remove the wax paper backing and place the tape on the prepared surface with the foam side down, that is, put the dull side down.

6.3.3 Hold the tape firmly on the surface and rub the circular cut-out portion (approximately ⅜ in. (6.5 mm) diameter) with the burnishing tool until a uniform gray color appears.

6.3.4 Remove the tape and place it between the anvils of a spring-loaded micrometer. Measure the thickness of the tape (compressed foam and non-compressible plastic film combined). Subtract the thickness of the noncompressible plastic film to obtain the surface profile.

6.3.5 Measure the profile at a sufficient number of locations to characterize the surface, as specified or agreed upon between the interested parties. At each location make three readings and determine the mean. Then determine the mean for all the locations and report it as the profile of the surface.

7. Report

7.1 Report the range and the appropriate average (mean or mode) of the determinations, the number of locations measured, and the approximate total area covered.

8. Precision

8.1 Precision is under active study.[6]

[6] Other organizations, such as National Association of Corrosion Engineers (NACE), are currently involved in such studies.

Designation: D 4537 - 91

Standard Guide for Establishing Procedures to Qualify and Certify Inspection Personnel for Coating Work in Nuclear Facilities[1]

This standard is issued under the fixed designation D 4537; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

1. Scope

1.1 This guide delineates the requirements for development of procedures for the qualification of personnel who perform inspection of coating work. These activities are accomplished to verify conformance to specified requirements for nuclear facility coatings work whose satisfactory performance is required in order not to compromise systems used to mitigate the consequences of postulated accidents.

1.2 This guide provides a uniform interpretation of the requirements in ANSI/ASME N45.2.6-1978 for the inspection of coating work in nuclear facilities.

1.3 This guide meets the intent of ANSI/ASME NQA-1.

1.4 It is the intent of this guide to provide a recommended basis for qualification, not to mandate a singular basis for all qualifications. Variations or simplifications of the qualifications described in this guide are appropriate for special coating work outside of safety-related areas.

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

2. Referenced Documents

2.1 *ANSI/ASME Standards:*

ANSI/ASME N45.2.6 Qualifications of Inspection, Examination, and Testing Personnel for Nuclear Power Plants[2]

ANSI/ASME NQA-1 Quality Assurance Program Requirements for Nuclear Facilities.[2]

3. Terminology

3.1 *Description of Terms Specific to This Standard*

3.1.1 *certification*—written documentation of qualification.

3.1.2 *coating work inspection*—a phase of quality control which, by means of examination, observation, or measurement, determines the conformance of coating work to predetermined quality requirements.

3.1.3 *qualifications*—skills, training, and experience required for personnel to perform properly the duties and execute the responsibilities of the appropriate certification level.

3.1.4 *training*—the program developed to ensure that personnel receive the knowledge and skills necessary for qualification.

4. Significance and Use

4.1 The requirements of this guide apply to personnel who perform inspections of coating work during (*1*) fabrication, (*2*) receipt of items at the construction site, (*3*) construction, (*4*) pre-operational and startup testing, and (*5*) operational phases of nuclear facilities.

4.2 It is the responsibility of each organization participating in the project to ensure that only those personnel within their respective organizations who meet the requirements of this guide are permitted to perform inspection activities covered by this guide.

4.3 The organization(s) responsible for establishing the applicable requirements for activities covered by this guide shall be identified, and the scope of their responsibility shall be documented. Delegation of this responsibility to other qualified organizations is permitted and shall be documented.

4.4 It is the responsibility of the organization performing these activities to specify the detailed methods and procedures for meeting the requirements of this guide, unless they are otherwise specified in the contract documents.

5. General Requirements for Inspection Personnel

5.1 Provisions shall be made for the indoctrination of personnel as to the technical objectives of the project, the codes and standards that are to be used, and the quality assurance elements that are to be employed.

5.2 The need for formal training programs shall be determined, and such training activities shall be conducted as required to qualify personnel who perform inspections. On-the-job participation shall also be included in the program, with emphasis on first-hand experience gained through actual performance of inspections.

5.3 A candidate's qualifications for certification shall be initially determined by a suitable evaluation of the candidate's education, experience, training, examination results, and capability demonstration.

5.4 The job performance of coating work inspection personnel shall be reevaluated at periodic intervals not to exceed three years. Reevaluation shall be by evidence of continued satisfactory performance or redetermination of capability in accordance with 5.3. If, during this evaluation or at any other time, it is determined by the responsibile organization that the capabilities of an individual are not in

---

[1] This guide is under the jurisdiction of ASTM Committee D-33 on Protective Coating and Lining Work for Power Generation Facilities and is the direct responsibility of Subcommittee D33.04 on Inspection.

Current edition approved Aug. 15, 1991. Published October 1991. Originally published as D 4537 - 86. Last previous edition D 4537 - 86.

[2] Available from American National Standards Institute, 11 W. 42nd Street, 13th Floor, New York, NY 10036.

VISION TEST RECORD

Expires _____

NAME: _____
(Last) (First) (Middle Initial)

JOB NUMBER: _____ JOB NAME: _____

NEAR DISTANCE VISUAL ACUITY

1. Jaeger J-1 letters

Uncorrected, normal	YES	NO
Corrected, normal	YES	NO

-OR-

2. Alternative Method: _____

_____

Uncorrected, normal	YES	NO
Corrected, normal	YES	NO

COLOR VISION

1. Ishihara's test chart	YES	NO

2. Alternative Method: _____

_____

Color vision test findings: _____

_____

_____

The above-named individual has Passed/Failed the vision test as specified in Section 7 of this Guide.

THIS CERTIFICATION IS VALID FOR ONE YEAR FROM THE DATE OF EXAMINATION.

EXAMINER: _____
Type or print name followed by signature

TITLE: _____ DATE: _____

FIG. 1 Sample Vision Test Record

accordance with the qualifications specified for the job, that person shall be removed from that activity until the required capability has been demonstrated.

5.5 Any person who has not been actively engaged in the performance or supervision of coating work inspection for a period of one year shall be reevaluated in accordance with 5.3.

6. Functional Qualifications of Inspectors

6.1 All physical inspection activities can be performed by certified Level I, Level II, or Level III inspectors.

6.2 *Level I Coatings Inspector*, shall be capable of the following:

6.2.1 Implementing and recording all inspections required by the applicable procedures.

6.2.2 Verifying instrument calibration.

6.2.3 Performing hold point inspections in accordance with the applicable procedures.

6.3 *Level II Coatings Inspector*, shall be capable of the following:

6.3.1 Performing all of the duties and responsibilities of a Level I coatings inspector.

6.3.2 Planning and supervising inspections, initiating and reviewing inspection procedures, and evaluating the adequacy of activities.

6.3.3 Reviewing, organizing, and approving results of inspections.

6.3.4 Monitoring the performance of and supervising the work of Level I coatings inspectors.

6.3.5 Training and verifying the qualifications of Level I coatings inspectors for certification.

6.3.6 Initiating changes to quality procedures.

6.3.7 Implementing the Quality Assurance Program if assigned that authority by company policy or the Quality Assurance Program.

6.4 *Level III Coatings Inspector*, shall be capable of the following:

6.4.1 Carrying out all of the duties and responsibilities of a Level II coatings inspector.

6.4.2 Certifying Level I, Level II, and other Level III coatings inspectors.

EDUCATION AND EXPERIENCE RECORD

NAME: _____
(Last) (First) (Middle Initial)

EDUCATION:

EXPERIENCE:

PROFESSIONAL DATA:

I certify that the above information is accurate.

SIGNED: _____ DATE: _____
Candidate

FIG. 2 Sample Education and Experience Record

6.4.3 Responsible for evaluating the adequacy of programs used to train coatings inspectors.

6.4.4 Responsible for authorizing Level II coatings inspectors to carry out training and examination duties.

6.4.5 Responsible for approving all safety-related inspection procedures.

7. Physical Qualifications of Inspectors

7.1 Each inspector shall be examined annually to ensure natural or corrected near-distance visual acuity in at least one eye. The individual shall read the J-1 letters on a Standard Jaeger Test Chart, or equivalent, at a distance of not less than 12 in. with one or both eyes, uncorrected or corrected.

7.2 Each candidate shall be examined for color preception using the Ishihara Test or the Farnsworth D-15 Test when being certified or recertified. If a candidate does not pass the Red/Green Sensitive Ishihara Test, the candidate may take the Farnsworth D-15 Test.

7.3 If a candidate does not pass the Farnsworth D-15 Test the candidate may be evaluated by a licensed medical practitioner to provide the necessary data to determine the candidate's color perception. Individuals certified after an evaluation by a licensed medical practioner may only be certified to perform inspection work that is within the candidates's color perception capability.

7.4 The examinations required by 7.1 and 7.2 shall be administered by a licensed medical practitioner or a person familiar with the tests involved. The results of vision tests shall be documented on a Vision Test Record (Fig. 1 or equivalent form).

7.5 The responsible organization shall identify any other physical qualifications required to perform the assigned inspection duties. Inspectors requiring the identified physical qualifications shall have them confirmed by examinations at intervals not to exceed one year.

8. Education, Training, and Experience Qualifications

8.1 Candidates for certification as coatings inspectors shall have sufficient education, experience, and training to ensure an understanding of the principles and procedures in those areas of inspection, examination, and testing activities for which they are being considered for certification.

8.2 *Level I Coatings Inspectors*, shall, as a minimum, meet one or more of the following requirements:

ORGANIZATIONAL TRAINING RECORD

NAME: _____
(Last) (First) (Middle Initial)

TRAINING COURSES, SEMINARS, LECTURES, ETC.

Given by and Date	Description of Training	Test Score	Pass/Fail	Initials

FIG. 3 Sample Organization Training Record

8.2.1 High school graduation plus six months of related experience in equivalent inspection activities.

8.2.2 Completion of college level work leading to an Associate Degree or higher, plus three months of related experience in equivalent inspection activities.

8.3 *Level II Coatings Inspectors*, shall, as a minimum, meet one or more of the following requirements:

8.3.1 High school graduation plus one year of satisfactory performance as a Level I coating inspector in the corresponding inspection activity.

8.3.2 High school graduation plus three years of related experience in equivalent inspection activities.

8.3.3 Completion of college level work leading to an Associate Degree plus one year of related experience in equivalent inspection activities.

8.3.4 Four-year college graduation plus six months of related experience in equivalent inspection activities.

8.4 *Level III Coatings Inspectors*, shall meet one or more of the following requirements:

8.4.1 High school graduation plus six years of satisfactory performance as a Level II coatings inspector in the corresponding inspection activity.

8.4.2 High school graduation plus ten years of related experience in equivalent inspection activities; or high school graduation plus eight years experience in equivalent inspection activities, with at least two years as a Level II coatings inspector. The candidate shall have at least two years associated with nuclear facilities or sufficient training to be knowledgeable of the quality assurance requirements for nuclear coating work.

8.4.3 Completion of college level work leading to an Associate Degree and seven years of related experience in equivalent inspection activities. The candidate shall have at least two years of this experience associated with nuclear

RECORD OF CERTIFICATION

Date Certified: _____

Expiration: _____

TO WHOM IT MAY CONCERN:

SUBJECT: Coatings Inspector Certification, Level ___

REFERENCE: ASTM Standard Guide _____ Rev. ___

_____ has complied with, and successfully passed, all of the applicable requirements of the referenced Standard Guide.

EXAMINATION SCORES

GENERAL PORTION _____
SPECIFIC PORTION _____
PRACTICAL PORTION _____

I certify that the above statements are correct and recommend certification as a Level _____ Coatings Inspector.

RECOMMENDED BY

NAME: _____
Type or print followed by signature

TITLE: _____

The above statement and recommendation have been reviewed for conformance to the requirements of the referenced Standard, and are correct. This individual is certified as Level ___ coatings inspector in accordance with the referenced Standard Guide.

CERTIFIED BY

_____
Type or print name followed by signature
(must comply with 11.3 of the Standard Guide)

FIG. 4 Sample Record of Certification

facilities or sufficient training to be knowledgeable of the quality assurance requirements for nuclear coating work.

8.4.4 Four-year college graduation plus five years of related experience in equivalent inspection activities. The candidate shall have at least two years of this experience associated with nuclear facilities or sufficient training to be knowledgeable of the quality assurance requirements for nuclear coating work.

8.5 Compliance with the requirements of 8.1, 8.2, 8.3, and 8.4 shall be documented on an Education and Experience Record (Fig. 2 or equivalent form).

8.6 Training leading to certification or recertification as a qualified coatings inspector shall be documented on an Organizational Training Record (Fig. 3 or equivalent form).

9. Examination

9.1 Each candidate for coatings inspector shall be given an examination covering the general, specific, and practical aspects of coatings inspection. The general and specific portions of the examination may be written, in the form of a personal interview, or a combination of both. The examination results shall be documented in accordance with 11.1.

9.1.1 The general portion of the examination shall cover the basic principles of quality assurance and coating work inspection.

9.1.2 The specific portion of the examination shall cover specific coating work requirements and inspection procedures.

9.1.3 The practical portion of the examination shall cover the use of coating work inspection equipment and inspection procedures.

9.1.4 All parts of the examination for a Level I or Level II coatings inspector shall be administered by a Level III

coatings inspector or a duly authorized Level II coatings inspector.

9.1.5 Examinations for a Level III coatings inspector shall be administered by a certified Level III coatings inspector or by the responsible organization's management.

10. Performance

10.1 Personnel assigned the responsibility and authority to perform functions covered by this guide shall have, as a minimum, the appropriate level of capability given in Section 6. When a single inspection requires implementation by a team or group, personnel not meeting the requirements of this Guide may be used in data-taking assignments or in plant or equipment operation provided they are supervised or overseen by a qualified individual participating in the inspection.

10.2 A certified coatings inspector shall submit annually a summary of coatings related inspection/testing activities performed between certification anniversary dates in order to maintain the validity of the certification. This summary for a Level I or Level II coatings inspector shall be reviewed by a certified Level III coatings inspector or his designee, signed and placed in the coatings inspector's certification file. The summary review for a Level III coatings inspector shall be conducted by another certified Level III coatings inspector or the responsible organization's management, signed and placed in the inspector's certification file.

10.3 Any certified coatings inspector not performing coatings related inspection/testing work between certification anniversary dates shall be recertified in accordance with 11.2, after it is reconfirmed that the inspector's capabilities meet the requirements of this guide.

11. Certification of Inspectors

11.1 Level I and Level II coatings inspection certifications are valid for a period not to exceed three years. Level III coatings inspector certifications are valid for a period not to exceed five years. Coatings inspectors are certified after review of the candidate's qualifications for compliance with this guide. The examiner shall document the interview of the candidate and the review of the candidate's capabilities, education, experience, vision records, training records, and applicable examination records. Certifications are documented on a Record of Certification (Fig. 4 or equivalent form).

11.2 Coatings inspectors shall be recertified as required by 11.1 after evaluation of their work record. Individual work records shall show evidence of continuing satisfactory performance.

11.3 Level I and Level II coatings inspectors are certified or recertified by a certified Level III coatings inspector. Level III coatings inspectors are certified or recertified by the responsible organization's management or by a certified Level III coatings inspector.

11.4 Certification by a given employer shall be considered revoked when employment is terminated.

12. Records

12.1 A personnel qualification records file shall be established and maintained by the employer. Collection, storage, and control of records required by this guide shall be in accordance with the requirements of the responsible organization and appropriate specifications.

13. Keywords

13.1 certified coatings inspector; coatings inspection; coatings inspector; inspector certification; Level II Coatings Inspector; Level III Coatings Inspector; nuclear coatings inspector; qualified coatings inspector

Designation: D 4538 - 90a

Standard Terminology Relating to Protective Coating and Lining Work for Power Generation Facilities[1]

This standard is issued under the fixed designation D 4538; 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.

alligatoring—*in protective coatings*, surface cracking of coating film having an appearance similar to alligator hide.

certification—*in protective coatings*, the written documentation of the qualification of personnel or material.

checking—*in protective coatings*, the formation of slight breaks in a coating film that do not penetrate to the underlying surface.

coating applicator—*in protective coatings*, an organization or individual responsible for applying a protective or decorative coating.

coating system—*in protective coatings*, a protective film consisting of one or more coats, applied in a predetermined order by prescribed methods.

coating work—*in protective coatings*, an all-inclusive term to define all operations required to accomplish a complete coating job; construed to include materials, equipment, labor, preparation of surfaces, control of ambient conditions, application of coating systems, and inspection.

cobwebbing—*in protective coatings*, the formation of fine filaments (cobwebs) or partly dried coating, during spray application.

cracking—*in protective coatings*, the formation of breaks in a coating film that extend through to the underlying surface.

cratering—*in protective coatings*, the formation of round depressions in a coating film that do not expose the previous coat or the substrate.

crawling—*in protective coatings*, a defect in which a wet coating film recedes from a small area to form an uneven surface shortly after application.

crazing—*in protective coatings*, the formation of a criss-cross pattern of minute cracks on the surface of a coating film.

delamination—*in protective coatings*, a separation of one coat from another coat within a coating system; or from the substrate.

deviation—*in protective coatings*, a departure of a characteristic from established procedures or from specified requirements.

drips—*in protective coatings*, the small drops of coating that collect on the edge of the coated work.

dry spray—*in protective coatings*, a rough, powdery, noncoherent film produced when an atomized coating partially dries before reaching the surface.

flaking—*in protective coatings*, the detachment of small pieces of the coating film.

foreign matter—*in protective coatings*, insoluble foreign particles such as sand, lint, dust, and dirt that get mixed with the coating material before, during, or after application; causing the formation of raised specks in the dried film.

hairline crack—*in protective coatings*, a very fine crack (having a hairlike appearance) that is visible on the surface of a dried coating film.

heavy-centered spray pattern—*in protective coatings*, an uneven spray pattern having more coating in the center, and less at the edges.

intercoat contamination—*in protective coatings*, the presence of foreign matter between successive coats.

mudcracking—*in protective coatings*, a particular pattern of cracking in a coating with the appearance of a dried mud puddle (see cracking and checking).

orange peel—*in protective coatings*, the dimpled appearance of a dried coating film resembling the surface of an orange.

pinhole—*in protective coatings*, minute holes through a coat or coats that expose an underlying coat or the substrate.

pinholes—small pore-like flaws in a coating that extend entirely through the applied film and have the general appearance of pin pricks when viewed by reflected light (see Definitions D 16[2]).

qualification—*in protective coatings:* The characteristics or abilities gained through training or experience, or both, that enable an individual to perform a required function.

wrinkling—*in protective coatings*, the formation of a surface appearance in a coating film resembling the skin of a prune.

[1] These definitions are under the jurisdiction of ASTM Committee D-33 on Protective Coating and Lining Work for Power Generation Facilities and are the direct responsibility of Subcommittee D 33.92 on Definitions.

Current edition approved Nov. 30, 1990. Published January 1991. Originally published as D 4538 - 86a. Last previous edition D 4538 - 90.

[2] Definitions D 16, of Terms Relating to Paint, Varnish, Lacquer, and Related Products (Committee D - 1 on Paint and Related Coatings and Materials).

Designation: D 4540 – 92

Standard Guide for Testing Interior Latex Semigloss and Gloss Paints[1]

This standard is issued under the fixed designation D 4540; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

1. Scope

1.1 This guide covers the selection and use of procedures for testing latex semigloss or gloss paints intended for use on interior walls or trim. The test methods included are listed in Tables 1 and 2.

1.2 The latex semigloss and gloss paints covered by this guide are intended for application by brushing, rolling, spraying, or other means, on plaster, masonry surfaces, wood, wallboard, previously painted surfaces and other interior architectural surfaces.

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

2. Referenced Documents

2.1 *ASTM Standards:*

D 16 Terminology Relating to Paint, Varnish, Lacquer, and Related Products[2]
D 185 Test Methods for Coarse Particles in Pigments, Pastes, and Paints[3]
D 344 Test Method for Relative Hiding Power of Paints by the Visual Evaluation of Brushouts[2]
D 522 Test Methods for Mandrel Bend Test of Attached Organic Coatings[2]
D 523 Test Method for Specular Gloss[2]
D 562 Test Method for Consistency of Paints Using the Stormer Viscometer[2]
D 869 Test Method for Evaluating Degree of Settling of Paint[4]
D 1210 Test Method for Fineness of Dispersion of Pigment-Vehicle Systems[2]
D 1475 Test Method for Density of Paint, Varnish, Lacquer, and Related Products[2]
D 1640 Test Methods for Drying, Curing, or Film Formation of Organic Coatings at Room Temperature[3]
D 1729 Practice for Visual Evaluation of Color Differences of Opaque Materials[2]
D 1736 Test Method for Efflorescence of Interior Wall Paints[4]
D 1849 Test Method for Package Stability of Paint[4]
D 2196 Test Methods for Rheological Properties of Non-Newtonian Materials by Rotational (Brookfield) Viscometer[2]
D 2243 Test Method for Freeze-Thaw Resistance of Water-Borne Paints[4]
D 2244 Test Method for Calculation of Color Differences from Instrumentally Measured Color Coordinates[2]
D 2369 Test Method for Volatile Content of Coatings[2]
D 2486 Test Method for Scrub Resistance of Interior Latex Flat Wall Paints[4]
D 2574 Test Method for Resistance of Emulsion Paints in the Container to Attack by Microorganisms[2]
D 2805 Test Method for Hiding Power of Paints by Reflectometry[2]
D 2831 Test Method for Evaluating the Ability of a Latex Paint to Resist Efflorescence from the Substrate[2]
D 3258 Test Method for Porosity of Paint Films[4]
D 3450 Test Method for Washability Properties of Interior Architectural Coatings[4]
D 3793 Test Method for Low-Temperature Coalescence of Latex Paint Films[4]
D 3925 Practice for Sampling Liquid Paints and Related Pigmented Coatings[2]
D 3928 Test Method for Evaluation of Gloss or Sheen Uniformity[4]
D 3960 Practice for Determining Volatile Organic Compound (VOC) Content of Paints and Related Coatings[2]
D 4062 Test Method for Leveling of Paints by Draw-Down Method[4]
D 4213 Test Method for Wet Abrasion Resistance of Interior Paints[4]
D 4287 Test Method for High-Shear Viscosity Using the ICI Cone/Plate Viscometer[2]
D 4400 Test Methods for Sag Resistance of Paints Using a Multinotch Applicator[4]
D 4707 Test Method for Measurement of Paint Spatter Resistance to Roller Application[4]
D 4958 Test Method for Comparison of the Brush Drag of Latex Paints[4]
E 70 Test Method for pH of Aqueous Solutions with the Glass Electrode[5]
E 105 Practice for Probability Sampling of Materials[6]

2.2 *U.S. Federal Test Methods Standard No. 141:*[7]

2112 Application by Roller
2131 Application of Sprayed Films
2141 Application of Brushed Films

[1] This guide is under the jurisdiction of ASTM Committee D-1 on Paint and Related Coatings, Materials and Applications and is the direct responsibility of Subcommittee D01.42 on Architectural Finishes.

Current edition approved May 15, 1992. Published July 1992. Originally published as D 4540 – 85. Last previous edition D 4540 – 91.

[2] *Annual Book of ASTM Standards*, Vol 06.01.
[3] *Annual Book of ASTM Standards*, Vol 06.03.
[4] *Annual Book of ASTM Standards*, Vol 06.02.
[5] *Annual Book of ASTM Standards*, Vol 15.05.
[6] *Annual Book of ASTM Standards*, Vol 14.02.
[7] Available from Standardization Documents Order Desk, Bldg. 4 Section D, 700 Robbins Ave., Philadelphia, PA 19111-5094.

3011 Condition in Container
4061 Drying Time
4321 Brushing Properties
4541 Working Properties and Appearance of Dried Film

3. Terminology

3.1 *Definitions:*

3.1.1 For definitions of terms used in this guide, see Terminology D 16.

4. Conditions Affecting Latex Semigloss and Gloss Paints

4.1 *Substrate Type*—The substrate to be painted can affect not only the application properties and the physical properties of a latex paint, such as gloss and uniformity, but may also be a factor in determining the type of latex paint to be used.

4.2 *Substrate Condition*—Dirty, alkaline, or water-soluble surfaces may affect the practical requirements and performance of these paints.

4.3 *Application Properties*—The application properties of paints are affected by temperature, humidity, and the texture and porosity of the surface to be painted. Application is also affected by the type and quality of equipment used.

5. Selection of Tests

5.1 Many conditions affect interior latex semigloss and gloss paints, so that different types of latex paints have been developed specifically to meet the requirements of these various conditions. Although the recommended test methods in Tables 1 and 2 cover most of the properties of such paints, all of the tests may not be required for each paint. If a paint is to be used only in a warm climate for instance, then freeze-thaw tests or low temperature coalescence tests need not be considered.

5.2 The purchaser should first determine which properties a latex paint must have and then select only the test methods that will measure or evaluate those properties. After selecting the desired tests, the purchaser should determine which of these properties are the most important and establish the appropriate requirements or specifications for obtaining the desired properties. Since paint properties frequently tend to oppose each other, some properties may need to be attenuated if others are to be accentuated. This balance of properties must be considered when selecting the tests and establishing their requirements. A normal range of values is indicated in many of the tests methods.

5.3 This guide does not indicate relative importance of the various tests nor does it recommend specific values for each test, since the properties that are important to one purchaser may not be important to another.

TABLE 1 List of Test Methods by Properties

Test Method	Section	ASTM Test Method	Federal Test Method Standard No. 141
Sampling	6	D 3925	
Liquid Paint Properties:			
Condition in container	7.1		3011
Coarse particles and foreign matter	7.2	D 185	
Density (weight per gallon)	7.3	D 1475	
Fineness of dispersion	7.4	D 1210	
Odor	7.5		
Color compatibility	7.6		
Package Stability:	7.7	D 1849	
Accelerated heat-aged stability	7.7.1		
Freeze-thaw stability	7.7.2	D 2243	
Microorganism resistance	7.7.3	D 2574	
pH stability	7.7.4	E 70	
Settling	7.7.5	D 869	
Paint Application and Film Formation:			
Application properties	8.1		4541
Application by brush	8.1.1		2141
Brush drag	8.1.1.1	D 4958	
Application by roller	8.1.2		2112
Roller spatter	8.1.2.1	D 4707	
Application by spray	8.1.3		2131
Drying time	8.2	D 1640	
Low-temperature coalescence of paints	8.3	D 3793	
Touch-up uniformity	8.4	D 3928	
Rheological Properties:			
Leveling	9.1	D 4062	
Low shear viscosity (consistency)	9.2	D 562	
High shear viscosity (ICI cone and plate viscosity)	9.3	D 4287	
Sag resistance	9.4	D 4400	
Rheological properties, non-Newtonian liquids	9.5	D 2196	
Appearance of Dry Paint Film:			
Color difference by visual evaluation	10.1	D 1729	
Color difference using instrumental measurements	10.2	D 2244	
Hiding power	10.3	D 344, D 2805	
Specular gloss	10.4	D 523	
Properties of Dry Paint Film:			
Block Resistance	11.1		
Efflorescence of paint film	11.2	D 1736	
Efflorescence from substrate	11.3		
Flexibility	11.4	D 522	
Film porosity	11.5	D 3258	
Print resistance	11.6		
Scrubbability (wet abrasion)	11.7	D 4213 or D 2486	
Stain removal (washability)	11.8	D 3450	
Wet adhesion	11.9		
Analysis of Paint:			
Chemical analysis	12.1		
Nonvolatile content	12.2	D 2369	
Volatile organic compound (VOC)	12.3	D 3960	

6. Sampling

6.1 Prior to sampling, the condition of the container should be established since damage to it may cause evaporation or skinning of the pigment or other undesirable effects in the coating. Determine the condition of the coating in accordance with 7.1 and 7.2.

6.2 Sample in accordance with Practice D 3925. Determine the weight per gallon in accordance with Test Method D 1475. Repeat this procedure until successive readings agree within 0.2 lb (90 g) or as agreed upon between purchaser and seller. Samples for testing may then be taken.

6.3 Specify the identification codes. A 1 U.S. gallon (or 4-L) sample is usually sufficient for the recommended tests, but for guidance in selecting a sampling plan, consult Practice E 105.

7. Liquid Paint Properties

7.1 *Condition in the Container*—Thickening, settling, and separation are undesirable and objectionable if the paint

TABLE 2 Alphabetical List of Test Methods

Test Method	Section	ASTM Test Method	Federal Test Method Standard No. 141
Accelerated heat-aged stability	7.1.1		
Application properties	8.1		4541
Application by brush	8.1.1		2141
Application by roller	8.1.2		2112
Application by spray	8.1.3		
Block resistance	11.1		
Brush drag	8.1.1.1	D 4958	4321
Chemical analysis	12.1		
Coarse particles and foreign matter	7.2	D 185	
Color compatibility	7.6		
Color difference using instrumental measurements	10.2	D 2244	
Color difference by visual evaluation	10.1	D 1729	
Condition in container	7.1		3011
Consistency (viscosity)	9.2	D 562	
Density (weight per gallon)	7.3	D 1475	
Drying time	8.2	D 1640	4061
Efflorescence of paint film	11.2	D 1736	
Efflorescence from substrate	11.3	D 2831	
Film Porosity	11.5	D 3258	
Fineness of dispersion	7.4	D 1210	
Flexibility	11.4	D 522	
Freeze-thaw stability	7.7.1	D 2243	
Hiding power	10.3	D 344, D 2805	
High shear viscosity	9.3	D 4287	
Leveling	9.1	D 4062	
Low temperature coalescence of paints	8.3	D 3793	
Microorganism resistance	7.7.3	D 2574	
Nonvolatile content (see volatile content)	12.2		
Odor	7.5		
Package stability	7.7	D 1849	
pH	7.7.4	E 70	
Print resistance	11.6		
Rheological properties of non-Newtonian liquids	9.5	D 2196	
Roller spatter	8.1.2.1	D 4707	
Sag resistance	9.4	D 4400	
Sampling	6	D 3925	
Scrubbability (wet abrasion, scrub resistance)	10.7	D 2486, D 4213	
Settling	7.7.5	D 869	
Specular gloss	10.4	D 523	
Stain removal (washability)	11.8	D 3450	
Touch-up uniformity	8.4	D 3928	
Volatile content	12.2	D 2369	
Volatile organic compound (VOC)	12.3	D 3960	
Wet adhesion	11.9		

cannot be reconditioned with a reasonable amount of stirring. The referenced method covers procedures for determining changes in properties of paints after storage. Determine the condition in the container in accordance with Method 3011 of Federal Test Method Standard No. 141. (See also 7.7 on Package Stability.)

7.2 *Coarse Particles and Foreign Matter:*

7.2.1 Paints must be free of coarse particles to form uniform films of good appearance, a typical maximum being 1 weight % of total paint. The specified test with a 325-mesh (45-μm) screen and water as the wash liquid gives the percent of these particles in a latex paint. Determine coarse particles and foreign matter in accordance with Test Methods D 185.

7.2.2 Another test method used in industry to determine whether coarse particles are present in a dry film is to scrape the surface of the film with a spatula or metal edge of a ruler. Any particles larger than 325 mesh (45 μm) can be clearly seen after the surface has been scraped.

7.3 *Density (Weight per Gallon)*—The density as measured by weight per gallon (kilograms per litre) is used to assure product uniformity from batch to batch. It does not necessarily measure the quality of a paint. In the referenced method, the density is expressed as the weight in pounds per U.S. gal (or kg/L) of the paint at a specified temperature. Most interior semigloss and gloss paints have densities of about 10 to 12 lb/gal (1.2 to 1.4 kg/L). Determine density in accordance with Test Method D 1475.

7.4 *Fineness of Dispersion:*

7.4.1 The more finely a pigment is dispersed, the more efficiently it is being used. One method for measuring the degree of dispersion (commonly referred to as "fineness of grind") is to draw the material down a calibrated tapered groove varying in depth from 4 to 0 mils (100 to 0 μm). The Hegman scale is one commonly accepted measurement method. The point at which the continuous groupings of particles or agglomerates, or both, protrude through the surface of the liquid is taken as the fineness reading. Lower readings in mils or micrometres or higher readings in Hegman units indicate better fineness dispersion. Measure fineness of dispersion in accordance with Test Method D 1210.

7.4.2 The referenced method was designed primarily for coatings with good fineness of dispersion such as enamels. Most interior semigloss and gloss latex paints have a fineness of about 7.5 to 5 Hegman (6 to 40 μm).

7.5 *Odor*—One of the advantages of latex paints is that they do not have odors characteristic of solvent-reducible coatings. However, other ingredients, such as ammonia, may be used that might also be objectionable in confined spaces. Thus, interior latex paints should be tested for odor acceptability. Determine whether the paint has an unpleasant or irritating odor during application or drying.

7.6 *Color Compatibility*—A test method to determine how well colorants can be dispersed in paints so that the paint will have uniformity of color when applied is in preparation and will be included in the guide when adopted by ASTM.

7.7 *Package Stability*—Since paints cannot normally be used immediately after manufacture they must remain stable in the can for some time. At normal temperatures, most latex paints can be stored for over a year with little change in properties. Although indications of long term package stability can usually be obtained in several days or weeks at an elevated temperature, such as 140°F (60°C) or 122°F (50°C), occasionally the results of the accelerated test do not agree with those at prolonged normal storage conditions. The referenced method predicts the change in consistency and certain other properties in packaged latex paint when stored at temperatures above freezing. Determine package stability in accordance with Test Method D 1849.

7.7.1 *Heat Stability*—Heating is used to accelerate changes in viscosity with time and to predict their affect on other properties. An excessive increase or decrease in viscosity after heat-aging is unacceptable. There is a general correlation between short-term high temperature oven stability and long-term shelf storage at ambient temperature. This test is meant to predict which paints will not be stable

when stored by customers or consumers under elevated temperature for a short period of time or at room temperature for a longer period of time. After heat-aging, such properties as viscosity, flow, gloss, pH drift, foam resistance, color uniformity, and wet adhesion are usually rechecked versus room temperature-aged controls.

7.7.2 *Freeze-Thaw Stability*—Water-reducible paints may be subjected to freezing conditions during shipping and storage. Suitably stabilized paints will resist several cycles of freezing and thawing without showing deleterious changes such as coagulation, graininess, or excessive viscosity increase. Many latex paints will increase in viscosity but can still be considered satisfactory if other properties that may be affected by a higher viscosity, such as leveling and brushability, are satisfactory. Determine freeze-thaw stability in accordance with Test Method D 2243.

7.7.3 *Microorganism Resistance*—Bacteria in a latex paint can cause gassing, putrefactive or fermentative odors, and loss of viscosity. Determine if the paint contains living bacteria or if it is resistant to attack by bacteria in accordance with Test Method D 2574.

7.7.4 *pH*—Latex paints with low (acidic) pH can corrode metal containers. pH may vary from about 5 to 10 depending upon the type of latex used and general formulation. pH does not determine the quality of a latex paint and should only be used to assure product uniformity. However, a change in pH during storage may indicate poor stability and unacceptable change in the properties of a paint. Determine pH in accordance with Test Method E 70.

7.7.5 *Settling*—Latex paints are generally resistant to hard settling, but do at times show separation and soft settling. The referenced method covers the degree of pigment suspension and ease of remixing a shelf-aged sample of paint to a homogeneous condition suitable for the intended use. Determine settling in accordance with Method D 869.

8. Paint Application and Film Formation

8.1 *Application Properties*—Determine the ease with which a paint can be applied to various wall surfaces with brush, roller, or spray equipment, in accordance with Method 4541 of Federal Test Method Standard No. 141. Application properties are generally compared to a standard, or described by requirements in a product specification.

8.1.1 *Brush Application*—Brushed films should be smooth and free of seeds and on vertical surfaces should show no sagging, color streaking, or excessive brush marks. The specified method covers the determination of the brushing properties of coatings. The test is subjective although those experienced in the art can produce quite consistent results, particularly in the evaluation of "drag" properties. Determine brushing properties in accordance with Method 4321 of Federal Test Method Standard No. 141.

8.1.1.1 *Brush Drag*—As the brush drag (resistance encountered when applying a coating by brush) increases, any natural tendency of the painter to overspread the paint is reduced. All other factors being constant, increased brush drag results in greater film thickness with consequent improvements in hiding and film durability. Conversely, increasing brush drag too much can cause difficulties in spreading the paint easily and uniformly, leading to excessive sagging, prolonged drying time and, in highly-pigmented latex paints, possibly to "mud-cracking" due to excessive thickness. The referenced method covers the determination of relative brush drag of a series of coatings applied by brush by the same operator. It has been established that the subjective ratings thus obtained correlate well with high-shear viscosities obtained instrumentally using Test Method D 4287 (see 9.3), provided that the paints differ in viscosity by at least 0.3 poise (0.03 Pa·s). Determine brush drag ratings in accordance with Test Method D 4958.

8.1.2 *Roller Application*—Wall coatings are frequently applied by roller. This type of application tends to produce some stipple pattern. The referenced method covers the evaluation of a material's characteristics when applied by roller. Determine roller coating properties in accordance with Method 2112 of Federal Test Method Standard No. 141.

8.1.2.1 Some coatings spatter more than others when applied by roller. The degree to which a paint spatters when roller-applied can be determined by the density of the spatter. In the referenced method, a specially designed notched spool is rolled through a film of the test material that has been applied to a plastic panel. Any spatter generated falls upon a catch paper and after drying is rated against photographic standards. This procedure eliminates the influence of the roller cover, thus determining the spattering characteristics of the paint alone. Determine spatter resistance in accordance with Test Method D 4707.

8.1.3 *Spray Application*—Interior coatings are sometimes applied by spray. Both air and airless spray are used on commerical work. Determine the spray application properties in accordance with Method 2131 of Federal Test Method Standard No. 141. The method can be modified to include application by airless spray equipment.

8.2 *Drying Properties*—The drying time of an interior latex paint is important in determining when a freshly painted room can be put back to use. Under average conditions most semigloss and gloss latex paints are dry to touch in 1 to 2 h when the water has evaporated from the film. Because of the glycols usually present in these paints, it is prudent to recoat after at least an 18-h dry. Ultimate properties may take a few days to develop for some latex paints while others may require a few weeks depending on the composition. Determine the drying time in accordance with Test Methods D 1640.

8.3 *Low-Temperature Coalescence of Paints*—The referenced test method determines how well the latex particles in a paint will fuse together or coalesce, to form a continuous film at low temperatures. Determine low-temperature coalescence in accordance with Test Method D 3793.

8.4 *Touch-Up Uniformity*—After paint has dried, areas where less material was applied sometimes become noticeable. If the paint has suitable touch-up properties, additional paint can be applied to these areas only, instead of refinishing the complete wall. The color, gloss, and leveling of the touched-up areas and the previously painted area should be uniform. Differences in these properties are often caused by short wet edge time, poor leveling on recoat and pigment orientation or floatation during and after application. Determine touch-up properties in accordance with Test Method D 3928.

9. Rheological Properties

9.1 *Leveling*—Leveling is an important factor when uniform surfaces are to be produced as it affects hiding power and appearance. Brush marks and imperfections are much more conspicuous in semigloss and gloss paints than they are in flat paints. The referenced method covers the leveling characteristics of liquid coatings. Evaluate leveling in accordance with Test Method D 4062.

9.2 *Low Shear Viscosity (Consistency)*—Paints of a given type should fall within a stated consistency range for satisfactory reproduction of a specific formula. While consistency is an important property, it does not determine the quality of a paint and should be used mainly to ensure product uniformity. In the referenced method, consistency is defined as the load in grams to produce a specified rate of shear. Although the consistency of most latex wall paint is about 150 to 300 g, a much wider range is possible because of the wide variations in rheological properties of these paints. Two paints of the same consistency may have quite different rheological properties since this is only a measure of their low shear viscosity. Optimized application properties are generally used to determine the optimum consistency. Measure the consistency in accordance with Test Method D 562.

9.3 *High Shear Viscosity (ICI Cone and Plate Viscosity)*—The shear rate for this measurement (10 000 reciprocal seconds) is similar to that occurring during brush application, and the viscosity measured at this shear rate therefore is related to brush drag, which is in turn related to spreading rate and film build. Measure the high shear viscosity in accordance with Test Method D 4287.

9.4 *Sag Resistance*—This is an important property particularly for semigloss and gloss latex paints because sagging results in unsightly film appearance. Measure the sag resistance in accordance with Test Methods D 4400.

9.5 *Rheological Properties, Non-Newtonian Liquids*—Rheological properties are related to application and leveling properties of the liquid paint. The referenced methods cover the determination of rheological properties and are particularly suited for use with paints that display thixotropic characteristics. They actually measure viscosity under different shear rates. Latex paints generally range from 0.5 to 3 poise (0.05 to 0.3 Pa·s) when the high-shear viscosity is measured with the cone and plate viscometer. Determine rheological properties in accordance with Test Methods D 2196 or D 4287, or both.

10. Appearance of Dry Film

10.1 *Color Differences by Visual Evaluation*—Visual comparison of color is fast and often acceptable although numerical values are not obtained. The referenced method covers the spectral, photometric, and geometric characteristics of light source, illuminating and viewing conditions, size of specimens, and general procedures to be used in the visual evaluation of color differences of opaque materials. Determine color differences in accordance with Practice D 1729.

10.2 *Color Differences Using Instrumental Measurements*—The differences in color between a product and its standard can be measured by instrument. Generally, the tolerance is agreed upon by the purchaser and the seller and may also be required if a product specification is involved. Color instruments provide numerical values that can be compared to subsequent measurements. The referenced method covers the instrumental determination of small color differences observable in daylight illumination between nonmetameric, opaque surfaces such as coated specimens. If metamerism is suspected, visual evaluation (see 10.1) should be used to verify the results. Calculate in accordance with Test Method D 2244 the color differences that have been measured instrumentally.

10.3 *Hiding Power (Dry Opacity)*—Hiding power is the measure of the ability of a paint to hide the substrate. It is, however, dependent upon uniform film thickness that is influenced by flow and leveling. Test Method D 344 is a practical test in which paint is applied with a brush, film thickness is approximately measured, opacity is evaluated visually compared to a standard paint, and results are affected by flow and leveling application properties of the paint. Test Method D 2805 is considered to be a more precise and accurate test that does not need a material paint standard. Paint is applied with an applicator bar to minimize the effects of flow and leveling, film thickness is rigorously measured, and opacity is instrumentally evaluated. Determine hiding power in accordance with Test Methods D 344 or D 2805.

10.4 *Specular Gloss*—The method given, using the 20° geometry for high gloss paints and 60° geometry for semigloss paints, is useful in characterizing the direct appearance of gloss and semigloss paints. According to the *Paint/Coatings Dictionary*,[8] the semigloss range is usually 35 to 70 using the 60° geometry. Full gloss is usually above 70 using the 60° geometry. Although paints with good uniformity of appearance are often paints of lower gloss and paints with good cleanability are often ones with higher gloss, this is not always the case, and the gloss of a paint should not be used as a measure of other paint properties. Determine the gloss at 20° and 60°, as appropriate, gloss in accordance with Test Method D 523.

11. Properties of Dry Film

11.1 *Block Resistance*—This is an important property of an interior semigloss or gloss since it is the resistance of the painted surfaces to stick together when stacked or placed in contact with each other. An interior paint often comes in contact with itself especially in the cases of doors, windows and drawers and sometimes sticks to itself (blocks) depending on the hardness of the coating, the pressure, temperature, humidity, and duration of time the surfaces are in contact.

11.2 *Efflorescence of the Paint Film*—The referenced method measures efflorescence that comes from the paint itself, not from the substrate. Few interior latex paints effloresce due to improvements in latex and latex paint formulations. Salt formation is produced by specific conditions of temperature and humidity if a paint contains sufficient solid water-soluble material to cause a noticeable deposit on the film. Determine efflorescence resistance in accordance with Test Method D 1736.

11.3 *Efflorescence from Substrate*—Cementitious sub-

[8] Available from Federation of Societies for Coatings Technology, 492 Norristown Rd., Blue Bell, PA 19422.

stances may contain sufficient solid water-soluble materials to cause a surface deposit through leaching and evaporation.

11.4 *Flexibility*—Elongation is a measure of the flexibility of a paint film. Most interior latex paints can be bent over a ⅛-in. (3.2-mm) mandrel without affecting the film. Determine elongation in accordance with Test Methods D 522.

11.5 *Film Porosity*—The more porous a paint is, the worse will be its cleanability and enamel holdout. Determine film porosity in accordance with Test Method D 3258.

11.6 *Print Resistance*—The ability of a coating to resist printing is important because its appearance is adversely affected if the surface texture is modified by contact with another surface particularly one with a pattern. Interior gloss and semigloss systems on window sills and other horizontal surfaces often have flower pots placed on them that may tend to leave a permanent impression from the pressure. This tendency for a paint film to "print" is often a function of the hardness of the coating, the pressure, temperature, humidity, and duration of time that the painted surface is in contact with the object.

11.7 *Scrubbability*—The ability of an interior finish to resist scrubbing is an important property. The referenced method provides a measure of the wet abrasion resistance of a film. However, wet abrasion resistance is not necessarily a measure of how well soils or stains can be removed since some paints have good scrubbability but poor stain cleanability because they are porous. Determine the scrubbability in accordance with Test Method D 4213 or D 2486. A control paint should always be tested at the same time because of the variability of the method.

11.8 *Stain Removal (Cleanability)*—The ability to remove marks satisfactorily without damaging the film is an important property of interior finishes. Determine stain removal in accordance with Test Method D 3450.

11.9 *Wet Adhesion*—It is essential that an interior finish adhere tightly to a given substrate or primer under the wet conditions of washing or scrubbing.

12. Analysis of Paint

12.1 *Chemical Analysis*—If a specification requires certain raw materials or certain components in a given amount, then chemical analysis is required to determine whether the specified materials are present and in what amounts. Analysis does not necessarily establish paint quality that can also be greatly affected by manufacturing techniques. Most ASTM analytical methods apply to solvent-based coatings. However, some of them can be adapted for analysis of latex paints.

12.2 *Volatile Content*—The percent of volatile matter is a measure of the amount of a liquid coating lost as it dries. This quantity is not necessarily indicative of the quality of a coating. It is useful, however, for determining the similarity of two batches. The referenced method covers the determination of the volatile content by weight of solvent- and water-reducible coatings. The quantity determined subtracted from 100 % gives the nonvolatile content. Determine volatile content in accordance with Test Method D 2369.

12.3 *Volatile Organic Compound (VOC) Content*—Several local jurisdictions in California have adopted air pollution controls that severely limit the amount of solvent (Volatile Organic Compound (VOC) content) permitted in architectural coatings, including interior latex gloss and semigloss paints. Since these paints may contain solvents such as coalescents and cosolvent wet edge aids, it is essential that these products not exceed the established VOC limits. Determine VOC content in accordance with Practice D 3960.

13. Field Testing

13.1 Although many of the recommended test methods attempt to simulate conditions under which latex semigloss and gloss wall paints are applied, it is not possible to accurately simulate all possible conditions. Testing latex semigloss and gloss wall paints under field conditions is recommended for the final evaluation of suitability.

14. Keywords

14.1 architectural coatings; gloss paints; interior paints; latex paints; semigloss paints

Designation: D 4541 – 85 (Reapproved 1989)$^{\epsilon 1}$

Standard Test Method for Pull-Off Strength of Coatings Using Portable Adhesion Testers[1]

This standard is issued under the fixed designation D 4541; 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.

$^{\epsilon 1}$ NOTE—Editorial changes were made throughout in April 1989.

1. Scope

1.1 This test method covers a procedure and apparatus for evaluating the pull-off strength (commonly referred to as "adhesion") of a coating by determining either the greatest perpendicular force (in tension) that a surface area can bear before a plug of material is detached, or whether the surface remains intact at a prescribed force (pass/fail). Failure will occur along the weakest plane within the system comprised of the test fixture, adhesive coating system, and substrate and will be exposed by the fracture surface. This test method maximizes tensile stress as compared to the shear stress applied by other methods such as scratch or knife adhesion and results may not be comparable.

1.2 This test method uses a class of apparatus known as pull-off adhesion testers.[2] They are portable and capable of applying a concentric load and counter load to a single surface so that coatings can be tested even though only one side is accessible. Measurements are limited by the strength of adhesion bonds between the loading fixture and the specimen surface or the cohesive strength of the substrate.

1.3 This test can be destructive and spot repairs may be necessary.

1.4 *This standard may involve hazardous materials, operations, and equipment. This standard does not purport to address all of the safety problems associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.* For specific hazard statements, see Notes 2 and 3.

2. Referenced Documents

2.1 *ASTM Standards:*

D 2651 Practice for Preparation of Metal Surfaces for Adhesive Bonding[3]

D 3933 Practice for Preparation of Aluminum Surfaces for Structural Adhesives Bonding (Phosphoric Acid Anodizing)[3]

2.2 *ANSI Standard:*

N 512 Protective Coatings (Paints) for the Nuclear Industry[4]

2.3 *ISO Standard:*

4624 Paints and Varnish—Pull-Off Test for Adhesion[4]

3. Summary of Test Method

3.1 The general pull-off test is performed by securing a loading fixture (dolly) normal (perpendicular) to the surface of the coating with an adhesive. After the adhesive is cured, a testing apparatus is attached to the loading fixture and aligned to apply tension normal (perpendicular) to the test surface. The force applied to the loading fixture is then gradually increased and monitored until either a plug of coating material is detached, or a specified value is reached. When a plug of material is detached, the exposed surface represents the plane of limiting strength within the system. The nature of the failure is qualified in accordance with the percent of adhesive and cohesive failures, and the actual interfaces and layers involved. The pull-off strength is computed based on the maximum indicated load, the instrument calibration data, and the original surface area stressed (see Fig. 1).

4. Significance and Use

4.1 The pull-off strength (commonly referred to as adhesion) of a coating is an important performance property that has been used in specifications. This test method serves as a means for uniformly preparing and testing coated surfaces, and evaluating and reporting the results. This test method is applicable to any portable apparatus meeting the basic requirements for determining the pull-off strength of a coating.

5. Apparatus

5.1 *Adhesion Tester,* commercially available, or comparable apparatus specific examples of which are listed in Annexes A1 and A2 (see Fig. 1):

5.1.1 *Loading Fixtures,* having a flat surface on one end that can be adhered to the coating and a means of attachment to the tester on the other end.

5.1.2 *Detaching Assembly* (adhesion tester), having a central grip for engaging the fixture.

[1] This test method is under the jurisdiction of ASTM Committee D-1 on Paint and Related Coatings and Materials and is the direct responsibility of Subcommittee D01.46 on Industrial Protective Coating.

Current edition approved Nov. 29, 1985. Published January 1986.

[2] The term adhesion tester may be somewhat of a misnomer, but its adoption by two manufacturers and at least two patents indicates continued usage.

[3] *Annual Book of ASTM Standards,* Vol 15.06.

[4] Available from American National Standards Institute, 11 W. 42nd St., 13th Floor, New York, NY 10036.

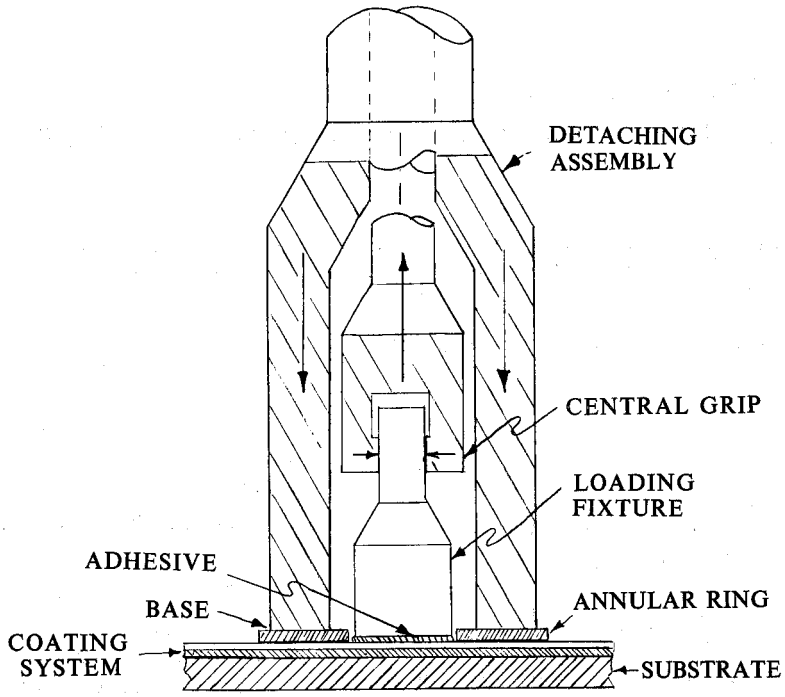


FIG. 1 Schematic of Pull-Off Adhesion Tester

5.1.3 *Base,* on the detaching assembly, or an annular bearing ring if needed for uniformly pressing against the coating surface around the fixture either directly, or by way of an intermediate bearing ring. A means of aligning the base is needed so that the resultant force is normal to the surface. If shims are required when a bearing ring is employed, place them between the tester base and bearing ring rather than on the coating surface.

5.1.4 Means of moving the grip away from the base in as smooth and continuous a manner as possible so that a torsion free, co-axial (opposing pull of the grip and push of the base along the same axis) force results between them.

5.1.5 *Timer,* or means of limiting the rate of stress to less than 150 psi/s (1 MPa/s) so that the maximum stress is obtained in less than about 100 s. A timer would be the minimum equipment when used by the operator along with the force indicator in 5.1.6.

5.1.6 *Force Indicator and Calibration Information,* for determining the actual force delivered to the loading fixture.

5.2 *Solvent,* or other means for cleaning the loading fixture surface. Finger prints, moisture, and oxides tend to be the primary contaminants.

5.3 *Fine Sandpaper,* or other means of cleaning the coating that will not alter its integrity by chemical or solvent attack. If any light sanding is anticipated, choose only a very fine grade abrasive that will not introduce flaws or leave a residue.

5.4 *Adhesive,* for securing the fixture to the coating that does not affect the coating properties. Two component epoxies[5] and acrylics[6] have been found to be the most versatile.

5.5 *Magnetic or Mechanical Clamps,* if needed, for holding the fixture in place while the adhesive cures.

5.6 *Cotton Swabs,* or other means for removing excess adhesive and defining the adhered area. Any method for removing excess adhesive that damages the surface, such as scoring, must generally be avoided since induced surface flaws may cause premature failure of the coating.

5.7 *Circular Hole Cutter* (optional), to score through to the substrate around the loading fixture.

6. Test Preparation

6.1 The method for selecting the coating sites to be prepared for testing depends upon the objectives of the test and agreements between the contracting parties. There are, however, a few physical restrictions imposed by the general method and apparatus. The following requirements apply to all sites:

6.1.1 The selected test area must be a flat surface large enough to accommodate the specified number of replicate tests. The surface may have any orientation with reference to gravitational pull. Each test site must be separated by at least the distance needed to accommodate the detaching appa-

[5] Araldite Adhesive, available from Ciba-Geigy Plastics, Duxford, Cambridge, CB2 4QA, England, Scotch Weld Adhesive 1838B/A, available from 3M, Adhesive Coatings amd Sealers Div., 3M Center, St. Paul, MN 55144, and Hysol Epoxy Patch Kit 907, available from Hysol Div., The Dexter Corp., Willow Pass Rd., Pittsburg, CA 94565, have been found satisfactory for this purpose.

[6] Versiloc 201 and 204 with accelerator, available from Lord Corp., Industrial Adhesive Div., 2010 W. Grandview Blvd., P.O. Box 10038, Erie, PA 16514, have been found satisfactory for this purpose.

ratus. The size of a test site is essentially that of the secured loading fixture. At least three replications are usually required in order to statistically characterize the test area.

6.1.2 The selected test areas must also have enough perpendicular and radial clearance to accommodate the apparatus, be flat enough to permit alignment, and be rigid enough to support the counter force.

6.2 Since the rigidity of the substrate affects pull-off strength results and is not a controllable test variable in field measurements, some knowledge of the substrate thickness and composition should be reported for subsequent analysis or laboratory comparisons. For example, steel substrate of less than ⅛-in. (3.2-mm) thickness may reduce pull-off strength results compared to ¼ in. (6.4 mm) thick panels.

6.3 Subject to the requirements of 6.1, select representative test areas and clean the surfaces in a manner that will not affect integrity of the coating or leave a residue. Surface abrasion may introduce flaws and should generally be avoided. A light abrasive should only be used if needed to remove loose or weakly adhered surface contaminants.

6.4 Clean the loading fixture surface as indicated by the apparatus manufacturer. Failures at the fixture-adhesive interface can often be avoided by treating the fixture surfaces in accordance with an appropriate ASTM standard practice for preparing metal surfaces for adhesive bonding.

NOTE 1—Practices D 2651 and D 3933 are typical of well-proven methods for improving adhesive bond strengths to metal surfaces.

6.5 Mix the adhesive in accordance with the adhesive manufacturer's recommendations, applying the adhesive between the fixture and the surface to be tested using a method preferred by the adhesion-tester manufacturer. Carefully remove the excess adhesive from around the fixture.

NOTE 2: **Caution**—Movement, especially twisting, can cause tiny bubbles to coalesce into large holidays that constitute stress discontinuities during testing.

6.6 Based on the adhesive manufacturer's recommendations and the anticipated environmental conditions, allow enough time for the adhesive to set up and reach the recommended cure. During the adhesive set and early cure stage, a constant contact pressure should be maintained on the fixture. Magnetic or mechanical clamping systems work well, but systems relying on tack, such as masking tape, should be used with care to ensure that they do not relax with time and allow air to intrude between the fixture and the test area.

6.7 Scoring around the fixture violates the fundamental in-situ test criterion that an unaltered coating be tested. If scoring around the test surface is employed, extreme care is required to prevent micro-cracking in the coating. Such cracks may cause failures at diminished strengths. Scored samples constitute a different test, and this procedure should be clearly reported with the results.

6.8 Note the approximate temperature and relative humidity during the time of test.

7. Test Procedure

7.1 Select an adhesion-tester with a detaching assembly having a force calibration spanning the range of expected values along with its compatible loading fixture. Mid-range measurements are usually the best, but before proceeding, read the manufacturer's operating instructions.

7.2 If a bearing ring or comparable device (5.1.3) is to be used, place it concentrically around the loading fixture on the coating surface.

7.3 Carefully connect the central grip of the detaching assembly to the loading fixture without bumping, bending, or otherwise prestressing the sample and connect the detaching assembly to its control mechanism, if necessary. For nonhorizontal surfaces, the detaching assembly should be manually supported so that its weight does not contribute to the force exerted in the test.

7.4 Align the device according to the manufacturer's instructions and set the force indicator to zero.

NOTE 3: **Caution**— Proper alignment is critical. If shims are needed for fixed alignment devices, report the manner in which used.

7.5 Increase the load to the fixture in as smooth and continuous a manner as possible, at a rate of less than 150 psi/s (1 MPa/s) so that failure occurs or the maximum stress is reached in about 100 s or less.

7.6 Record the force attained at failure or the maximum force applied.

7.7 If a plug of material is detached, label and store the fixture for qualification of the failed surface in accordance with the procedure in 8.3.

7.8 Report any departures from the procedure such as possible misalignment, hesitations in the force application, etc.

8. Calculation and Interpretation of Results

8.1 Use the instrument calibration factors to convert the indicated force for each test into the actual force applied in units of pounds-force (1 N = 0.1 kgf).

8.2 Compute the relative stress applied to each coating sample as follows:

$$X = 4F/d^2\pi$$

where:

X = greatest mean pull-off stress applied during a pass/fail test, or the pull-off strength achieved at failure. Both have units of psi (MPa = 1 N/mm^2).

F = highest force applied to the test surface as determined in procedure in 8.1, and

d = equivalent diameter of the original surface area stressed having units of inches (or millimetres). This is usually equal to the diameter of the loading fixture.

8.3 For all tests to failure, estimate the percent of adhesive and cohesive failures in accordance to their respective areas and location within the test system comprised of coating and adhesive layers. A convenient scheme that describes the total test system is outlined in procedures in 8.3.1 through 8.3.3. (See ISO 4624.)

8.3.1 Describe the specimen as substrate A, upon which successive coating layers B, C, D, etc., have been applied, including the adhesive, Y, that secures the fixture, Z, to the top coat.

8.3.2 Designate cohesive failures by the layers within which they occur as B, C, etc., and the percent of each.

8.3.3 Designate adhesive failures by the interfaces at which they occur as A/B, B/C, C/D, etc., and the percent of each.

8.4 Erratic errors should be dropped. Unpredictable errors

may result if alignment of the apparatus is not normal to the surface, from poor definition of the area stressed due to improper preparation of the adhesive, poorly defined glue lines and boundaries, holidays in the adhesive caused by voids, inclusions, improperly prepared surfaces, or sliding or twisting the fixture during the initial cure. Scratched or scored samples may contain stress concentrations leading to premature fractures. These should be retested at adjacent areas.

8.5 Further information relative to the interpretation of the test results is given in Appendix A1.

9. Report

9.1 Report the following information:

9.1.1 Brief description of the general nature of the test, such as, field or laboratory testing of the general type of coating as applied to a given substrate, etc.

9.1.2 Temperature and relative humidity and any other pertinent environmental conditions during the test period.

9.1.3 Apparatus used, fixed or self-aligning, which includes: apparatus manufacturer and model numbers, loading fixture type and dimensions, and bearing ring type and dimensions.

9.1.4 Description of the test system, if possible, by the indexing scheme outlined in 8.3 including: product identity and generic type for each coat and any other information supplied, the substrate identity (thickness, type, orientation, etc.), and the adhesive used.

9.1.5 Test results.

9.1.5.1 Date, test location, testing agent.

9.1.5.2 For pass/fail tests, stress applied along with the result, for example, pass or fail and note the plane of any failure (see ANSI N512).

9.1.5.3 For tests to failure, all values computed in 8.2 along with the nature and location of the failures as specified in 8.3, or, if only the average strength is required, report it along with the statistics.

9.1.5.4 If corrections of the results have been made, or if certain values have been omitted such as the lowest or highest values or others, reasons for the adjustments and criteria used.

9.1.5.5 For any test where scoring was employed, indicate it by placing a footnote superscript beside each data point affected and a footnote to that effect at the bottom of each page on which such data appears. Note any other deviations from the procedure.

10. Precision and Bias

10.1 The precision and bias is primarily dependent upon the accuracy of the force measurement, the alignment of the device, and the care exercised in preparation and testing.

10.2 Since no standard for pull-off strength of coatings has been developed prior to this test method, precision and bias statements will be developed in round-robin testing.

11. Keywords

11.1 adhesion; adhesive strength; bond strength; coatings; cohesion; cohesive strength; paints; pull-off strength

ANNEXES

(Mandatory Information)

A1. FIXED-ALIGNMENT ADHESION TESTERS—ELCOMETER MODEL 106 ADHESION TESTER (Fig. A1.1)[7]

A1.1 *Apparatus:*

A1.1.1 This is a fixed-alignment portable tester.

A1.1.2 The tester is comprised of detachable aluminum loading fixtures having a flat conic base that is 0.8 in. in diameter on one end for securing to the coating, and a circular T-bolt head on the other end, a central grip for engaging the loading fixture that is forced away from a tripod base by the interaction of a handwheel (or nut), and a co-axial bolt connected through a series of belleville washers,or springs in later models, that acts as both a torsion relief and a spring that displaces a dragging indicator with respect to a scale.

A1.1.3 The force is indicated by measuring the maximum spring displacement when loaded. Care should be taken to see that substrate bending does not influence its final position or the actual force delivered by the spring arrangement.

A1.1.4 The devices are available in four ranges: from 0 to 500, 0 to 1000, 0 to 2000, and 0 to 4000 psi (35, 70, 140 and 280 kgf/cm^2).

A1.2 *Procedure:*

A1.2.1 Center the bearing ring on the coating surface concentric with the loading fixture. Turn the hand wheel or nut of the tester counter-clockwise, lowering the grip so that it slips under the head of the loading fixture.

A1.2.2 Align or shim the three instrument swivel pads of the tripod base so that the instrument will pull perpendicularly to the surface at the bearing ring.

A1.2.3 Take up the slack between the various members and slide the dragging (force) indicator located on the tester to zero.

A1.2.4 Firmly hold the instrument with one hand. Do not allow the base to move or slide during the test. With the other hand, turn the handwheel clockwise using as smooth and constant a motion as possible. Do not jerk or exceed a stress rate of 150 psi/s (1 MPa/s) which is attained by allowing in excess of 7 s/1000 psi stress. If the 2000 or 4000 psi models are used, the handwheel is replaced with a nut requiring a wrench for tightening. The wrench must be used in a plane parallel to the substrate so that the loading fixture will not be removed by a shearing force or misalignment thus negating the results. The maximum stress must be reached within about 100 s.

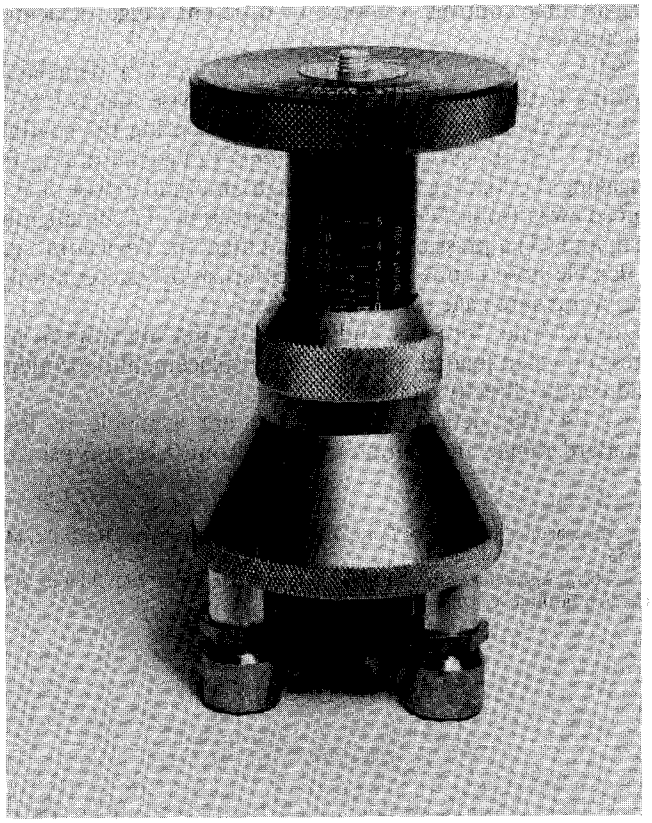


FIG. A1.1 Elcometer Model 106 Adhesion Tester

A1.2.5 The pulling force applied to the loading fixture is increased to a maximum or until the system fails at its weakest locus. Upon failure, the scale will rise slightly, while the dragging indicator retains the apparent load. The apparatus scale indicates an approximate stress directly in pounds per square inch, but may be compared to a calibration curve.

A1.2.6 Record the highest value attained by reading along the bottom of the dragging indicator.

[7] Manufactured by Elcometer Instruments, Ltd., Edge Lane, Droylston, Manchester 356UB, England.

A2. SELF-ALIGNING ADHESION TESTERS—SEMICRO PNEUMATIC ADHESION TESTER (Fig. A2.1)[8]

A2.1 *Apparatus:*

A2.1.1 This is a self-aligning tester, although a non-self-aligning pneumatic apparatus is in use in Europe.[9] It is portable and has a common pressure source and measuring system that controls a choice of different range detaching assemblies.

A2.1.2 The apparatus is comprised of: (*1*) detachable loading fixtures having a flat cylindrical base that is 0.5 in. (13 mm) in diameter on one end, for securing the coating, and ⅜ UNC threads on the other end; (*2*) a central grip for engaging the loading fixture through an annular base that is forced away from the grip by the interaction of a self-aligning seal; and (*3*) a pressurized gas that enters the device through a flexible hose connected to a pressurization rate controller and a pressure gage (or electronic sensor).

A2.1.3 The force is indicated by the maximum gas pressure when loaded, which is not displacement dependent, and can be directly calibrated.

A2.1.4 The detaching assemblies are available in four standard ranges in multiples of two from 0 to 500 psi (3.5 MPa) to 0 to 4000 psi (28 MPa). Special ranges to 10 000 psi (70 MPa) are available.

A2.1.5 The standard System 2000 is a fully automated electronic monitoring and control system of briefcase size that can be used with any detaching assembly. Special manually controlled pneumatic devices can be ordered.

A2.2 *Procedure:*

A2.2.1 Position the annular ring on the coating concentric with the fixture, and loosely engage the fixture via the central threaded grip. Leave at least 1/32-in. (0.8-mm) clearance between the detaching assembly and the annular ring so that the seal can protrude enough to align itself when pressurized.

A2.2.2 Make the appropriate pneumatic connections, and adjust the pressure.

A2.2.3 Initialize the system by nulling the force indicator and introducing a small amount of gas in order to set the seal and align the device.

A2.2.4 If the device is fully automated, select the desired rate of load and set the mode switch to its run position; otherwise, manually control the gas pressure to the device so that the rate of stress does not exceed 150 psi/s (1 MPa/s) yet reaches its maximum within 100 s.

A2.2.5 Record both the maximum pressure attained and the appropriate force or stress multiplier for the specific detaching assembly.

[8] Manufactured by SEMicro Corp., 15817 Crabbs Branch Way, Rockville, MD 20855.

[9] Saberg Apparatus, available from Scandinavian Paint and Printing Inc., Research Institute, Copenhagen, Denmark.

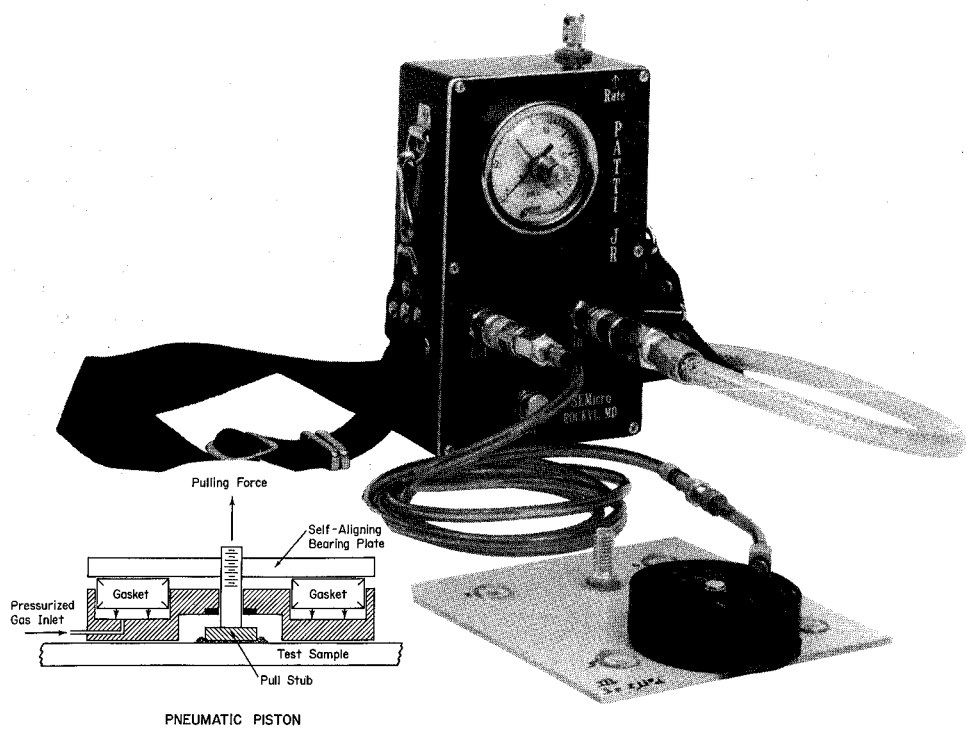


FIG. A2.1 SEMicro Pneumatic Adhesion Tester

APPENDIX

(Nonmandatory Information)

X1. STRESS CALCULATION

X1.1 The stress computed in 8.2 is equal to the uniform pull-off strength of the analogous rigid coating system if the applied force is distributed uniformly over the critical locus at the instant of failure. For any given continuous stress distribution where the peak-to-mean stress ratio is known, the uniform pull-off strength may be approximated as:

$$U = XR$$

where:

U = uniform pull-off strength, representing the greatest force that could be applied to the given surface area, psi (MPa),
X = measured in-situ pull-off strength calculated in 8.2, psi (or MPa) and
R = peak-to-mean stress ratio.

It is important to note that a difference between these pull-off strengths does not necessarily constitute an error; rather the in-situ measurement simply reflects the actual character of the applied coating system with respect to the analogous "ideal" rigid system.

X1.2 An error is introduced if the alignment of the apparatus is not normal to the surface. An approximate correction by the peak-to-mean stress ratio is:

$$R = (1 + 0.14\ az/d),$$

where:

z = distance from the surface to the first gimbal or the point at which the force and counter force are generated by the action of the driving mechanism, in. (mm),
d = diameter of the loading fixture, in. (mm),
a = angle of misalignment, degrees (less than 5), and
R = maximum peak-to-mean stress ratio for the misaligned rigid system.

Designation: D 4618 - 92

Standard Specification for Design and Fabrication of Flue Gas Desulfurization System Components for Protective Lining Application[1]

This standard is issued under the fixed designation D 4618; 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 design and fabrication of metal components for Flue Gas Desulfurization (FGD) equipment, including absorbers, tanks, chimney liners, ductwork and associated equipment that are to be lined for corrosion or abrasion resistance, or both.

1.2 *Limitations*

1.2.1 This specification is intended only to define the design considerations for successful application and performance of protective linings for FGD system components.

1.2.2 It does not cover structural performance of FGD components.

1.2.3 It does not cover use of metalic linings.

1.3 This specification represents the minimum requirements for lining work. In cases where the manufacturer's instructions and recommendations differ from this specification, these differences must be resolved before fabrication is started.

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.

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

2. Design/Engineering Requirements

2.1 *Rigidity:*

2.1.1 The components shall be designed so that the interior metal surfaces are sufficiently rigid for the intended lining materials. Manufacturer's recommendations for maximum strains or deflection limits for the lining material shall be followed.

2.1.2 The weight of the lining system shall be considered in the structural design of the component.

2.1.3 The design shall consider the effects of pressure, wind, seismic and other design loads.

2.1.4 Vibration may cause flexing or high surface strains on the lining. This is of particular concern to rigid lining materials and shall be minimized.

2.1.5 Special consideration shall be given to all conditions of potentially excessive strain such as unsupported bottom areas, oil-canning, out of roundness, sidewall-to-bottom joints, etc.

2.1.5.1 Where a component is on a concrete foundation, grouting shall be done if necessary to correct unsupported bottom areas.

2.1.5.2 Sand fill shall not be used for bottom support unless provisions are made to ensure that the sand cannot be lost due to erosion.

2.2 *Accessibility:*

2.2.1 All interior surfaces of the components shall be designed to be readily accessible for welding, grinding, surface preparation, and lining application.

2.2.2 The minimum manway size for a working entrance during lining application shall be 36 in. (900 mm) in diameter or 24 in. (600 mm) width by 36 in. (900 mm) height.

2.2.2.1 Closed components shall have a minimum of two manways, one near the top and one near the bottom, preferably located 180° apart to facilitate adequate ventilation for workers.

2.2.2.2 Additional or larger openings may be required to facilitate ventilation and material handling. The lining material applicator should be consulted for specific requirements.

2.3 *Shell Penetrations:*

2.3.1 Openings such as, inlets, manholes, and outlet nozzles shall be flush with the interior wall.

2.3.1.1 Inlet nozzles may extend into vessels if incoming fluids will be detrimental to lining materials.

2.3.2 Any exterior or interior connection shall be flanged in order to facilitate lining.

2.3.3 The maximum length of flanged nozzles, 4 in. (100 mm) and greater in diameter, shall not exceed the dimensions in Table 1.

2.3.3.1 Only 4 in. (100 mm) diameter and larger nozzles shall be used for maximum reliability of the lining system.

2.3.3.2 As an alternative to lined nozzles, compatible prefabricated, reinforced plastic, ceramic or alloy metal inserts (sleeves) may be used if they offer superior corrosion and abrasion protection. Lining shall overlap onto prefabricated liners.

TABLE 1 Maximum Length of Nozzles

Nominal Nozzle Size, in. (mm)	Maximum Nozzle Length—Shell to Face of Flange, in. (mm)
4 (100)	8 (200)
6 (150)	12 (300)
8–24 (200–600)	16 (400)
26–36 (600–900)	24 (600)
Over 36 (900)	any length

[1] This specification is under the jurisdiction of ASTM Committee D-33 on Protective Coating and Lining Work for Power Generation Facilities and is the direct responsibility of Subcommittee D33.09 on Protective Linings for FGD Systems.

Current edition approved Aug. 15, 1992. Published October 1992. Originally published as D 4618 – 87. Last previous edition D 4618 – 87.

2.3.3.3 If an insert is used as an alternate, the lining shall overlap unto the insert or some other means of ensuring an adequate seal should be provided.

2.3.3 Lining thickness may dictate changes in nozzle dimensions to achieve design flow rates.

2.4 *Appurtenances Inside Components:*

2.4.1 The requirements in Sections 2 and 3 apply to any appurtenances that are being lined and installed inside a lined component, such as agitators, anti-swirl baffles, gaging devices, internal piping, ladders, and support brackets.

2.4.2 If appurtenances inside the component cannot be lined, they shall be made of corrosion-resistant materials. If alloys are used, the lining shall carry over the welded area onto the alloy a minimum of 3 in. (76 mm). Some linings may require special designs to protect the edge of the lining. If bolted connections are used, dielectric insulation shall be provided.

2.4.3 Heating elements shall be attached with a minimum clearance of 6 in. (150 mm) from the surface of the lined component. Greater clearance may be required to protect the lining from excessive temperature conditions depending on the temperature of the element.

2.4.4 Special precautions shall be taken in lined components where severe abrasion/impingement damage may occur. Precautionary design measures, such as wear plates, brick liners or added coating thickness, shall be considered when necessary.

2.5 *Structural Reinforcement Members and Supports:*

2.5.1 Structural reinforcement members (stiffeners) should be installed on the vessel exterior, wherever necessary. However, if such members are installed internally they shall be fabricated of simple closed shapes such as round bars, pipe, or box beams for ease of applying the lining material.

2.5.2 The use of box beams or pipe for internal supports is recommended. The use of angles, channels, I-beams and other complex shapes shall be avoided wherever possible. If they must be installed internally, these members shall be fully seal welded and the edges ground to a ⅛ in. (3 mm) minimum radius.

2.5.3 If closed chambers are formed with internal box beams or pipes, they shall be vented to the vessel exterior at the lowest point, so that pressures are not developed during operation and possible curing procedures and so that corrosion, due to localized lining failures, can be observed early.

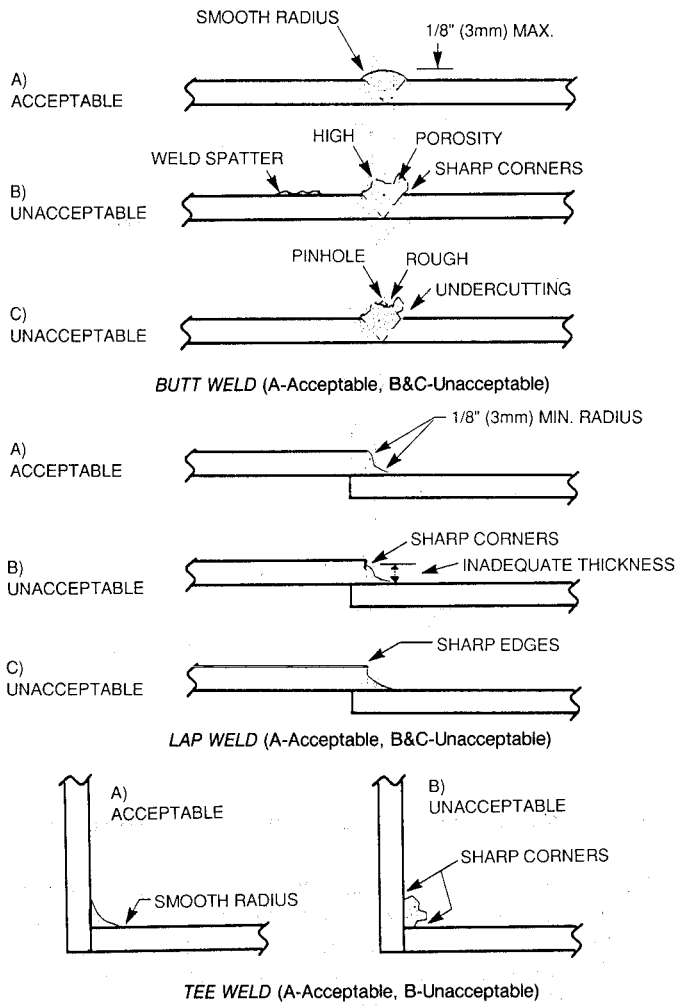


FIG. 1 Weld Fabrication for Lining Application

3. Fabrication

3.1 *Welds:*

3.1.1 All internal welds to be lined shall be continuous without imperfections such as weld slag, weld spatter, rough surfaces, undercutting, high peaks, porosity, sharp corners, sharp edges and inadequate thickness shall be corrected (see Fig. 1).

3.1.2 The degree of weld preparation prior to lining depends on the type of lining to be applied. The lining manufacturer must be consulted for specific requirements for weld preparation during the design of the component and prior to start of fabrication.

3.1.3 Use of weld display samples before and after grinding may be of help to the component fabricator in supplying acceptable welds with a minimum required rework. All welds shall be inspected, corrected, and reinspected prior to blast cleaning. Whenever possible, shop welds shall be inspected and imperfections corrected in the fabricator's shop.

3.1.3.1 All weld areas shall be inspected before and after blast cleaning. Pinholes, pits, blind holes, porosity, undercutting or similar depressions are not permissible in the finished surface. These shall be repaired. The profile shall be reestablished as required by the lining manufacturer.

3.1.4 Weld spatter shall be removed. Chipping may be utilized only if followed by grinding for the required surface finish.

3.1.4.1 The use of non-silicone, anti-spatter coating applied adjacent to weld areas is suggested. This coating shall be of a type that can be removed by the final blast cleaning.

3.1.5 After inspection, all undercuts and pinholes shall be eliminated by welding or grinding. All rough welds shall be ground to remove sharp edges. Chipping may be used to remove sharp edges if followed by grinding.

3.1.6 All edges and similar abrupt contours shall be rounded off by grinding or machining to a ⅛-in. (3 mm) minimum radius.

3.1.7 Flame cut edges shall be avoided.

3.1.7.1 Where flame cut edges are necessary, they should be ground to removed hardened material prior to blasting.

3.1.8 Fillets and changes in contour shall be ground to a

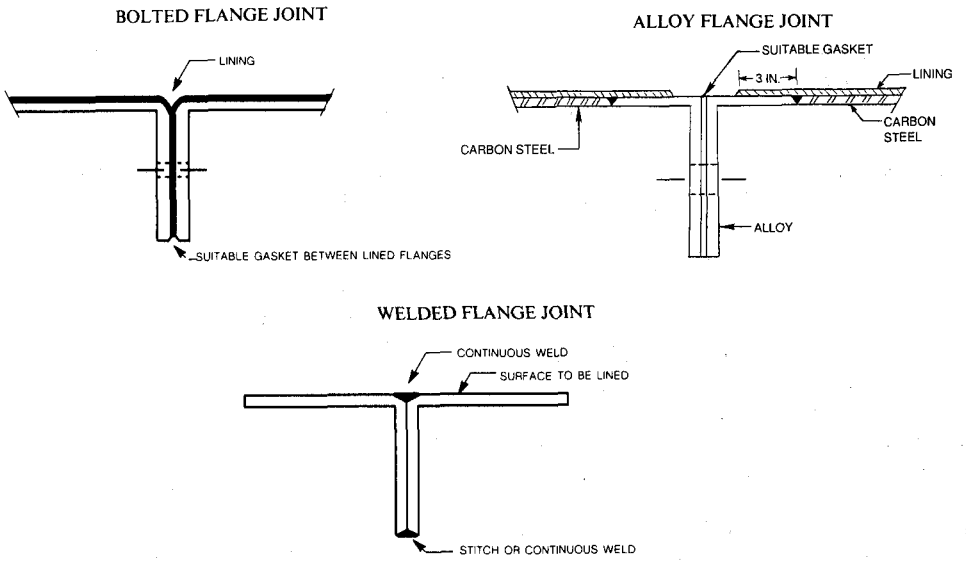


FIG. 2 Joint Fabrication for Lining Application

⅛-in. (3-mm) minimum radius where required for the selected lining material. Any grinding done on welds, edges, and fillets shall be done carefully to eliminate potential problems caused by gouging of the parent metal.

3.1.8 All internal and external welding shall be completed prior to any lining application.

3.2 *Joints:*

3.2.1 All welds shall be continuous. Intermittent or spot welding is not permitted (see Fig. 2).

3.2.2 Riveted joints shall not be used. Internal bolted joints shall not be used except to avoid welding on an already lined surface. In this case, corrosion resistant alloy or nonmetallic bolts and suitable gasket or sealant shall be used.

3.2.3 If bolts are used to facilitate installation or welding, or both, of a component, they shall be removed and holes plug welded before lining application.

3.2.4 Lap welded joints shall be avoided whenever possible. Where they are necessary, the interior lap shall be a full fillet weld and finished as in accordance with 3.1.6.

3.2.5 Expansion joints and bolted flanged duct or shell joints require special lining consideration. Bolted flange joint surfaces shall be lined before assembly. Special consideration shall be given during erection and fit-up so as not to damage the lining.

3.2.5.1 If alloy flanges are used at expansion joints, the design must allow for the lining system to be applied over the alloy by 3 in. (75 mm). Some linings may require special designs to protect the leading edge.

3.3 During and after the lining of the equipment, no welding shall be allowed on the interior or exterior surfaces.

3.4 Signs shall be hung or stenciled on the exterior surface of the equipment designating the following: LINED EQUIPMENT, DO NOT BURN OR WELD. They shall be visible from all elevations and sides of the equipment.

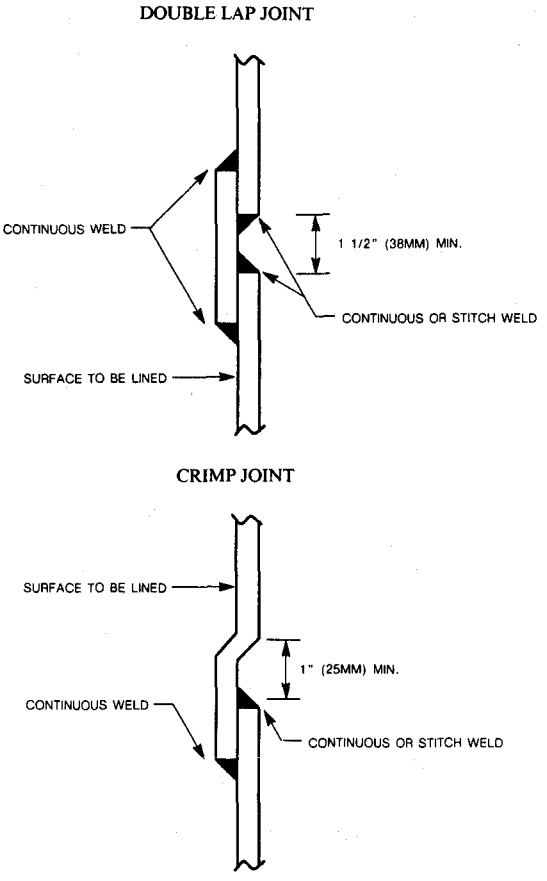


FIG. 2 (*Continued*) Joint Fabrication for Lining Application

4. Miscellaneous

4.1 All lined surfaces should be clearly identified on all detail and arrangement drawings.

4.2 The following note shall appear on appropriate detail and arrangement drawings: All surfaces to be lined shall meet the requirements of ASTM Specification D 4618.

4.3 If hydrostatic testing is to be done prior to lining, it shall be performed with clean potable water.

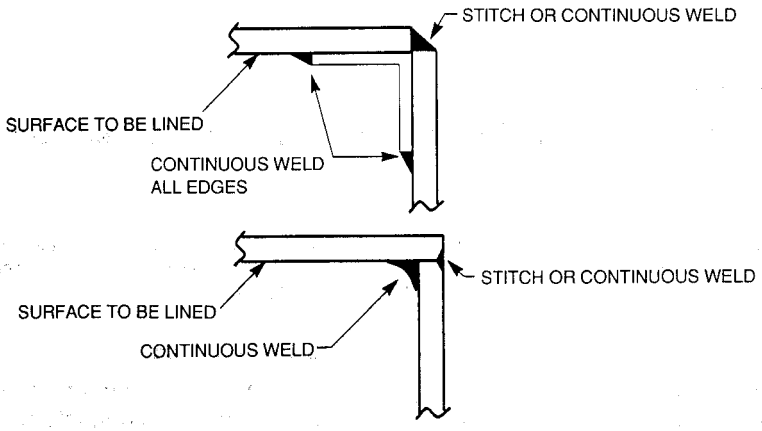


FIG. 2 (*Continued*) Joint Fabrication for Lining Application

Designation: D 4619 - 91

Standard Practice for Inspection of Linings in Operating Flue Gas Desulfurization Systems[1]

This standard is issued under the fixed designation D 4619; 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 describes procedures for conducting inspections of the conditions of various linings in operating Flue Gas Desulfurization (FGD) system components.

1.2 *This standard does not purport to address all of the safety problems, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.* For specific hazard statements, see Section 7.

2. Significance and Use

2.1 Periodic inspections are essential to evaluate lining performance, to detect existing damage potential problems, and to plan scheduled maintenance. The frequency of these inspections may diminish or increase with time depending upon lining performance.

3. Recordkeeping

3.1 Lining condition will depend on the operating conditions experienced by the lining systems. Records of these conditions that are maintained by the owner/operator should be evaluated for potential effects upon the linings. These may include:

3.1.1 Dates of lining installation and initial operation,
3.1.2 Solution/gas temperatures in lined components,
3.1.3 Solution/gas chemistry (pH, composition),
3.1.4 Start up/shut down dates,
3.1.5 Gas velocities and particulate loading, and
3.1.6 Ambient conditions.

3.2 Any known change in the process criteria or modifications of the physical design shall be identified and dated.

3.3 All past history pertaining to the lining systems should be available during the inspection process. They may include:

3.3.1 Copies of existing lining specifications and installation procedures.

3.3.2 Quality control documents of the existing lining installation.

3.3.3 Copies of previous inspection reports.

3.3.4 Documentation pertaining to any maintenance of existing lining systems.

4. Inspection Team

4.1 The owner/operator should select a team of experienced personnel to conduct the inspection. Personnel representing the following may be included:

4.1.1 Owner's representative,
4.1.2 Lining manufacturer,
4.1.3 Lining applicator,
4.1.4 Equipment designer,
4.1.5 Architect engineer,
4.1.6 Third party inspectors, and
4.1.7 System designer.

5. Pre-Inspection Procedure

5.1 Prior to conducting an inspection of the lining, the owner/operator shall ensure that the following services and equipment are provided.

5.1.1 *Safety*—The inspection team shall verify that the equipment being inspected has been made safe for entry. This shall include lockout procedures for related equipment such as, but not limited to, the boiler, dampers, valves, fans, and pumps.

5.1.2 *Lighting*—Sufficient lighting shall be provided to assure general lighting of the overall area plus localized high intensity lights for close visual observation or taking of photographs, or both. The lighting fixtures shall be equipped with a safety guard to minimize breakage and injury.

5.1.3 *Access to Lining Surfaces*—The access equipment must meet all safety requirements of OSHA and the owner/operator. The equipment must be capable of placing the inspectors close enough to the lining surface to perform all inspection procedures.

5.1.4 *Cleaning*—Selected lining surfaces to be inspected shall be cleaned of any deposits or buildup that will obscure examination of the lining. The cleaning procedure selected must not cause damage to the lining.

5.1.5 *Ventilation*—Provisions must be made to assure that adequate fresh air is provided in all FGD components being inspected. If some components are on line, provisions must be taken to adequately isolate such components.

6. Hazards

6.1 All safety requirements of OSHA and the owner/operator, must be met when performing all inspection operations. Residues, including acids, heavy metals, or other hazardous materials, may be present in deposits, on the lining surfaces, or in the atmosphere. Precautions shall be taken to protect personnel. Confined entry safety requirements shall be adhered to where applicable.

---

[1] This practice is under the jurisdiction of ASTM Committee D-33 on Protective Coating and Lining Work for Power Generation Facilities and is the direct responsibility of Subcommittee D33.09 on Protective Linings for FGD Systems.

Current edition approved Aug. 15, 1991. Published October 1991. Originally published as D 4619 - 86. Last previous edition D 4619 - 86.

7. Inspection Procedures

7.1 The inspection should include visual examination, photographic examination, mapping of potential problem areas, specific destructive or nondestructive testing, and removal (if required) of representative samples for analysis (see Table 1).

7.2 Temperature may influence observed or tested lining parameters, such as crack width, hardness, and adhesion. During inspection, temperature of the lining surface and the interior and exterior ambient temperatures of the component should be measured and recorded.

7.3 Other parameters important to the inspection should be discussed with the parties involved and agreed to prior to the inspection.

8. Report

8.1 The owner/operator shall designate who is responsible for the preparation of an inspection report.

8.2 Report the following information:

8.2.1 Pertinent background information contained in Section 3,

8.2.2 Date(s) of inspection,

8.2.3 Participants and their affiliation,

8.2.4 Documentation of inspection,

8.2.5 Photographs, as applicable,

8.2.6 Mapping of problem areas,

8.2.7 Test results, and

8.2.8 Conclusions and recommendations.

9. Repairs

9.1 If repairs of the lining are required, the owner/operator or his representative shall prepare specific repair specifications or procedures, or both, with the input of the lining manufacturer(s), the applicator(s), and others as necessary.

9.2 These specifications or procedures, or both, may be prepared in advance or as a result of the inspection.

10. Keywords

10.1 cementitious linings; chemical resistant linings; flue gas desulfurization (FGD); inorganic linings; inspection of linings; organic linings; power generation facility linings

TABLE 1 Lining Maintenance Inspection Parameters

Organic Resins	Organic Elastomers	Inorganic/Cementitious	Inorganic/Masonry
Visual Inspection:	*Visual Inspection:*	*Visual Inspection:*	*Visual Inspection:*
Rust	Rust	Erosion/mechanical damage	Erosion/mechanical damage
Chemical Degradation	Chemical Degradation	Cracking	Cracking:
Surface Effects:	Surface Effects:	Softening	Mortar joint
Abrasion/erosion	Abrasion/erosion	Spalling	Brick face
Aligatoring/checking	Swelling	Rust staining	Spalling
Discoloration/charring	Softening	Efflorescence	Softening:
Flaking	Crazing	Anchor exposure	Brick
Cracking	Cracking	Delaminations	Mortar
Softening	Surface sloughing	Substrate exposure	Expansion joint
Blistering/delamination:	Blistering:	*Physical Testing:*	Color Change:
Size	Size	Hardness (Schmidt hammer)	Brick
Density	Density	Measure crack widths and pattern	Mortar
Entrapped contents for analysis	Entrapped contents for analysis	Core samples, if required	*Physical Testing:*
Mechanical Damage	Mechanical Damage:	Remove cementitious layer to permit visual examination of underlaying membrane/substrate	Hardness (Schmidt hammer)
Physical Testing:	Gouging		Core samples, if required
Lining thickness	Cutting		Petrographic analysis, if required
Continuity testing of suspect areas, (confirm test voltage with lining manufacturer)	Tearing		
	Overcompression (mating surfaces)		
Adhesion testing, if required	Adhesive failure		
	Cohesive failures		
	Reversion (Reverting to soft conditions with loss of physical properties)		
	Physical Testing:		
	Lining thickness		
	Continuity testing of suspect areas, (confirm test voltage with lining manufacturer)		
	Adhesion testing, if required		
	Shore durometer hardness		

Designation: D 4707 – 87 (Reapproved 1991)

Standard Test Method for Measuring Paint Spatter Resistance to Roller Application[1]

This standard is issued under the fixed designation D 4707; 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 the determination of the tendency of a paint to spatter when applied with a paint roller to a substrate.

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

2. Referenced Documents

2.1 *ASTM Standards:*

D 3924 Specification for Standard Environment for Conditioning and Testing Paint, Varnish, Lacquer, and Related Materials[2]

D 3925 Practice for Sampling Liquid Paints and Related Pigmented Coatings[2]

2.2 *Other Document:*

Photographic Standards of Paint Roller Spatter[3]

3. Summary of Test Method

3.1 The test paint is applied to a black plastic panel by draw-down. The coated plastic panel is immediately mounted on an essentially vertical surface above a sheet of paper used to catch any spatter. A specially designed notched spool roller (see 5.1) is rolled through the film following a defined procedure, tending to generate spatter. Any spatter falls upon the spatter catch paper, and after drying is rated against the photographic standards.

4. Significance and Use

4.1 Paint spatter generated by roller application is dependent on the properties of both the paint being applied and the paint roller cover used for the application. To eliminate the influence of the paint roller cover as a variable, and thus restrict the spatter-inducing variable to the paint under test only, the paint roller cover is replaced by a standard notched spool roller to generate spatter by a mechanism that simulates that of a paint-applying roller cover.

4.2 Although most of the development work to establish this test method was undertaken using latex paints, sufficient work was also done to show its applicability to solvent-reducible paints.

4.3 Tests during the development of this test method showed that the spattering properties of paints, like other physical properties, may in time change. Therefore, the results of this test are valid only for the time when the test is run.

5. Apparatus

5.1 *Notched Spool Test Roller* (Fig. 1).[4]

5.2 *Glass Plate*, at least 9 by 19 in. (230 by 485 mm) by ¼ in. (6 mm) thick.

5.3 *U-shaped Film Caster*,[5] having a 7-mil (175-μm) clearance by 5¼ in. (135 mm) wide.

5.4 *Mechanical Metronome*, with swinging arm.

6. Materials

6.1 *Black Plastic Panels*,[6] 6½ by 17 in. (165 by 430 mm).

6.2 *Flannel Cloth.*

6.3 *Masking Tape*, 1 in. (25 mm) wide.

6.4 *Spatter Catch Paper*, 18 by 18 in. (455 by 455 mm). This paper can be any convenient paper to which the spatter droplets will adhere and of a color to contrast with the color of the paint under test.

7. Sampling and Conditioning

7.1 Sample the material in accordance with Practice D 3925.

7.2 Prior to testing, the samples shall be conditioned in accordance with the standard atmosphere described in Specification D 3924. The testing shall take place under the same conditions.

8. Procedure

8.1 Clean the top of the glass plate and both sides of the black plastic panel to ensure that they are free of specks. Place the black plastic panel on the glass plate and tape the narrow end at the top to the glass plate. Smooth the panel along the plate to ensure a close fit.

8.2 Stir the paint under test thoroughly and strain to remove all skins and particles. Place the film caster with the

---

[1] This test method is under the jurisdiction of ASTM Committee D-1 on Paint and Related Coatings and Materials and is the direct responsibility of Subcommittee D01.42 on Architectural Finishes.

Current edition approved May 29, 1987. Published July 1987.

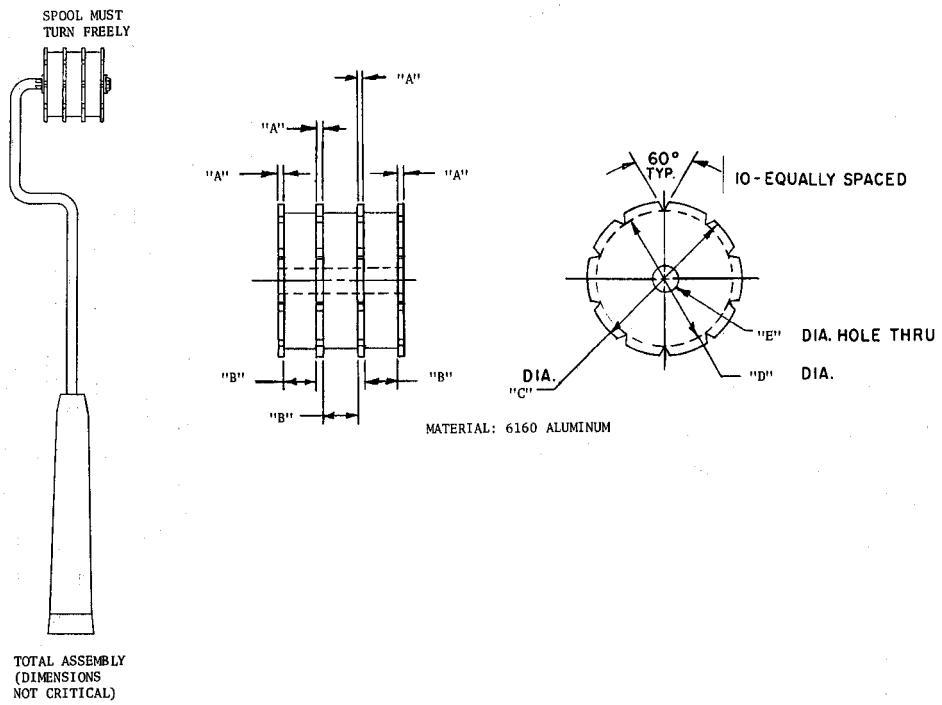
[2] *Annual Book of ASTM Standards*, Vol 06.01.

[3] Copies of the pictorial photographic reference standards are contained in *Pictorial Standards of Coatings Defects* and may be obtained from the Federation of Societies For Coatings Technology, 492 Norristown Rd., Blue Bell, PA 19422.

[4] The E-Z Paintr Notched Spool Test Roller, obtainable from the Precision Gage and Tool Co., 28 Volkenand Ave., Dayton, OH 45410, has been found suitable for this purpose.

[5] The Dow film caster, available from BYK-Gardner, Inc., Gardner Laboratory, 2435 Linden Lane, Silver Spring, MD 20910, has been found suitable for this purpose.

[6] Leneta P-121-10N dull black plastic panels 6½ by 17 in. by 10 mil (production tolerance: ±1 mil) (165 by 432 by 250 μm) in size, obtainable from the Leneta Co., P.O. Box 86, Ho-Ho-Kus, NJ 07423, are suitable for the purpose.



Dimensions

		in.	mm
A	Flange thickness	0.063 ± 0.005	1.60 ± 0.13
B	Space between flanges	0.343 ± 0.005	8.71 ± 0.13
C	Total diameter	1.600 ± 0.015	40.16 ± 0.38
D	Diameter under notches	1.400 ± 0.015	35.56 ± 0.38
E	Hole diameter	0.281 ± 0.005	7.14 ± 0.13

FIG. 1 Notched Spool Roller

7.0-mil (175-μm) side down immediately below the taped portion of the black plastic panel. Turn on the metronome, adjusted for 80 beats/min. Into the well formed by the film caster, pour sufficient paint so that the well is filled from corner to corner. Draw down the paint the full length of the black plastic panel, until the film caster is fully beyond the far edge. The rate of application should be fairly slow, 3 to 4 s. from end to end, to prevent pinholes or holidays in the paint film.

8.3 Immediately upon completion of the draw-down, remove the black plastic panel from the glass plate, keeping the masking tape intact, and tape, with the long direction vertical, to a surface that is vertical or nearly vertical (within 5° of vertical, top sloping away from the operator) with the bottom of the black plastic panel about 1 in. (25 mm) above the laboratory bench or table (Fig. 2). It is desirable that the surface under the black plastic panel be firm but with a little resilience. A backing of ¼-in. (6-mm) thick pasted fiberboard[7] is ideal as very hard surfaces make proper performance of the test difficult. Center the spatter catch paper on the laboratory bench or table under the black plastic panel.

8.4 Using the clean, notched spool roller, start in one of the upper corners and roll downward and upward through the paint film. Always keep the notched spool in contact with the black plastic panel, not removing the roller from the film when changing directions. Make ten passes in each direction (20 passes total), 15 ± ½ in. (380 ± 15 mm) per pass, progressively moving sideways from one edge of the film to the other (Fig. 3). Each pass should coincide with a beat of the metronome and the motion should be continuous, not jerky. Try to emulate the motion of the metronome, using the metronome for accurate timing (practice the motion with the metronome to gain the necessary rhythm and timing), since the speed of the rolling of the notched spool roller through the paint film has been found to be the only variable significantly affecting the results of the test. Make sure that all four flanges of the notched spool roller are within the draw-down area at all times. Use sufficient pressure to maintain constant contact between the notched spool roller and the black plastic panel. Note that as long as constant contact is maintained, pressure variations have not been found to noticeably affect the results.

8.5 Remove the spatter catch paper and lay it in a suitable place to dry.

8.6 Repeat the test with a second plastic panel after cleaning the apparatus.

[7] Upson or universal board, manufactured by Domtar Gypsum Co., P. O. Box 508, Lockport, NY 14094, and available at most lumberyards, has been found suitable for this purpose.

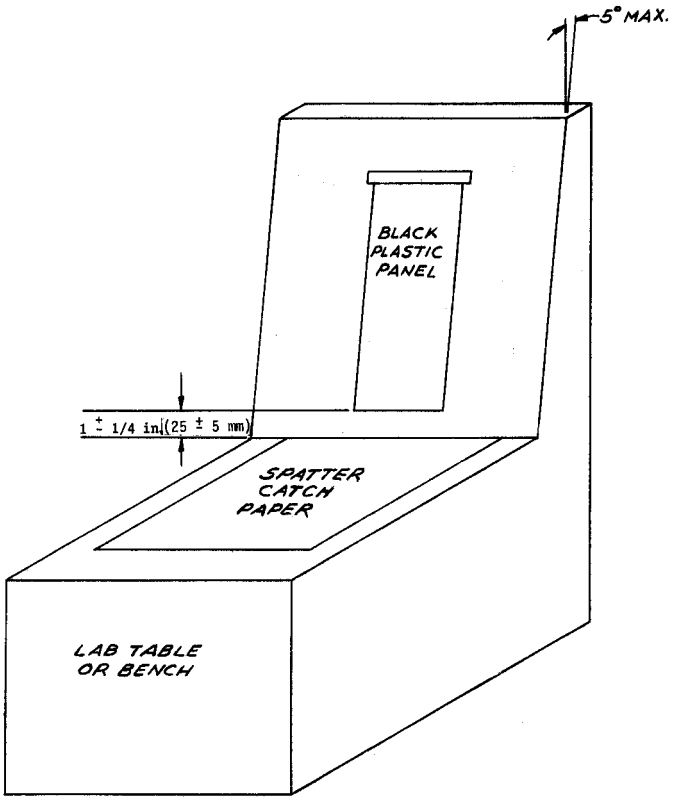
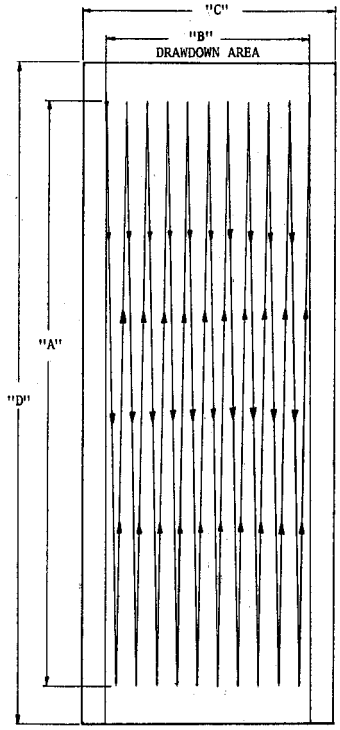


FIG. 2 Test Set-Up Schematic



Dimensions

		in.	mm
A	Notched spool pass length	15 ± ½	380 ± 15
B	Drawdown width (determined by blade)	5¼	140
C	Panel width	6½	165
D	Panel length	17	430

FIG. 3 Test Pattern Schematic

9. Grading Procedure

9.1 Carefully cut an area 7½ by 9½ in. (190 by 240 mm) out of the front edge (edge nearest the paint) of the spatter catch paper. The 7½-in. side will be the front edge. Center the area with respect to the spatter so a maximum of spatter is on this sheet (Fig. 4).

9.2 Using the photographic standards numbered 1, 3, 5, 7, and 9 for comparison, rate each test with a number from 0 (low spatter resistance) to 10 (no spatter), interpolating as needed for ratings 2, 4, 6, and 8.

NOTE—Figures 5 through 9 are duplications thereof for sample purposes, not meant to be used for test grading purposes.

9.3 In rating the paints using the photographic standards, consider the population of spatter droplets of greater importance than the average size of the spatter droplets.

9.4 If the ratings of two tests do not agree within 1 unit, repeat until such precision is obtained.

10. Precision and Bias

10.1 A precision and bias statement is in development.

11. Keywords

11.1 paint spatter resistance; resistance—paint spatter; roller application; spattering

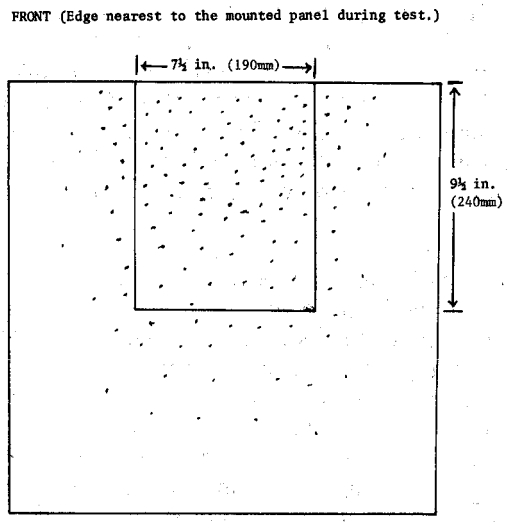


FIG. 4 Cutting Out Section of Spatter Catch paper for Evaluation

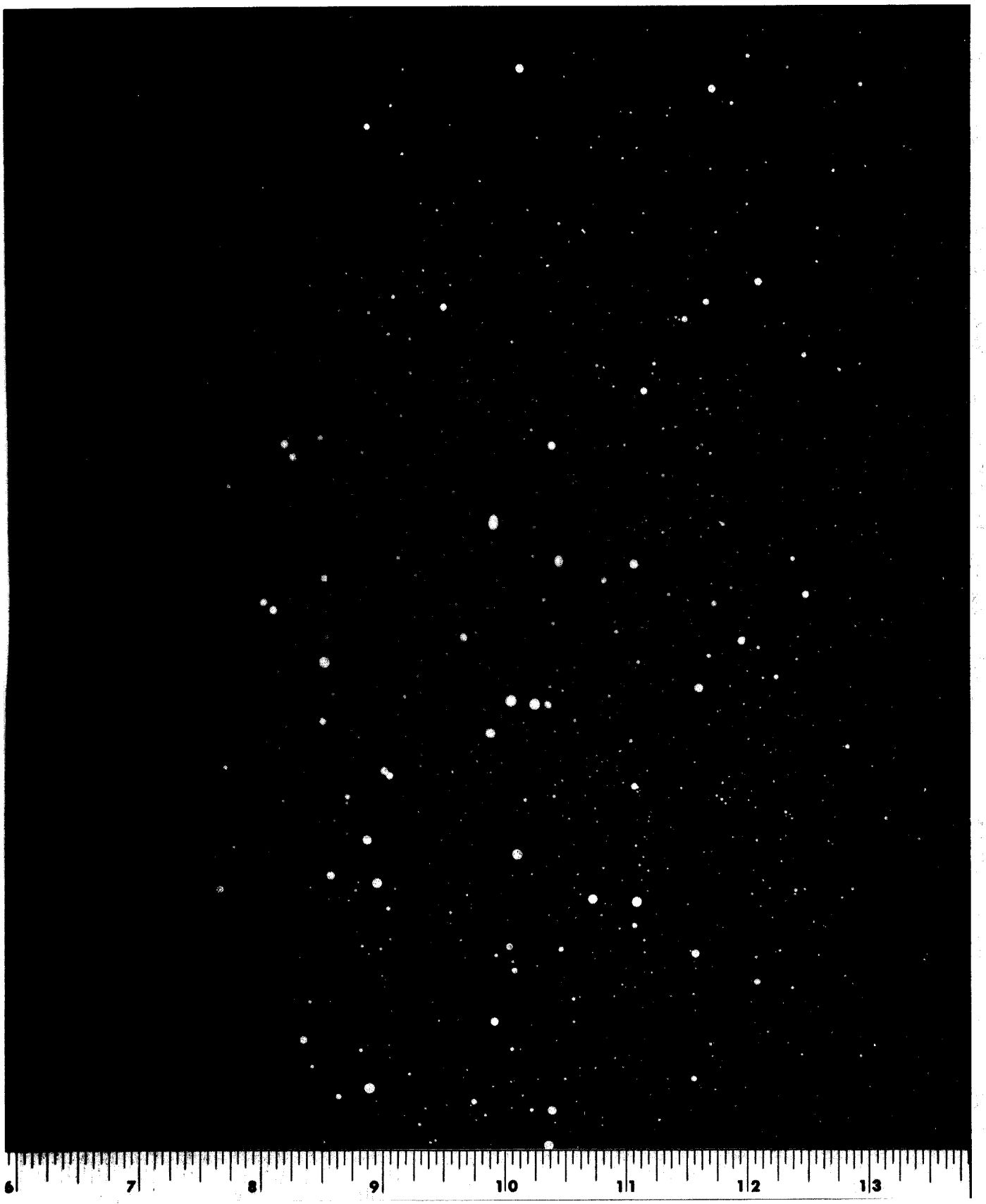


FIG. 5 Paint Spatter Resistance to Roller Application Rating Standard No. 1

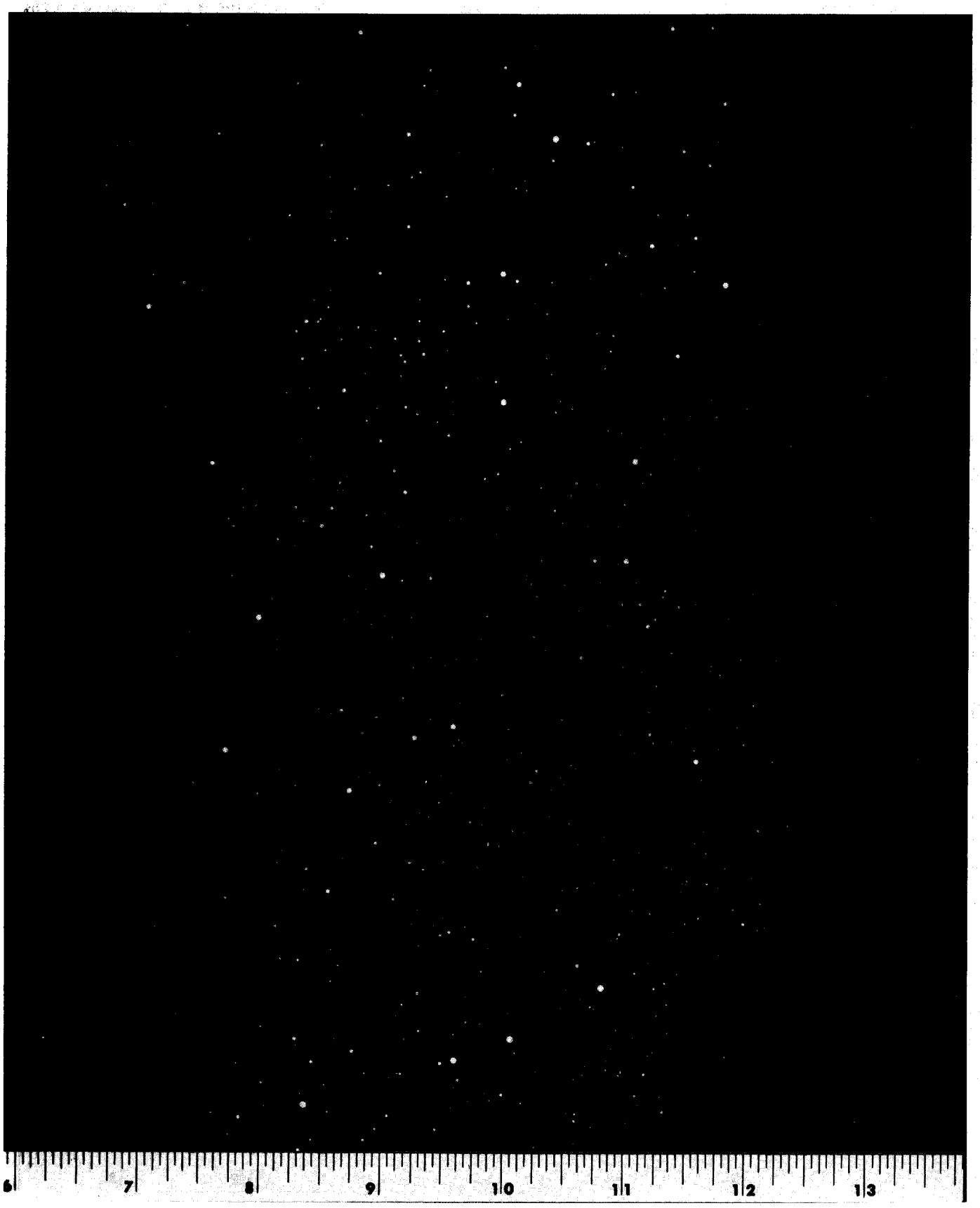


FIG. 6 Paint Spatter Resistance to Roller Application Rating Standard No. 3

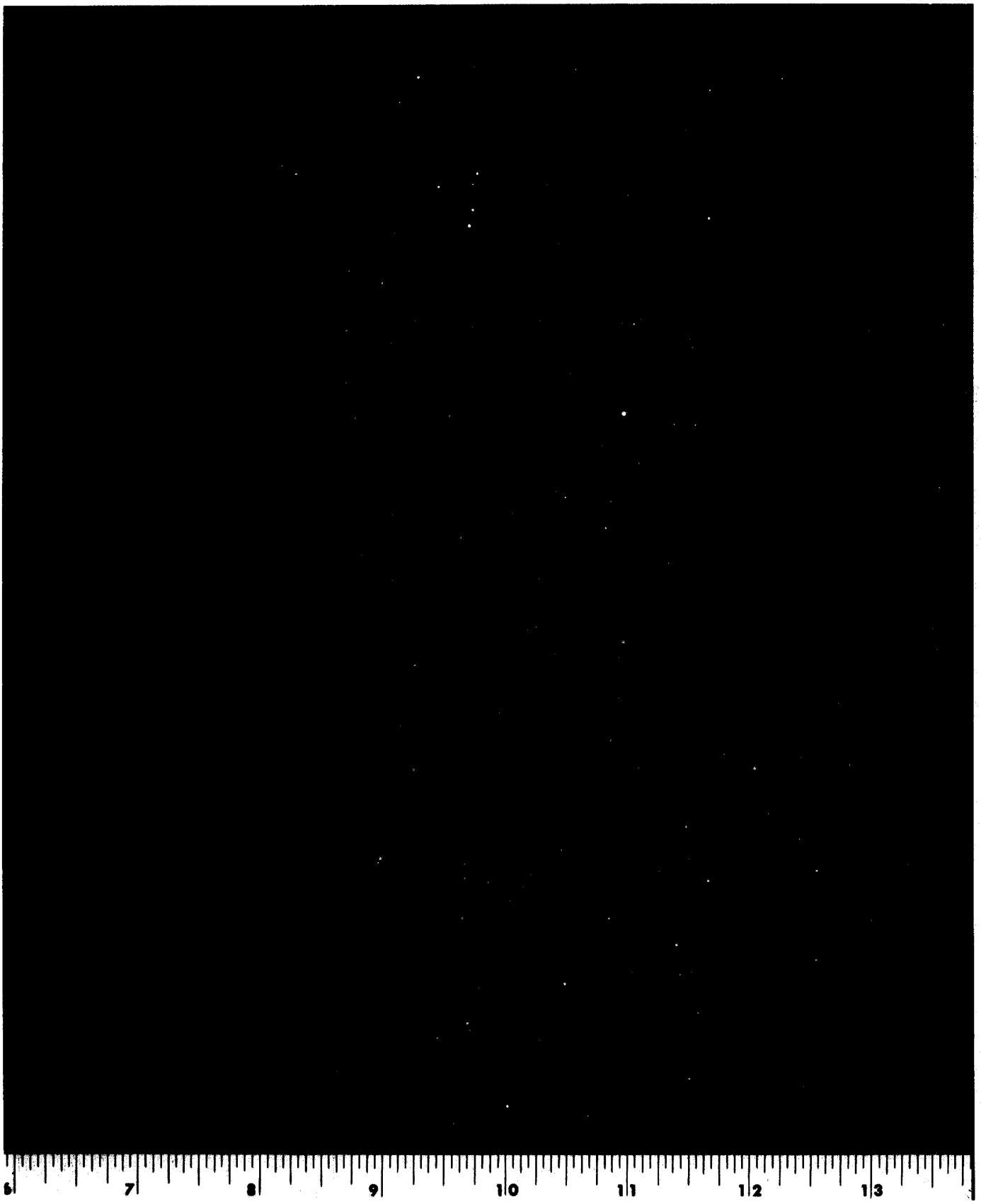


FIG. 7 Paint Spatter Resistance to Roller Application Rating Standard No. 5

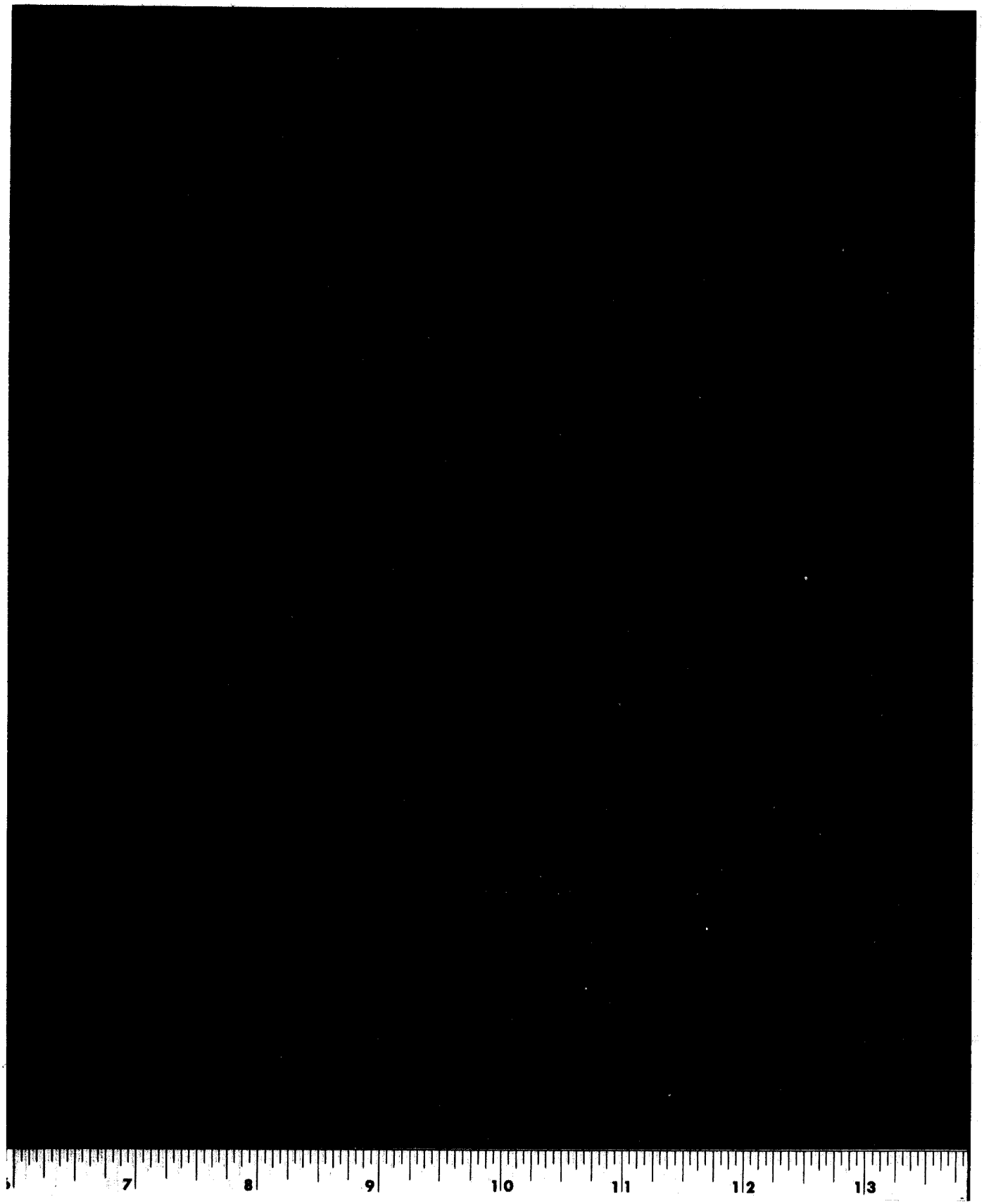


FIG. 8 Paint Spatter Resistance to Roller Application Rating Standard No. 7

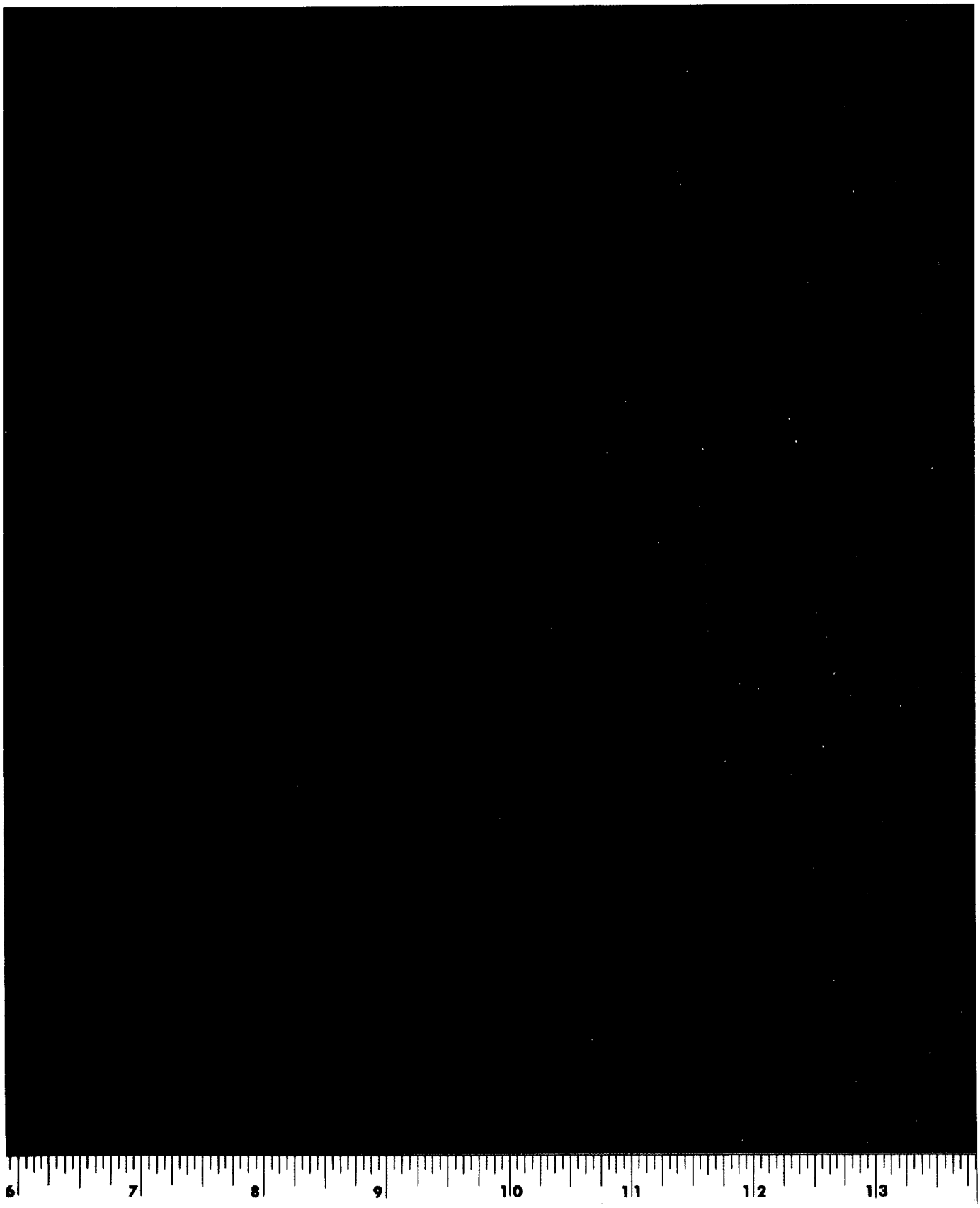


FIG. 9 Paint Spatter Resistance to Roller Application Rating Standard No. 9

Designation: D 4712 – 87a (Reapproved 1991)

Standard Guide for Testing Industrial Water-Reducible Coatings[1]

This standard is issued under the fixed designation D 4712; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

1. Scope

1.1 This guide covers the selection and use of procedures for testing water-reducible coatings, both pigmented and clear, utilizing synthetic latices, synthetic resin emulsions, or water-reducible alkyds. The methods included are listed in Table 1. Where more than one standard is listed for the same characteristic, no attempt is made to indicate superiority of one standard over another. Selection of the standards to be followed must be governed by experience and the requirements in each individual case, together with agreement between producer and user.

1.2 This guide covers the testing of liquid coatings as applied by conventional spray, airless spray, electrostatic spray, dip, fancoat, flowcoat, roller coat, and curtain coat.

1.3 This guide includes procedures relating to proper and safe packaging, shipping and receiving, and storage and handling during use and application.

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

2. Referenced Documents

2.1 *ASTM Standards:*

B 117 Method of Salt Spray (Fog) Testing[2]
B 287 Method of Acetic Acid-Salt Spray (Fog) Testing[3]
D 16 Definitions of Terms Relating to Paint, Varnish, Lacquer, and Related Products[4]
D 56 Test Method for Flash Point by Tag Closed Tester[5]
D 93 Test Methods for Flash Point by Pensky-Martens Closed Tester[5]
D 185 Test Methods for Coarse Particles in Pigments, Pastes, and Paints[6]
D 344 Test Method for Relative Hiding Power of Paints by the Visual Evaluation of Brushouts[4]
D 522 Test Method for Mandrel Bend Test of Attached Organic Coatings[4]
D 523 Test Method for Specular Gloss[4]
D 562 Test Method for Consistency of Paints Using the Stormer Viscometer[4]
D 609 Practice for Preparation of Cold-Rolled Steel Panels for Testing Paint, Varnish, Conversion Coatings, and Related Coating Products[4]
D 610 Test Method for Evaluating Degree of Rusting on Painted Steel Surfaces[7]
D 658 Test Method for Abrasion Resistance of Organic Coatings by the Air Blast Abrasive[4]
D 659 Method for Evaluating Degree of Chalking of Exterior Paints[8]
D 660 Test Method for Evaluating Degree of Checking of Exterior Paints[4]
D 661 Test Method for Evaluating Degree of Cracking of Exterior Paints[4]
D 662 Test Method for Evaluating Degree of Erosion of Exterior Paints[4]
D 714 Test Method for Evaluating Degree of Blistering of Paints[4]
D 772 Test Method for Evaluating Degree of Flaking (Scaling) of Exterior Paints[4]
D 822 Practice for Conducting Tests on Paint and Related Coatings and Materials Using Filtered Open-Flame Carbon-Arc Light- and Water-Exposure Apparatus[4]
D 823 Test Methods for Producing Films of Uniform Thickness of Paint, Varnish, and Related Products on Test Panels[4]
D 869 Test Method for Evaluating Degree of Settling of Paint[7]
D 870 Practice for Testing Water Resistance of Coatings Using Water Immersion[4]
D 968 Test Methods for Abrasion Resistance of Organic Coatings by Falling Abrasive[4]
D 1005 Test Methods for Measurement of Dry-Film Thickness of Organic Coatings Using Micrometers[4]
D 1014 Method for Conducting Exterior Exposure Tests of Paints on Steel[7]
D 1125 Test Methods for Electrical Conductivity and Resistivity of Water[9]
D 1150 Single and Multi-Panel Forms for Recording Results of Exposure Tests of Paints[4]
D 1186 Test Methods for Nondestructive Measurement of Dry-Film Thickness of Nonmagnetic Coatings Applied to a Ferrous Base[4]
D 1200 Test Method for Viscosity by Ford Viscosity Cup[4]
D 1210 Test Method for Fineness of Dispersion of Pigment-Vehicle Systems[4]
D 1212 Test Methods for Measurement of Wet Film Thickness of Organic Coatings[4]

[1] This guide is under the jurisdiction of ASTM Committee D-1 on Paint and Related Coatings and Materials and is the direct responsibility of Subcommittee D01.55 on Factory-Applied Coatings on Preformed Products.

Current edition approved June 26 and Oct. 30, 1987. Published December 1987.

[2] *Annual Book of ASTM Standards*, Vols 03.02 and 06.01.
[3] Discontinued; See *1988 Annual Book of ASTM Standards*, Vol 06.01.
[4] *Annual Book of ASTM Standards*, Vol 06.01.
[5] *Annual Book of ASTM Standards*, Vols 05.01 and 06.01.
[6] *Annual Book of ASTM Standards*, Vol 06.03.
[7] *Annual Book of ASTM Standards*, Vol 06.02.
[8] Discontinued; see *1989 Annual Book of ASTM Standards*, Vols 06.01.
[9] *Annual Book of ASTM Standards*, Vol 11.01.

D 1308 Test Method for Effect of Household Chemicals on Clear and Pigmented Organic Finishes[7]
D 1400 Test Method for Nondestructive Measurement of Dry Film Thickness of Nonductive Coatings Applied to a Nonferrous Metal Base[4]
D 1474 Test Methods for Indentation Hardness of Organic Coatings[4]
D 1475 Test Method for Density of Paint, Varnish, Lacquers and Related Products[4]
D 1535 Test Method for Specifying Color by the Munsell System[4]
D 1540 Practice for Effect of Chemical Agents on Organic Finishes Used in the Transportation Industry[10]
D 1640 Test Methods for Drying, Curing, or Film Formation of Organic Coatings at Room Temperature[6]
D 1653 Test Method for Water Vapor Permeability of Organic Coating Films[4]
D 1654 Method for Evaluation of Painted or Coated Specimens Subjected to Corrosive Environments[4]
D 1729 Practice for Visual Evaluation of Color Differences of Opaque Materials[4]
D 1730 Practices for Preparation of Aluminum and Aluminum-Alloy Surfaces for Painting[11]
D 1731 Practices for Preparation of Hot-Dip Aluminum Surfaces for Painting[11]
D 1732 Practices for Preparation of Magnesium Alloy Surfaces for Painting[11]
D 1735 Practice for Testing Water Resistance of Coatings Using Water Fog Apparatus[4]
D 1737 Test Method for Elongation of Attached Organic Coatings with Cylindrical Mandrel Apparatus[4]
D 1848 Classification for Reporting Paint Film Failures Characteristic of Exterior Latex Paints[7]
D 1849 Test Method for Package Stability of Paint[7]
D 2091 Test Method for Print Resistance of Lacquers[7]
D 2092 Practice for Preparation of Zinc-Coated (Galvanized) Steel Surfaces for Painting[7]
D 2196 Test Methods for Rheological Properties of Non-Newtonian Materials by Rotational (Brookfield) Viscometer[4]
D 2197 Test Methods for Adhesion of Organic Coatings by Scrape Adhesion[4]
D 2201 Test Method for Preparation of Hot-Dipped Nonpassivated Galvanized Steel Panels for Testing Paint, Varnish, Lacquer, and Related Products[4]
D 2243 Test Method for Freeze-Thaw Resistance of Water-Borne Paints[7]
D 2244 Test Method for Calculation of Color Differences from Instrumentally Measured Color Coordinates[4]
D 2246 Test Method for Finishes on Primed Metallic Substrates for Humidity-Thermal Cycle Cracking[4]
D 2247 Practice for Testing Water Resistance of Coatings in 100 % Relative Humidity[4]
D 2248 Practice for Detergent Resistance of Organic Finishes[4]
D 2353 Test Method for Flow Ratings of Organic Coatings Using the Shell Flow Comparator[4]
D 2354 Test Method for Minimum Film Formation Temperature (MFT) of Emulsion Vehicles[7]
D 2369 Test Method for Volatile Content of Coatings[4]
D 2371 Test Method for Pigment Content of Solvent-Reducible Paints[4]
D 2454 Practice for Determining the Effect of Overbaking on Organic Coatings[4]
D 2574 Test Method for Resistance of Emulsion Paints in the Container to Attack by Microorganisms[4]
D 2616 Test Method for Evaluation of Visual Color Difference With a Gray Scale[4]
D 2691 Test Methods for Microscopical Measurement of Dry-Film Thickness of Coatings on Wood Products[7]
D 2697 Test Method for Volume Nonvolatile Matter in Clear or Pigmented Coatings[4]
D 2794 Test Method for Resistance of Organic Coatings to the Effects of Rapid Deformation (Impact)[4]
D 2803 Test Method for Filiform Corrosion Resistance of Organic Coatings on Metal[4]
D 2805 Test Method for Hiding Power of Paints by Reflectometry[4]
D 2933 Test Method for Corrosion Resistance of Coated Steel Specimens (Cyclic Method)[4]
D 3002 Practice for Evaluation of Coatings for Plastics[7]
D 3023 Practice for Determination of Resistance of Factory-Applied Coatings on Wood Products to Stains and Reagents[7]
D 3134 Practice for Establishing Color and Gloss Tolerances[4]
D 3168 Practice for the Qualitative Identification of Polymers in Emulsion Paints[4]
D 3170 Test Method for Chipping Resistance of Coatings[7]
D 3278 Test Methods for Flash Point of Liquids by Setaflash Closed-Cup Apparatus[4]
D 3281 Test Method for Formability of Attached Organic Coatings with Impact-Wedge Bend Apparatus[7]
D 3359 Test Methods for Measuring Adhesion by Tape Test[4]
D 3361 Practice for Operating Light- and Water-Exposure Apparatus (Unfiltered Open-Flame Carbon-Arc Type) for Testing Paint, Varnish, Lacquer, and Related Products Using the Dew Cycle[4]
D 3793 Test Method for Low-Temperature Coalescence of Latex Paint Films[7]
D 3924 Specification for Standard Environment for Conditioning and Testing Paint, Varnish, Lacquer, and Related Materials[4]
D 3925 Practice for Sampling Liquid Paints and Related Pigmented Coatings[4]
D 3928 Test Method for Evaluation of Gloss or Sheen Uniformity[7]
D 4060 Test Method for Abrasion Resistance of Organic Coatings by the Taber Abraser[4]
D 4062 Test Method for Leveling of Paints by Draw-Down Method[7]
D 4399 Method for Measuring Electrical Conductivity of Electrocoat Baths[4]
D 4585 Practice for Testing Water Resistance of Coatings Using Controlled Condensation[4]
D 4587 Practice for Conducting Tests on Paint and Related Coatings and Materials Using a Fluorescent

[10] Discontinued; see *1992 Annual Book of ASTM Standards*, Vol 06.01.
[11] *Annual Book of ASTM Standards*, Vols 02.05 and 06.02.

UV-Condensation Light- and Water-Exposure Apparatus[4]
E 70 Test Method for pH of Aqueous Solutions with the Glass Electrode[12]
2.2 *U.S. Federal Test Method Standard No. 141c:*[13]
2131.1 Application of Sprayed Films
3011.2 Condition in Container

3. Terminology

3.1 *Definitions:*
3.1.1 For definitions of terms used in this guide, refer to Definitions D 16.

4. Significance and Use

4.1 This compilation of standards is intended to provide assistance in selecting appropriate tests for evaluating water-reducible coatings and for determining what characteristics should be considered for a given end use. Either single-coat operations or multicoat systems may be addressed by the proper selection of tests. Results from the various tests are not all necessarily useful in evaluating the performance of different systems for various end uses. The list can be useful to those developing coatings and coating systems and to those seeking coating systems for products.

5. Equipment

5.1 Use the equipment as specified in each standard.

6. General Requirements

6.1 Tests and observations shall be at standard laboratory conditions as specified in Specification D 3924 unless otherwise specified or agreed upon by the producer and user.

7. Sampling and Specimen Preparation

7.1 Sample the water-reducible coatings in accordance with Practice D 3925.
7.2 Prepare specimens as required for the specific tests on the liquid coating and the dry coating.

8. Conditions Affecting Performance

8.1 Practical requirements and performance of water-reducible coatings may vary with:
8.1.1 Type of substrate.
8.1.2 Substrate condition, for example, porosity, hardness, smoothness, flexibility, etc.
8.1.3 Type, quality, and suitability of the surface treatment or primer used under the water-reducible coating and the time before coating application.
8.1.4 Application methods and techniques.
8.1.5 Contaminants on the surface of the substrate.
8.1.6 Environmental conditions such as temperature and relative humidity.
8.1.7 Damage to container, size, and type of container.
8.1.8 Storage variables, for example storage time, excessive temperature fluctuations that may cause physical or chemical change. Special needs arise due to carbon dioxide absorption, dissolved metal compatibility, and ultrafiltration treatments.

9. Liquid Coatings Properties

9.1 *Condition in Container*—Thickening, settling, and separation are undesirable and objectionable if a liquid coating cannot be reconditioned and made suitable for application with a reasonable amount of stirring. The referenced method covers procedures for determining changes in properties after storage. Determine the condition in the container in accordance with Method 3011.1 of U.S. Federal Test Method Standard No. 141c.
9.2 *Coarse Particles and Foreign Matter*—To form uniform films of good appearance, the liquid coating must be free of coarse particles as agreed upon between the producer and the user, a typical maximum being 1 % by weight of the total paint. Determine coarse particles and foreign matter in accordance with Test Methods D 185.
9.3 *Density or Weight Per Gallon*—The density as measured by weight per gallon is used to help assure product uniformity from batch to batch. In the referenced test method, the density is expressed as the weight in pounds avoirdupois of 1 U.S. gal or the weight in kilograms of 1 L of the paint at a specified temperature. A calibrated weight-per-gallon cup is used. Determine the density in accordance with Test Method D 1475.
9.4 *Fineness of Dispersion*—The more finely a pigment is dispersed, the more efficiently it is being used. One test method for measuring the degree of dispersion (commonly referred to as "fineness of grind") is to draw the material down a calibrated, tapered groove in a hardened steel block with the groove varying in depth from 4 to 0 mils (100 to 0 μm). The point at which continuous groupings of particles or agglomerates, or both, protrude through the surface of the liquid is taken as the fineness reading. Lower readings in mils or μm or higher readings in Hegman units indicate better fineness of dispersion. Determine fineness of dispersion in accordance with Test Method D 1210.
9.5 *Pigment Suspension*—The amount and type of settling is an indication of how well the pigments remain in suspension and how easily settled pigment can be remixed. Determine degree of settling in accordance with Test Method D 869.
9.6 *Viscosity*—Viscosity refers to the flow resistance of a fluid and should fall within an agreed-upon range. Viscosities of Newtonian fluids (constant viscosity regardless of shear rate) may be measured with a Ford Cup. Viscosities of non-Newtonian materials should be measured at two or more speeds with a Brookfield rotational viscometer. Determine viscosity in accordance with Test Methods D 1200 or D 2196.
9.7 *Consistency*—Consistency is a less precise term than viscosity for evaluating the flow properties of a material. In the referenced test method, consistency is defined as the load in grams required to produce a specific rate of rotation in a specimen using the Stormer Viscometer. This is a one-speed test method and is not recommended for paints that show shear thinning or thixotropy. Determine consistency in

[12] *Annual Book of ASTM Standards*, Vol 15.05.
[13] Available from Standardization Documents Order Desk, Bldg. 4 Section D, 700 Robbins Ave., Philadelphia, PA 19111-5094, Attn: NPODS.

TABLE 1 List of Test Methods by Properties

Test Method	Section	ASTM Standard	Federal Test Method Standard 141
I. *Liquid Coating Properties:*	9		
Coarse particles and foreign matter	9.2	D 185	
Condition in container	9.1	...	3011.1
Conductivity	9.14	D 1125 or D 4399	...
Consistency	9.7	D 562	...
Density or weight per gallon	9.3	D 1475	...
Fineness of dispersion	9.4	D 1210	...
Flash point	9.13	D 56, D 93 or D 3278	...
Freeze-thaw stability	9.9	D 2243	...
Microorganism resistance	9.11	D 2574	...
pH	9.8	E 70	...
Package stability	9.10	D 1849	...
Pigment suspension	9.5	D 869	...
Surface tension	9.12	...	...
Viscosity	9.6	D 1200 or D 2196	...
II. *Application and Film Formation:*	10		
Panel preparation	10.1	D 609, D 1730, D 1731, D 1732, D 2092, D 2201	...
Drying properties	10.2.2	D 1640	...
Leveling properties	10.3	D 4062, D 2353	...
Low temperature coalescence	10.5	D 3793, D 2354	...
Spray properties	10.2.1	...	2131.1, 4331.1
Touch-up	10.6	D 3928	...
Uniform film preparation	10.4	D 823	...
Wet film thickness	10.3	D 1212	...
III. *Appearance of Dry Film:*	11		
Color difference by visual evaluation	11.1.1	D 1729, D2616	...
Color difference by instrumental evaluation	11.1.2	D 2244 and D 3134	...
Color description by visual evaluation	11.1.3	D 1535	...
Color description by instrumental evaluation	11.1.4	D 2244	...
Gloss	11.2	D 523	...
Hiding power	11.3	D 344, D 2805	...
IV. *Properties of Dry Film:*	12		
Abrasion resistance	12.1	D 658, D 968, D 4060	...
Adhesion	12.2	D 2197, D 3359	...
Elongation	12.3	D 522, D 1737, D 3281	...
Exterior exposure	12.4		...
Blistering	12.4.1	D 714	...
Chalking	12.4.2	D 659	...
Checking	12.4.3	D 660	...
Cracking	12.4.4	D 661	...
Erosion	12.4.5	D 662	...
Flaking	12.4.6	D 772	...
Rusting	12.4.7	D 610, D 2933	...
Accelerated weathering	12.4.8	D 822, D 3361, D 4587	...
Corrosive environments	12.4.9	D 1654	...
Hardness	12.5	D 1474	...
Impact resistance	12.6	D 2794, D 3170	...
Resistance to various forms of water	12.8		
Water immersion	12.8.1	D 870	...
Water fog	12.8.2	D 1735	...
Humidity resistance	12.8.3	D 2247	...
Moisture vapor permeability	12.8.4	D 1653	...
Salt spray	12.8.5	B 117, B 287	...
Humidity-thermal cycling	12.8.6	D 2246	...
Filiform corrosion	12.8.7	D 2803	...
Condensation	12.8.8	D 4585	...
Detergent resistance	12.8.9	D 2248	...
Resistance to chemicals	12.7	D 1308, D 1540, D 3023	...
Overbaking	12.9	D 2454	...
Print resistance	12.10	D 2091	...
Reporting results	12.4.10	D 1848	...
Dry film thickness	12.11	D 1186, D 1400	
V. *Analysis of Paint:*	13		
Volatile content	13.2	D 2369	...
Volume of nonvolatile	13.3	D 2697	...
Weight of nonvolatile	13.3	D 2369	...
Pigment content	13.4	D 2371	...
Identification of vehicle solids	13.6	D 3168	...

accordance with Test Method D 562.

9.8 *pH*—The pH of a water-reducible coating depends on the type of vehicle used and the general formulation. It may vary from about 4 to 10. A change in pH during storage may indicate poor stability or a change in properties of a water-reducible coating. Determine pH in accordance with Test Method E 70.

9.9 *Freeze-Thaw Resistance*—Water-reducible coatings may be subjected to freezing conditions during shipping and storage. Suitably stabilized paints will resist several cycles of freezing and thawing without showing deleterious changes. The referenced method covers the determination of the extent to which water-reducible coatings retain their original consistency and freedom from lumps when subjected to freezing and subsequent thawing. Determine freeze-thaw resistance in accordance with Test Method D 2243.

9.10 *Package Stability*—Since liquid coatings cannot normally be used immediately after manufacture, they must remain stable in the package for some time. The referenced test method covers the change in consistency and in certain related properties that may take place in packaged water-reducible coatings when stored at a temperature above room temperature. Determine package stability in accordance with Test Method D 1849, at a temperature and for a period of time agreed upon by the purchaser and the seller.

NOTE—Although there is no ASTM or Federal test method for determining gassing during normal storage, special containers may be necessary to vent any spontaneous pressure buildup.

9.11 *Microorganism Resistance*—Microorganisms in water-reducible coatings can cause gassing, putrefaction or fermentation odors, and loss of vicosity. Determine if the liquid coating contains living bacteria and if it is resistant to attack by bacteria in accordance with Test Method D 2574.

9.12 *Surface Tension*—Although there is no ASTM or Federal test method for determining surface tension of liquid coatings, this is an important property of a water-reducible resin or coating. If surface tension is too high, poor pigment and substrate wetting may occur, leading to cratering, low gloss, or other surface defects. The most common methods for measuring the surface tensions of coatings probably are the ring pull method and drop weight method. For a comprehensive discussion of these and other aspects of surface tension, see *Paint Flow and Pigment Dispersion.*[14]

9.13 *Flash Point*—Nearly all water-borne coatings are incapable of sustaining combustion, but many do contain volatile solvents whose vapors can ignite if near open flame. Because they do give flash points, water-borne coatings must be tested for flash point temperature to conform with many government regulations concerning transportation, labeling, packaging, etc. Determine flash point in accordance with Test Methods D 56, D 93 or D 3278.

9.14 *Conductivity*—Conductivity is an important factor in the application of some water-borne coatings. Test Methods available for determining conductivity are D 1125 (specifically Methods A and B) and D 4399.

10. Application and Film Formation

10.1 *Panel Preparation*—Select a substrate as agreed upon by the producer and the user. Prepare panels for testing the coating in accordance with Test Methods D 609, D 1730, D 1731, D 1732, D 2201, or D 2092. The preparation of plastics for paint testing is covered in Practice D 3002.

10.2 *Application Properties*—Determine the ease with which the liquid coating can be applied to various surfaces with brush, spray, or other application equipment. Application properties are generally compared to a standard, or described by requirements in a product specification. Application properties are related to such characteristics as kinematic viscosity, non-Newtonian rheology, surface tension, shear sensitivity, micelle stability, electrical resistivity, erosion abrasiveness, conductivity, heat capacity, and corrosiveness.

10.2.1 *Sprayed Film Application*—Liquid coatings can be applied by spray. Determine the spray application properties in accordance with Method 2131.1 of Federal Test Method Standard No. 141. The method can be modified to include application by airless spray equipment.

10.2.2 *Drying Properties*—The drying time of water-reducible coatings is important in determining when the applied coatings can be handled or packed. Also, inadequate drying of the film may result in poor film and poor appearance and, if used on an exterior surface, rain, dew, or snow may cause a nonuniform appearance. Determine drying time in accordance with Test Method D 1640, or as agreed upon by producer or user.

10.3 *Leveling Properties*—Leveling is an important factor when uniform surfaces are to be produced, as it affects hiding and appearance. The referenced methods cover the laboratory determination of the relative leveling characteristics of liquid coatings. Determine the leveling characteristics in accordance with Test Method D 4062. Measure wet film thickness in accordance with Test Method D 1212.

10.4 *Producing Films of Uniform Thickness*—The following test method covers the preparation of various films of uniform thickness essential in conducting tests. Prepare films in accordance with Test Methods D 823.

10.5 *Low Temperature Coalescence of Paints*—A test method to determine how well the latex particles in coating will fuse together or coalesce to form a continous film at low temperature is described in Test Method D 3793. A test for the minimum film formation temperature is described in Test Method D 2354.

10.6 *Touch-Up*—For many coating systems it is important to be able to repair damage sustained during production, delivery, or after delivery. A coating can be tested by applying it with a small nylon bristle brush or air brush to a small section of a panel previously coated with it. When the touch-up area has dried, it is examined to see if it differs significantly from the initial coating. Determine the ability to touch up the coating in accordance with Test Method D 3928. Test the adhesion of the original and touch-up areas in accordance with Test Methods D 3359 or other agreed-upon test method.

11. Appearance of Dry Film

11.1 *Color*—The color of a water-reducible coating may be specified independently or as the color-difference with respect to another color that is usually the standard. Visual and instrumental methods are both applicable. An opaque

[14] Patton, T., *Paint Flow and Pigment Dispersion*, 2nd Ed., Wiley-Interscience, New York, 1979, pp. 205–246.

film is preferred that may be prepared by making one or more applications of water-reducible coating onto a black and white substrate until the substrate is completely obscured. Each application should be performed in a normal manner with respect to application method, drying, and film thickness.

11.1.1 *Color Differences by Visual Evaluation*—Visual comparison of color is fast and often acceptable although numerical values are not obtained. The referenced standard covers the spectral, photometric, and geometric characteristics of light source, illuminating and viewing conditions, size of specimens, and general procedures to be used in the visual evaluation of color differences of opaque materials. Determine color difference by visual evaluation in accordance with Practice D 1729 or Test Method D 2616.

11.1.2 *Color Differences of Opaque Material by Instrumental Evaluation*—Color difference between a product and the standard can be measured by an instrument. Generally, the tolerance is agreed upon by the purchaser and the seller and may also be required if a product specification is involved. Color instruments provide numerical values that can be subsequently compared to later measurements. The referenced method covers the instrumental determination of small color differences observable in daylight illumination between nonfluorescent, nonmetameric, opaque surfaces such as coated specimens. If metamerism is suspected, visual evaluation (10.1.1) should be used to verify the results. Make instrumental measurement of color difference in accordance with Method D 2244. Tolerances are discussed in Recommended Practice D 3134.

11.1.3 *Color Description by Visual Evaluation*—In some cases it is necessary to specify or identify a color instead of a color difference from some standard. Various color atlases are available, the most common being the Munsell System. Describe or identify the Munsell color in accordance with Method D 1535.

11.1.4 *Color Description by Instrumental Evaluation*—Instrumental measurements involve the determination of CIE tristimulus values, X, Y, and Z, from which other color coordinates such as L*, a*, b*, or L, a, b values may be calculated or obtained directly with some instruments. Describe or identify in accordance with Method D 2244.

11.2 *Gloss*—Water-reducible coatings vary in gloss and the end use determines whether the gloss should be high, semi-gloss, eggshell, or flat. Determine the gloss in accordance with Test Method D 523 using 20, 60, or 85° geometry as appropriate.

11.3 *Hiding Power (Dry Opacity)*—Hiding power is the measure of the ability of a paint to hide the substrate. It is, however, dependent upon uniform film thickness which is influenced by flow and leveling. Test Method D 344 is a practical test in which paint is applied with a brush, film thickness is approximately measured, and opacity is evaluated visually as compared to a standard paint. Results are affected by flow and leveling application properties of the paint. Test Method D 2805 is considered to be a more precise and accurate test that does not need a material paint standard. Paint is applied with an applicator bar to minimize the effects of flow and leveling, film thickness is rigorously measured, and opacity is instrumentally evaluated. Determine hiding power in accordance with Test Methods D 344 or D 2805.

12. Properties of Dry Film

12.1 *Abrasion Resistance*—Abrasion resistance is a measure of the ability of a dried coating to withstand wear and marring from objects rolled or pulled across the surface. Determine abrasion resistance in accordance with Test Method D 658, D 968, or D 4060 (see methods to determine the applicability for interlaboratory use).

12.2 *Adhesion*—Adhesion is the property of the coating that resists removal from the substrate when scraped. Test Methods D 2197 covers the use of a scrape adhesion tester and a parallel groove adhesion tester. In Test Methods D 3359 cuts are made in the film and pressure-sensitive tape applied and removed. Determine adhesion in accordance with Test Methods D 2197 or D 3359.

12.3 *Elongation*—Elongation is a measure of the flexibility of coating films. Determine elongation in accordance with Test Methods D 522, D 1737, or D 3281.

12.4 *Exterior Exposure*—If the paint is intended for exterior exposure, tests may be run in accordance with Method D 1014, and Standard D 1150 and evaluated by the following methods:

12.4.1 *Blistering*—Determine the degree of blistering in accordance with Test Method D 714.

12.4.2 *Chalking*—Determine the degree of chalking in accordance with Method D 659.

12.4.3 *Checking*—Determine the degree of checking in accordance with Test Method D 660.

12.4.4 *Cracking*—Determine the degree of cracking in accordance with Test Method D 661.

12.4.5 *Erosion*—Determine the degree of erosion in accordance with Test Method D 662.

12.4.6 *Flaking*—Determine the degree of flaking in accordance with Test Method D 772.

12.4.7 *Rusting*—Determine the degree of rusting in accordance with Test Methods D 610 or D 2933.

12.4.8 *Accelerated Weathering*—Determine the resistance to accelerated weathering in accordance with Test Method D 822, D 3361, or D 4587.

12.4.9 *Corrosive Environment*—Determine the resistance to corrosive environment in accordance with Test Method D 1654.

12.4.10 *Reporting of Results*—The reporting of results can often be helped by reference to the classifications prescribed in Classification D 1848.

12.5 *Hardness*—Hardness is a measure of the ability of a dried coating to resist indentation. Determine hardness in accordance with Test Method D 1474.

12.6 *Impact Resistance*—An important property of a water-reducible coating is its ability to withstand a striking blow or impingement. Determine the impact resistance in accordance with Test Methods D 2794 or D 3170.

12.7 *Resistance to Chemicals*—An important property of a water-reducible coating is its ability to resist spotting, softening, or removal when subjected to household chemicals or strong cleaners. Determine resistance to chemicals in accordance with Test Methods D 1308 or D 1540 or Practice D 3023.

12.8 *Resistance to Various Physical Forms of Water*—

The ability of a dried coating to resist water in many different forms is an especially important property of water-reducible coatings.

12.8.1 *Water Immersion*—Determine the resistance to water absorption in accordance with Practice D 870.

12.8.2 *Water Fog*—Determine the resistance to water fog in accordance with Practice D 1735.

12.8.3 *Humidity Resistance*—Determine the resistance to 100 % relative humidity in accordance with Practice D 2247.

12.8.4 *Moisture Vapor Permeability*—Determine the resistance to moisture vapor transmission in accordance with Test Method D 1653.

12.8.5 *Salt Spray*—Determine the resistance to salt spray (fog) in accordance with Methods B 117 or B 287.

12.8.6 *Humidity-Thermal Cycling*—Determine the resistance to humidity-thermal cycling in accordance with Test Method D 2246.

12.8.7 *Filiform Corrosion*—Determine the resistance to filiform corrosion in accordance with Test Method D 2803.

12.8.8 *Condensation*—Determine the resistance to condensed water such as dew in accordance with Practice D 4585.

12.8.9 *Detergent Resistance*—Determine the resistance to detergent solution in accordance with Practice D 2248.

12.9 *Overbaking*—The ability of a coating to withstand a baking temperature moderately higher than initial bake or for a longer period of time is an important property. Measure the resistance to overbaking by Practice D 2454.

12.10 *Print Resistance*—Print resistance is the ability of a dried coating to withstand pressure from a textured surface without any noticeable marking on the coating. Measure print resistance in accordance with Test Method D 2091.

12.11 *Dry Film Thickness*—There are several methods currently being used for determining dry film thickness. Depending on the substrates being used, the following test methods should be considered: D 1005, D 1186, D 1400, and D 2691.

13. Analysis of Paint

13.1 *Chemical Analysis*—If a specification requires certain raw materials or certain components in a given amount, then chemical analysis is required. Chemical analysis determines whether the specified components are present, and if they are, in what amounts. It does not necessarily establish quality, which can also be greatly affected by manufacturing techniques. Most ASTM analytical methods, such as Method D 215, apply to solvent-type coatings. However, some of these can be adapted for analysis of water-reducible coatings.

13.2 *Volatile Content*—The percent of volatile matter indicates the water and organic solvent released from the film as it dries. This quantity subtracted from 100 % gives the nonvolatile content. Determine the volatile content in accordance with Test Method D 2369.

13.3 *Nonvolatile Content*—The percent of nonvolatile matter indicates the amount of material present that can be converted to the desired film. Determine the weight percent of nonvolatile in accordance with Test Method D 2369. Determine the volume percent of nonvolatile in accordance with Test Method D 2697.

13.4 *Pigment Content*—Although the referenced method describes the procedure for quantitative separation of the vehicle from the pigment in solvent-reducible coatings, it can be adapted for water-reducible coatings to determine the weight percent pigment in the paint. Determine the pigment content in accordance with Test Method D 2371.

13.5 *Pigment Analysis*—The analysis of pigment may be required if the product is covered by a specification, or if it is agreed upon between the producer and the user. Analyze the pigment in accordance with methods appropriate for the constituents present or specified.

13.6 *Identification of Vehicle Solids*—The suggested method covers the qualitative characterization or identification of separated paint vehicle solids by infrared spectroscopy. It is useful in detecting uniformity, batch to batch, and the presence of adulterants. Characterize vehicle solids in accordance with Practice D 3168.

14. Keywords

14.1 alkyds; appearance of materials; application properties; brush application; color; curtain coat; dip application; electrostatic spray; emulsion vehicles; exterior exposure; fancoat; film formation rates; flowcoat; instrumental evaluation; opaque film; paints and related coatings; paints, water-base; roller coat; spray method; visual examination; water-reducible coatings.

Designation: D 4713 – 92

Standard Test Methods for Nonvolatile Content of Heatset and Liquid Printing Ink Systems[1]

This standard is issued under the fixed designation D 4713; 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 cover the determination of weight content of nonvolatile matter in two types of printing inks.

1.2 Test Method A is applicable to heatset-type printing inks and resin solutions; solvents in such systems typically have initial boiling points in the range from 240 to 275°C (470 to 535°F) and vapor pressures less than 0.2 mm Hg.

1.3 Test Method B is applicable to liquid-type printing inks and vehicles based on aqueous or organic solvents that evaporate readily at ordinary room temperatures.

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

NOTE 1—Test Method A (for heatset systems) specifies a specimen film thickness that is much thinner than those produced by related test methods; one exception is Test Method B in Test Method D 1259, which is recommended as a referee test.

NOTE 2—Test Method B (for liquid ink systems) is similar to Test Method D 2369 except that a solvent is not required for spreading the test specimen.

2. Referenced Documents

2.1 *ASTM Standards:*

D 1259 Test Methods for Nonvolatile Content of Resin Solutions[2]

D 2369 Test Method for Volatile Content of Coatings[2]

E 1 Specification for ASTM Thermometers[3]

E 145 Specification for Gravity-Convection and Forced-Ventilation Ovens[4]

E 691 Practice for Conducting an Interlaboratory Study to Determine the Precision of a Test Method[5]

3. Summary of Test Methods

3.1 *Test Method A—Heatset Systems.* A 0.15-g specimen is mechanically spread in a 57-mm weighing dish to a nominal thickness of 80 ± 10 g/m^2 and heated in a forced ventilation oven at 110°C for 3 h.

3.2 *Test Method B—Liquid Ink Systems.* A 0.5-g specimen is dispensed into a 57-mm weighing dish by means of a disposable syringe, mechanically spread out, and heated in an oven at 110°C for 1 h.

4. Significance and Use

4.1 Nonvolatile content of printing inks is useful for specification acceptance between the producer and the user.

4.2 In order to obtain accurate results for heatset systems within the specified 3-h heating time, the specimen film thickness must be less than 100 g/m^2, and the oven must have forced ventilation. Thickness of the specimen film is less critical for liquid ink systems.

5. Apparatus

5.1 *Balance*, accurate to 1 mg.

5.2 *Oven*, forced-ventilation type conforming to Type IIB in Specification E 145 and maintained at 110 ± 2°C.

5.3 *Thermometer*, bulb-type, capable of reading 110 ± 2°C, such as Thermometer 88C prescribed in Specification E 1.

5.4 *Weighing Dish*, such as an aluminum foil dish 57 mm wide, the lid of a 1-lb ink can 94 mm wide, or other flat-bottomed container. The bottom of the container must not have a trough or depression into which the test material might collect.

5.5 *Spatula*, or small ink knife.

5.6 *Spreading Device*, one per weighing dish, of heat-stable material, such as a glass stirring rod or thick L-shaped wire.

5.7 *Forceps*,

5.8 *Desiccator*,

5.9 *Syringe*[6] *(for liquid ink systems only)*, single-use 2 to 5-mL capacity without needle, or other weighing device listed in the Apparatus section of Test Method D 1259.

6. Reagents

6.1 *Toluene*, technical grade.

7. Preparations of Equipment and Sample

7.1 Check the levelness of shelving in the oven; adjust, if necessary. Lay the thermometer on shelf with the bulb at the place where the samples will be placed. Adjust oven controls until thermometer reads 110 ± 2°C. If air flow is adjustable, set control dampers at 50 %.

7.2 Wear disposable gloves prior to handling weighing dish, spreading device, or syringe in order to minimize contamination by moisture from hands.

7.3 Measure diameter of bottom of weighing dish in

---

[1] These test methods are under the jurisdiction of ASTM Committee D-1 on Paint and Related Coatings, Materials, and Applications and are the direct responsibility of Subcommittee D01.56 on Printing Inks.

Current edition approved Oct. 15, 1992. Published December 1992. Originally published as D 4713 – 87. Last previous edition D 4713 – 87$^{\epsilon 1}$.

[2] *Annual Book of ASTM Standards*, Vol 06.01.

[3] *Annual Book of ASTM Standards*, Vols 05.03 and 14.03.

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

[5] *Annual Book of ASTM Standards*, Vols 06.04, 08.03, and 14.02.

[6] Available from any scientific supply house.

millimetres. For example, a catalogue listing of 57 mm refers to the top diameter, whereas the bottom diameter may be only 50 mm. The bottom diameter must be used in the calculations of weight per unit area in 9.1.

7.4 Mark weighing dishes with a suitable notation. Rinse with toluene and heat in oven at 110°C for ½ h.

7.5 Thoroughly mix ink in container to ensure that the sample is uniform. Close can after removing specimen. Reseal when finished.

8. Procedure

8.1 *Test Method A—Heatset Systems:*

8.1.1 For each specimen, tare to the nearest milligram two weighing dishes each with a spreading device. Retain spreading device throughout the test.

8.1.2 Transfer a representative portion of the sample to the tip of a spatula and dab about 0.15 ± 0.02 g around the bottom of each 57-mm dish, or 0.43 ± 0.02 g if a 94-mm can lid is used. Quickly reweigh and calculate the weight per unit area in accordance with 9.1. If in excess of 100 g/m^2, discard and weigh out a new specimen.

8.1.3 With spreader, smooth out the specimen into a reasonably uniform film covering the entire bottom of the dish. High viscosity inks may require a few drops of a suitable solvent to aid in spreading out the film.

8.1.4 Place the dishes in the forced draft oven at 110°C for 3 h. Remove dishes from oven, cool in desiccator, and reweigh.

8.2 *Test Method B—Liquid Ink Systems:*

8.2.1 Tare weighing dishes as in 8.1.1. Transfer 2 to 4 mL of representative sample to syringe and weigh. Dispense a 0.5 ± 0.1 g specimen from the syringe to a 57-mm dish, or 1.5 ± 0.1 g to a 94-mm can lid. Immediately spread out as in 8.1.2. Reweigh syringe.

8.2.2 Repeat 8.2.1 with second dish.

8.2.3 Place dishes in forced draft oven at 110°C for 1 h. Remove dishes from oven, cool in desiccator, and reweigh.

9. Calculation

9.1 Calculate initial weight/area of each specimen:

$$S/A = S \times 10^6/3.14\ R^2,\ \text{g/m}^2$$

where:

S = initial specimen weight, g,
A = area, and
R = radius of dish bottom, = diameter/2 mm.

NOTE 3—For a dish with a 50-mm bottom diameter, weight/area = 510 S. For a can lid with a 94-mm bottom diameter, weight/area = 145 S.

9.2 Calculate content of nonvolatile matter as follows:

$$NVM,\ \% = (W/S) \times 100$$

where:

W = specimen weight after heating, g.

9.3 *Optional:* The percent of volatile matter may be calculated by difference as follows:

$$VM,\ \% = 100 - NVM\ \%.$$

10. Report

10.1 Report *NVM* to the nearest 0.1 % as the mean of replicate determinations.

10.2 *Optional:* Report *VM* to the nearest 0.1 %.

10.3 Report the mean weight per unit area of the initial specimens to the nearest gram per square metre.

11. Precision and Bias

11.1 *Precision:*

11.1.1 *Test Method A—Heatset Systems.* An interlaboratory[7] study was conducted in which one operator in each of five laboratories tested in duplicate on each of two days four heatset printing inks, of which two were low *NVM* (about 50 %) and two were high *NVM* (about 60 %). The round-robin data were analyzed according to Practice E 691. There were no outliers. The within-laboratory pooled standard deviation was found to be 0.44 % absolute at 12 degrees of freedom, and the between-laboratories pooled standard deviation was 2.0 % absolute at 16 degrees of freedom. Based on these standard deviations, the following criteria should be used for judging the acceptability of results at the 95 % confidence level:

11.1.1.1 *Repeatability*—Two results, each the mean of two runs obtained by one operator, should be considered suspect if they differ by more than 1.2 % absolute.

11.1.1.2 *Reproducibility*—Two results, each the mean of two runs obtained by operators in different laboratories, should be considered suspect if they differ by more than 5.7 % absolute.

11.1.2 *Test Method B—Liquid Ink Systems.* See Precision section of Test Method D 2369.

11.2 *Bias*—In the interlaboratory study of heatset inks described in 11.1, the mean values for *NVM* agreed with the calculated values within 1 % absolute.

12. Keywords

12.1 heatset-type printing inks; liquid—printing ink; nonvolatile matter content; ovens; printing inks; resin solutions; solvents; vehicles

[7] Supporting data are available from ASTM Headquarters, 1916 Race St., Philadelphia, PA 19103. Request RR D01 - 1053.

Designation: D 4752 – 87

Standard Test Method for Measuring MEK Resistance of Ethyl Silicate (Inorganic) Zinc-Rich Primers by Solvent Rub[1]

This standard is issued under the fixed designation D 4752; 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 describes a solvent rub technique for assessing the MEK resistance of ethyl silicate (inorganic) zinc-rich primers. The MEK resistance of some two-component ethyl silicate zinc-rich primers has been shown to correlate well with the cure of the primer as determined by diffuse reflectance infrared spectroscopy.[2] The technique can be used in the laboratory, field, or in the fabricating shop.

1.2 *This standard may involve hazardous materials, operations, and equipment. This standard does not purport to address all of the safety problems 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.* Specific hazard statements are given in Section 6.

2. Referenced Documents

2.1 *ASTM Standards:*

D 740 Specification for Methyl Ethyl Ketone[3]

D 1186 Test Methods for Nondestructive Measurement of Dry Film Thickness of Nonmagnetic Coatings Applied to a Ferrous Base[4]

3. Description of Term Specific to This Standard

3.1 *double rub*—a back-and-forth motion over the test area of approximately 2 in. (50 mm).

4. Significance and Use

4.1 Ethyl silicate zinc-rich primers cure by the reaction of the vehicle with moisture thereby providing a binder. As relative humidity and temperature vary during the day, so does the rate of cure. A certain minimum degree of cure is necessary prior to topcoating. It has been shown that the degree of cure of ethyl silicate zinc-rich primers can be measured by the chemical changes occurring using diffuse reflectance infrared spectroscopy.[2] This solvent rub test has been shown to correlate well with the infrared spectroscopic results of two-component ethyl silicate inorganic zinc systems.

4.2 The cure rating required for the application of specific topcoats must be agreed upon before the test method is used.

5. Reagents and Materials

5.1 *Methyl Ethyl Ketone* (MEK), in accordance with Specification D 740.

5.2 *Cotton Cheesecloth.*

5.3 *Squeeze Bottle.*

6. Precautions

6.1 Methyl ethyl ketone is a flammable liquid. Its vapors form explosive mixtures in air. Repeated or prolonged contact can cause drying of the skin. Consult supplier's Material Safety Data Sheet(s) for specific hazard information.

7. Procedure

7.1 Select areas on the primer surface at least 2 in. (50 mm) long on which the tests will be run. Measure the dry film thickness of the primer in the selected areas in accordance with Test Methods D 1186.

7.2 Clean the surface first with fresh water to remove loose material.

7.3 Immediately fold the cheesecloth into a pad containing four thicknesses of the cloth. Saturate the cloth to a dripping wet condition with the methyl ethyl ketone.

7.4 Rub the test area with the saturated cloth, exerting moderate pressure with the thumb, using a 2-in. (50-mm) long stroke that encompasses the test area.

7.5 Continue rubbing the surface with the MEK saturated pad, wetting the pad as necessary without lifting it from the surface, until either the metal substrate is exposed or 50 double rubs have been completed. Record the number of rubs when the substrate is exposed.

7.6 Select an adjacent area to be used as a control. Repeat 7.1 through 7.5, except use a dry cheesecloth to establish the effect of burnishing without the influence of MEK.

TABLE 1 Scale for Resistance Rating

Resistance Rating	Description
5	No effect on surface; no zinc on cloth after 50 double rubs
4	Burnished appearance in rubbed area; slight amount of zinc on cloth after 50 double rubs
3	Some marring and apparent depression of the film after 50 double rubs
2	Heavy marring; obvious depression in the film after 50 double rubs
1	Heavy depression in the film but no actual penetration to the substrate after 50 double rubs
0	Penetration to the substrate in 50 double rubs or less

[1] This test method is under the jurisdiction of ASTM Committee D-1 on Paint and Related Coatings and Material and is the direct responsibility of Subcommittee D01.46 on Industrial Protective Coatings.

Current edition approved Nov. 27, 1987. Published January 1988.

[2] Starr, T. L., Henton, L. E., Lewis, W. S., and Rideout, F. A., "Improved Field Reliability of High Performance Coating Systems: Phase II—Develop Procedures and Criteria in Critical Performance Areas," available from Steel Structures Painting Council, 4400 Fifth Ave., Pittsburgh, PA 15213.

[3] *Annual Book of ASTM Standards*, Vol 06.04.

[4] *Annual Book of ASTM Standards*, Vol 06.01.

7.7 Inspect the test areas and the cheesecloths. Rate the results in accordance with Table 1.

8. Report

8.1 Report the following information:

8.1.1 Dry film thickness of the primer.

8.1.2 Elapsed time between the application of the primer and the running of the tests.

8.1.3 Number of tests conducted.

8.1.4 Resulting ratings.

8.1.5 In the case of a zero rating, number of double rubs required to expose the substrate.

8.1.6 *Field and Fabricating Shop Tests*—Identification of the area or piece tested.

9. Precision and Bias

9.1 Since no standard for measuring the MEK resistance of ethyl silicate zinc-rich primers has been developed prior to this test method, precision and bias statements will be developed in round-robin testing.

10. Indexing Terms

10.1 This test method is indexed under the following terms: curing characteristics, double rub method, drying or curing, ethyl silicate (inorganic) primer, methyl ethyl ketone, MEK (methyl ethyl ketone) resistance, primer, solvent rub method, visual examination, and zinc-rich primer.

Designation: D 4787 - 88

Standard Practice for Continuity Verification of Liquid or Sheet Linings Applied to Concrete Substrates[1]

This standard is issued under the fixed designation D 4787; 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 that may be used to allow the detection of discontinuities in nonconductive linings with thicknesses exceeding 20 mils (0.5 mm) applied to concrete substrates.

1.2 Discontinuities may include pinholes, internal voids, holidays, cracks, and conductive inclusions.

1.3 This practice utilizes high-voltage spark testing in conjunction with a continuous conductive membrane.

NOTE—For further information on discontinuity testing refer to Nace Standard RP0188-88.

1.4 *This standard may involve hazardous materials, operations, and equipment. This standard does not purport to address all of the safety problems associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.* For a specific hazard statement, see Section 6.

2. Referenced Documents

2.1 *ASTM Standards:*

D 149 Test Method for Dielectric Breakdown Voltage and Dielectric Strength of Solid Electrical Insulating Materials at Commercial Power Frequencies[2]

2.2 *NACE Standards:*[3]

RP0188-88 NACE Standard Practice Discontinuity (Holiday) Testing of Protective Coatings

3. Terminology

3.1 *Description of Terms Specific to This Standard:*

3.1.1 *discontinuity*—a localized lining site that has a dielectric strength less than a determined test voltage.

3.1.2 *conductive underlayment*—a continuous layer applied to the prepared concrete surface prior to the application of a nonconductive lining layer(s) that will allow high voltage spark testing for discontinuities in the lining.

3.1.3 *spark-over*—at a certain electrical voltage and distance from a grounded surface a spark from a high-voltage testing instrument will jump across the space.

3.1.4 *high voltage spark tester*—a high voltage electrical detector used to locate discontinuities in nonconductive linings applied to conductive substrates.

3.1.5 *test voltage*—that electrical voltage established which will allow a discontinuity at the thickest lining location site to be tested, but which will not damage the lining. The test voltage must always be set well below the dielectric breakdown strength of the lining. This voltage should normally be recommended by the lining manufacturer. The dielectric breakdown voltage strength of a solid can be determined by Test Method D 149.

4. Summary of Practice

4.1 This practice allows for high voltage electrical detection of discontinuities in new linings applied to concrete substrates through the utilization of a continuous conductive underlayment applied to the prepared concrete surface prior to the application of the nonconductive lining layer(s).

5. Significance and Use

5.1 The electrical conductivity of concrete is primarily influenced by the presence of moisture. Other factors which affect the continuity of concrete include the following:

5.1.1 Presence of metal rebars,
5.1.2 Cement content and type,
5.1.3 Aggregate types,
5.1.4 Admixtures,
5.1.5 Porosity,
5.1.6 Above or below grade elevation,
5.1.7 Indoor or outdoor location,
5.1.8 Temperature and humidity, and
5.1.9 Age of concrete.

5.2 The electrical conductivity of concrete itself may be successfully used for high-voltage continuity testing of linings applied directly with no specific conductive underlayment installed. However, the voltage required to find a discontinuity may vary greatly from point to point on the structure. This variance may reduce the test reliability to an unacceptable level.

5.3 Although the most common conductive underlayments are liquid primers applied by trowel, roller, or spray, and which contain carbon or graphite fillers, others may take the form of the following:

5.3.1 Sheet-applied graphite veils,
5.3.2 Conductive polymers,
5.3.3 Conductive graphite fibers,
5.3.4 Conductive metallic fibers, and
5.3.5 Conductive metallic screening.

5.4 Liquid-applied conductive underlayments may be desirable as they can serve to address imperfections in the concrete surface and provide a better base for which to apply the lining.

---

[1] This practice is under the jurisdiction of ASTM Committee D-33 on Protective Coating and Lining Work for Power Generation Facilities and is the direct responsibility of Subcommittee D33.04 on Inspection.

Current edition approved Sept. 30, 1988. Published November 1988.

[2] *Annual Book of ASTM Standards*, Vol 10.01.

[3] Available from National Association of Corrosion Engineers, P.O. Box 218340, Houston, TX 77218.

5.5 This practice is intended for use with new linings applied to concrete substrates. It may also be applicable for linings previously tested by this practice and subsequently placed in service. However, consideration must be given to potential changes to the electrical properties of the conductive and nonconductive layers comprising the system.

5.6 The user may consider this practice when performance requirements of the lining in a specified chemical environment requires assurance of a lining free of discontinuities.

5.7 Factors affecting the dielectric properties and test voltage shall be considered. Some factors are the curing time of liquid-applied linings; the possible presence of electrically conductive fillers or solvents, or both; the possible presence of air inclusions or voids; and the compatibility of conductive underlayments with the specified lining.

6. Apparatus

6.1 *High Voltage Spark Tester*—An electrical detector with a voltage rating in excess of 900 V. The detector is to consist of an electrical energy source, an exploring electrode, a ground connection, and ground wire. The detector shall be equipped with a visual or audible indicator, or both.

6.1.1 *Electrical Energy Source*—Either a-c, d-c, or pulsating d-c type with the appropriate test voltage.

6.1.2 *Exploring Electrode*—The full length shall be capable of maintaining continuous contact with the surface being inspected.

6.1.3 *Ground Wire*, stranded 14 to 16 gage copper wire.

6.1.4 *Visual or Audible Indicators*, or both, to signal a closed electrical circuit. Such signals shall be essential for testing the underlayment for electrical conductivity and for exposing discontinuities in the lining after it has been applied.

7. Hazards

7.1 Solvents retained in the applied conductive underlayment may create an explosive environment as well as produce erroneous results.

8. Conductive Underlayments

8.1 The conductive underlayment shall not rely on the concrete substrate's electrical properties.

8.2 The specified lining shall be compatible with the specified conductive underlayment.

8.3 *Application:*

8.3.1 The finished conductive underlayment surface shall be relatively smooth. The conductive underlayment shall be considered part of the lining system and must be installed in accordance with the manufacturer's latest published instructions.

8.3.2 Visually verify that the conductive underlayment covers the entire area to be lined. Breaks at expansion joints and construction joints are allowable unless otherwise specified.

8.4 *Verification of Underlayment Conductivity:*

8.4.1 The surface of the applied conductive underlayment shall be clean, dry, free of oil, grease, dirt, or other contaminants and be sufficiently cured in accordance with the manufacturer's latest published instructions at the time the high-voltage spark testing is performed. (**Warning**—See Section 7.)

8.4.2 Verify the operation of the high-voltage test instrument in accordance with Section 9.

8.4.3 Adjust the high-voltage test instrument in accordance with Section 10.

8.4.4 Ground the test instrument to the installed underlayment or other appropriate ground. If electrical isolation across an expansion joint is encountered, the ground wire must be moved to an appropriate ground in the same section being tested.

8.4.5 Place the exploring electrode on a nonconductive spacer so that an air gap between the surface of the underlayment and the electrode is equal to the maximum thickness of the lining.

8.4.6 The underlayment is conductive if a spark-over is emitted and the visual or audible indicator, or both, on the test instrument is activated.

8.4.7 *Test Sampling:*

8.4.7.1 A minimum of four test points shall be used for the first 100 $ft.^2$ Test points shall be approximately equally spaced within the test area. At least one additional test point shall be used for every 500 ft^2 thereafter.

8.4.7.2 Test points most distant from the ground connection shall be included in the test sampling.

8.4.8 The specified lining shall not be applied until the conductivity of the underlayment has been verified.

9. Verifying Operation of High-Voltage Spark Tester

9.1 Test electrical source for proper voltage output.

9.2 Follow the equipment manufacturer's operating instructions for verifying the operation of the high voltage tester.

9.3 If the tester fails to signal, it shall be considered defective.

10. Adjustment of High-Voltage Spark Tester for Verifying Conductivity of Underlayment

10.1 Establish the test voltage based on the maximum specified thickness of the nonconductive lining, its dielectric strength, and the lining manufacturer's recommendations.

10.2 Following the equipment manufacturer's instructions, set and check the test voltage established in 10.1.

11. Application of the Lining or Coating

11.1 Apply the specified lining in accordance with governing specifications.

12. Adjustment of High Voltage Spark Tester for Verifying Conductivity of the Applied Lining

12.1 Select the proper test voltage to provide reliable spark-over to locate a holiday under normal test conditions. The voltage selected must jump an air gap equal to the maximum specified dry film thickness of the lining being tested and not arc through the lining at the minimum specified dry film thickness.

12.2 Adjust the tester to the test voltage established in 12.1 as follows:

12.2.1 Connect a high-voltage voltmeter or a spark-gap calibrator between the electrode and the ground wire.

12.2.2 Switch the detector to the ON position.

12.2.3 Perform field checking of the test voltage with the electrode placed against the surface of the lining since the exploring electrode voltage may be reduced by the slight current flow to the lining.

12.2.4 If required, compare measured voltage with the selected test voltage. Depending on the type of tester, adjust to the selected voltage ±5 %.

12.2.5 Switch the detector to the OFF position.

12.2.6 Disconnect the voltmeter or spark-gap calibrator.

13. High Voltage Spark Testing for Verifying Continuity of Applied Lining

13.1 The surface of the applied lining shall be clean, dry, free of oil, grease, dirt, or other contaminants and be sufficiently cured in accordance with the manufacturer's latest published instructions at the time the high-voltage spark testing is performed (**Warning**—See Section 7).

13.2 Attach the ground wire from the instrument ground terminal to the conductive underlayment or appropriate ground in the same manner as was required in 8.4.4. Make contact with the exploring electrode at a known discontinuity to verify that the instrument is properly grounded. For each ground location, make contact with a known discontinuity. Conduct this test periodically during the test.

13.3 With the exploring electrode in continuous contact with the lining surface, move it over the entire surface of the lining at a rate of 1 ft/s (0.3 m/s) maximum in a sweeping motion with overlapping passes to ensure that the entire surface has been subjected to the test.

13.4 Identify discontinuities that require repair with a compatible marker.

13.5 Completely test the lining one time only. Repair all defects found in the lining and retest only those repaired areas.

Designation: D 4796 - 88

Standard Test Method for Bond Strength of Thermoplastic Traffic Marking Materials[1]

This standard is issued under the fixed designation D 4796; 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 provides an instrumental means for the determination of thermoplastic traffic marking material bond strengths using cement bricks and steel cubes.

1.2 *This standard may involve hazardous materials, operations, and equipment. This standard does not purport to address all of the safety problems 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:*

C 109 Test Method for Compressive Strength of Hydraulic Cement Mortars (Using 2-in. or 50-mm Cube Specimens)[2]

C 881 Specification for Epoxy-Resin-Base Bonding Systems for Concrete[3]

D 883 Terminology Relating to Plastics[4]

E 284 Terminology Relating to Appearance of Materials[5]

F 412 Terminology Relating to Plastic Piping Systems[6]

3. Terminology

3.1 *Definitions*—Definitions are in accordance with Definitions D 883, E 284, and F 412, unless otherwise indicated.

3.2 *Descriptions of Terms Specific to This Standard:*

3.2.1 *cement brick*—a brick formed by mixing cement and fine sand together and allowing to harden.

3.2.2 *thermoplastic*—traffic marking (same as 3.2.3).

3.2.3 *thermoplastic traffic marking*—a highly filled 100 % total solids highway marking system that when heated to a molten state can be extruded or sprayed onto a road surface and when cooled forms a solid durable delineator.

4. Summary of Test Method

4.1 The thermoplastic specimen is prepared for this test by first melting a sample to its application temperature under continuous agitation. The specimen is then applied to the specified cement brick by a hot drawdown blade. Two steel cubes are then immediately placed onto the hot thermoplastic line and the excess thermoplastic trimmed away from around the two steel cubes. After the trimming is complete, the steel cubes are removed. A heated steel cube is bonded with epoxy to the square of thermoplastic and allowed to cure overnight before determining the bond strength on a Dillon dynamometer or similar device.

5. Significance and Use

5.1 The function of this test method is to provide numerical instrumental results indicating the cohesive or adhesive, or both, bond strength of thermoplastic traffic marking to a specified cement brick substrate.

5.2 The use of this test method allows the user and manufacturer to control the quality of the product and make inferences about the performance of the thermoplastic traffic marking product. Results from these tests also provide information helpful in researching and developing thermoplastic traffic marking materials.

5.3 Strict adherence to the procedures outlined is necessary for precision of the test method. Under no conditions should the bond strength be accepted unless there is conformance to 9.14. Precise results are obtained only when one steel block is epoxied to the thermoplastic traffic marking on the cement brick.

6. Types of Separation in Bond Strength Tests

6.1 *Thermoplastic to Steel Cube Separation*—This type of separation occurs where there is an insufficient bond between the thermoplastic and steel cube probably due to insufficient coverage of the epoxy adhesive.

6.2 *Thermoplastic to Thermoplastic Separation*—This type of separation is caused by internal cohesive failure of the thermoplastic. This separation is acceptable when it exceeds the specified bond strength.

6.3 *Thermoplastic to Cement Brick Separation*—This type of separation is caused by the failure of the bond between the thermoplastic specimen and the cement brick.

6.4 *Cement Brick to Cement Brick*—This type of separation is caused by the internal cohesive failure of the brick. This is due, in most cases, to a bond between the thermoplastic and cement brick that exceeds the cohesive strength of the cement brick. This separation is not acceptable when the bond strength values are lower than specified.

7. Apparatus

7.1 *Agitator Blade*, 6 in. (15 cm) long with a ½-in. (1-cm) steel shaft and a 1¾ by 1 in. by ⅛-in. (4.5 by 2.5 by 0.3-cm) straight horizontal steel blade.

7.2 *Capped Bolts*, two, ⅝ in. (16 mm) in size.

---

[1] This test method is under the jurisdiction of ASTM Committee D-1 on Paint and Related Coatings and Materials and is the direct responsibility of Subcommittee D01.44 on Traffic Coatings.

Current edition approved Oct. 31, 1988. Published December 1988.

[2] *Annual Book of ASTM Standards*, Vol 04.01.

[3] *Annual Book of ASTM Standards*, Vol 04.02.

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

[5] *Annual Book of ASTM Standards*, Vol 06.01.

[6] *Annual Book of ASTM Standards*, Vol 08.04.

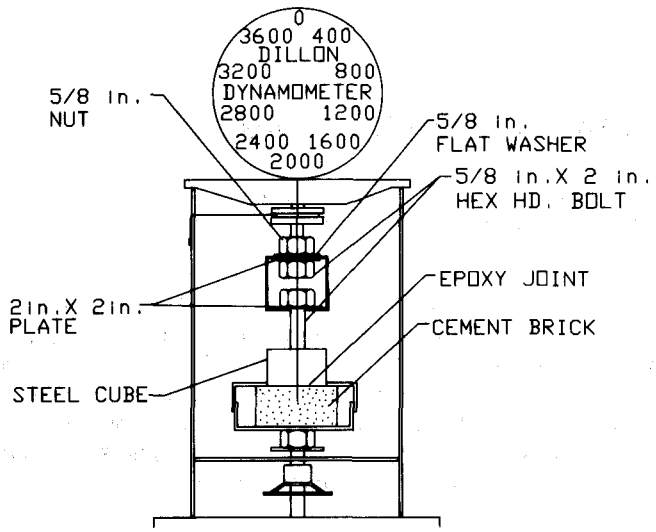


FIG. 1 Bond Strength Testing Apparatus

7.3 *Cement Bricks*, 3½ by 2 by 7½-in. (9 by 5 by 19 cm) in size with a compressive strength of 3000 to 5000 psi (Note 1).

NOTE 1—Concrete bricks conforming to Test Method C 109 have been used but proved more variable due to migration of a thin veneer of cement to the top of the brick making determinations erratic. The cement bricks may be obtained from local block plants. The term "cement" brick is common for the industry and is used in this test method extensively.

NOTE 2—The unit should be fitted with a steel frame to hold the cement brick for testing.

7.4 *Dynamometer*,[7] with a capacity of 6000 lbs in 25-lb divisions having a pull-rate capability of ¼ in./min. (Note 2) (See Figs. 1, 2, 3, and 4).

7.5 *Draw Down Blade*, 2 by 1 by 4 in. (5 by 2.5 by 10 cm) in size capable of laying down a 125 mil (0.125 in.) wet thermoplastic film 2 in. wide.

7.6 *Drill Press*, or other apparatus capable of agitating the thermoplastic during meltdown to the application temperature at 600 to 800 r/min in the jacketed electric pots.

7.7 *Epoxy Resin and Hardener*, Type I or II, Grade 2, Class C in accordance with Specification C 881.

7.8 *Hot Plate*, capable of maintaining 537°C.

7.9 *Gravity Convection Oven*, capable of maintaining 260°C.

7.10 *Electric Pots, Jacketed*, for heating and melting the thermoplastic to 218°C.

7.11 *Spatulas*, for cutting, stirring, and shaping the thermoplastic.

7.12 *Steel Cubes, two*, 2 by 2 by 2 in. (5 by 5 by 5 cm) in size threaded in the center of one side for a ⅝-in. (16-mm) capped bolt.

8. Sampling

8.1 Samples may be obtained by an appropriate quartering or riffle sampling method where deemed necessary considering the physical form of the material.

[7] A Dillon Dynamometer available from Weigh-Tranex, 1000 Armstrong Drive, P.O. Box 1000, Fairmount, MN 56031, or equivalent, has been found suitable for this purpose.

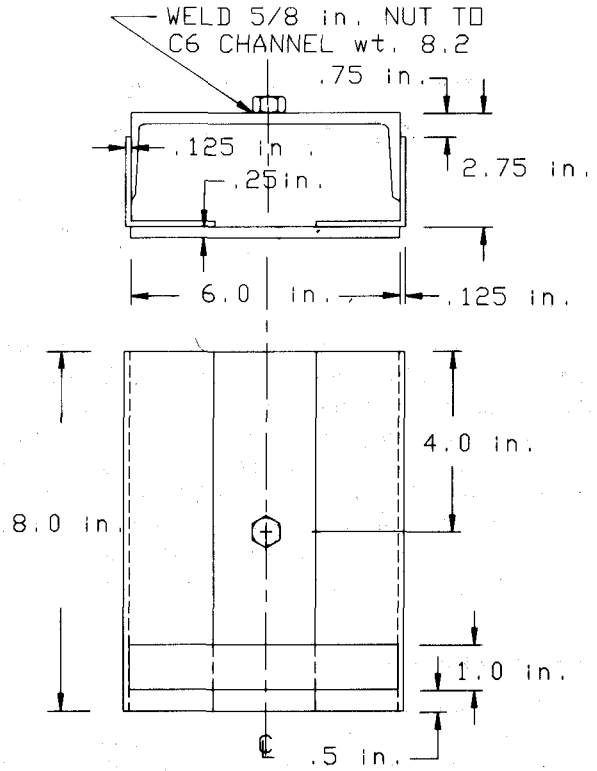


FIG. 2 Tension Bed

9. Procedure

9.1 Under continuous agitation melt a specimen of the thermoplastic to be tested to a temperature of 218°C. If the specimen is a dry powder mix, allow the specimen to cool to

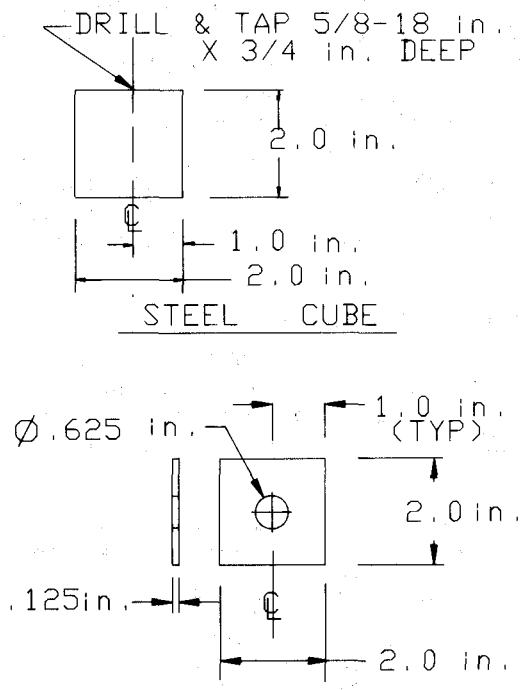


FIG. 3 Load Plate (2 Required)

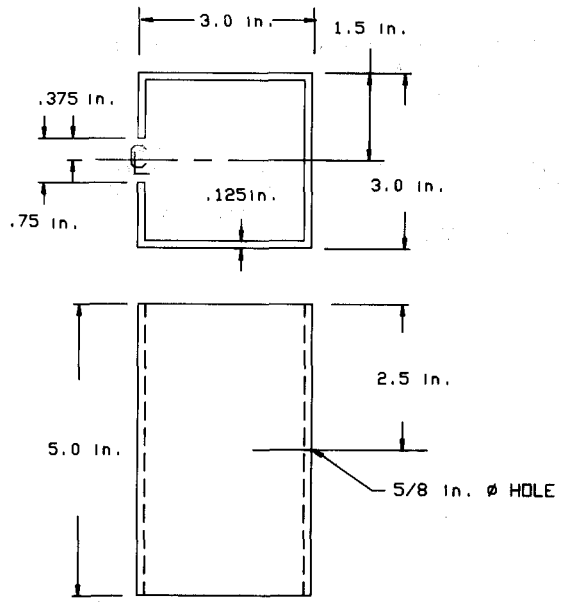


FIG. 4 Coupling Hitch

193°C under continuous agitation and reheat under agitation to 218°C.

NOTE 3—Dry powder mixed thermoplastic must be conditioned to ensure a homogeneous melt necessary for consistent results. Premelted block thermoplastic does not require this conditioning. The specimen may be melted on a hot plate set at 537°C or in a jacketed electric pot. Continuous agitation is necessary to prevent scorching and settling. If the specimen is melted in an oven set at 260°C, the specimen must be agitated every 15 min until 218°C is reached.

9.2 Heat the draw down blade to 218°C.

9.3 Obtain a dry room temperature cement brick that has been brushed or textured on the side to be coated with thermoplastic.

9.4 Heat one 2 by 2 by 2 in. (5 by 5 by 5 cm) steel cube in an oven or on a hot plate to 49°C for 2 h prior to making the thermoplastic draw down on the cement brick.

9.5 When the thermoplastic specimen is melted to 218°C under continuous agitation, remove the agitator blade from the thermoplastic.

9.6 Remove the draw down blade from the hot plate and immediately place it on the cement brick and make the draw down the full length of the brick with the melted thermoplastic on the brushed or rough textured side of the brick.

9.7 Immediately place two room temperature steel cubes on the thermoplastic approximately 1 in. from each end of the brick and trim the plastic from around the two steel cubes before the plastic cools and hardens.

9.8 Remove the steel cubes by hand and allow the thermoplastic to cool for 1 h.

9.9 Prepare the epoxy solution using the proper resin and hardener ratio and mix thoroughly.

9.10 Remove the steel cube heated to 49°C from the oven and place a small amount of epoxy on the heated cube. Place the steel cube on the thermoplastic square and rub to ensure an even coating and good adhesion. To ensure an even coating, remove the steel cube from the thermoplastic square and visually inspect the square and cube and then replace the steel cube on the square and rub. Do not allow any excess expoxy solution to flow from the steel cube and thermoplastic square onto the cement brick.

NOTE 4—Only one steel cube can be epoxied at a time to the thermoplastic on the brick because the shock of the first pull will cause a premature release of the second thermoplastic square.

9.11 Place a weight such as a cement brick on the steel cube epoxied to the thermoplastic square and allow to cure for a minimum time of 8 h.

9.12 Screw the 5/8-in. (15.9-mm) capped bolt into the steel cube epoxied to the thermoplastic and place the brick into the steel frame mounted onto the dynamometer.

9.13 Set the dynamometer to zero and pull the steel cube at 1/4 in./min.

9.14 Two tests are run on each brick. Separations involving at least 80 % of the thermoplastic area to the cement brick, thermoplastic to thermoplastic, and cement brick to cement brick are acceptable for reporting bond strengths.

10. Calculations

10.1 Calculate the bond strength as follows:

10.1.1 Average the readings obtained in 9.13 if the conditions in 9.14 are met.

10.1.2 Divide the average reading obtained by 4. The result is the bond strength in pounds per square inch.

10.1.3 If one of the two tests fails then that test is repeated until the conditions of 9.14 are met.

11. Report

11.1 Report the following information:

11.1.1 The type of separation and bond strength, the batch number, color, and type of thermoplastic.

11.1.2 The determination of the area of separation is subjective. The area not involved in the separation is usually attached to the steel cube or cement brick.

12. Precision and Bias

12.1 *Precision*—No general statement of precision can be made because of lack of sufficient data at this time.

12.2 *Bias*—No statement of bias can be prepared for this test method since there is no absolute method for use as a comparative basis.

12.3 Experience dictates that test results with ±50 psi are acceptable.

13. Index Terms

13.1 This test method is indexed under the following terms: thermoplastic—traffic marking; bond strength; cement brick.

Designation: D 4828 – 92

Standard Test Method for Practical Washability of Organic Coatings[1]

This standard is issued under the fixed designation D 4828; 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 the determination of the relative ease of removal of common soil and stains from interior coatings by manual or mechanical washing with a sponge and a liquid or powder cleanser.

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

2. Referenced Documents

2.1 *ASTM Standards:*

D 1193 Specification for Reagent Water[2]

D 3450 Test Method for Washability Properties of Interior Architectural Coatings[3]

D 3924 Specification for Standard Environment for Conditioning and Testing Paint, Varnish, Lacquer, and Related Materials[4]

3. Summary of Test Method

3.1 The test material is applied to a plastic panel and allowed to dry for 7 days or as mutually agreed. Soilants or stains, or both, are applied to the film. The film is washed for up to 100 cycles using a sponge and a liquid or powder cleanser. After rinsing and drying, the panel is evaluated for the degree of soil or stain removal, difference in erosion, and any change in gloss/sheen or color between the washed and unwashed area.

4. Significance and Use

4.1 Interior architectural paints are subjected in use to soiling by dirt or other stains. This test method provides a way to assess relative ease of soil or stain removal from a paint film using materials common to households. This test method includes a way to evaluate the film for washability properties and changes in appearance. Thus, a formulator may evaluate the effects of composition on the washability properties of a paint. Users may also compare the ease of soil removal from difference paints that are tested, preferably at the same time.

5. Apparatus

5.1 *Sponge and Holder.*[5]

5.2 *Soil and Stain Applicator* (see Fig. 1).

5.3 *Weight*, 100 g.

5.4 *Balance*, weighing accurately to 0.1 g.

5.5 *Doctor or Bird Film Applicator*, having a 7-mil (0.18-mm) clearance by 6-in. (150-mm) film width.

5.6 *Glass Plate*, 17½ by 6½ by ¼ in. (455 by 165 by 6.3 mm).

5.7 *Washability Machine.*[6]

5.8 *Black Plastic Panels.*[7]

5.9 *Masking Tape.*

5.10 *Straightedge*, approximately 17 in. (430 mm) in length.

5.11 *Cotton Tipped Swabs.*

5.12 *Medicine Droppers.*

5.13 *Suction Plate*, for drawdowns.

6. Reagents and Materials

6.1 *Purity of Water*—Unless otherwise indicated, references to water shall be understood to mean reagent water as defined by Type IV of Specification D 1193.

6.2 *Soil and Staining Medium*—Examples found acceptable for use with this test method include, but are not limited to pencil, crayon, mercurochrome, ball-point pen, waterborne felt-tip markers, lipstick and mineral-oil-borne soilant as outlined in Test Method D 3450.

6.3 *Cleaning Media*—Examples found acceptable for use with this test method include, but are not limited to, commercial liquid cleansers, laboratory standardized liquid cleaners as outlined in Test Method D 3450, and powder cleansers. Powder cleansers containing chlorine may effect the color of the washed portion of the test panel.

7. Preparation of Apparatus

7.1 *Washability Machine*—Level the apparatus before use and operate at 37 ± 1 cpm. (A cycle consists of a complete forward and reverse stroke.)

7.2 *Sponge and Holder*—Add sufficient weight to the

---

[1] This test method is under the jurisdiction of ASTM Committee D-1 on Paint and Related Coatings and Materials and is the direct responsibility of Subcommittee D01.42 on Architectural Finishes.

Current edition approved Sept. 15, 1992. Published November 1992. Originally published as D 4828 – 88. Last previous edition D 4828 – 91.

[2] *Annual Book of ASTM Standards*, Vol 06.01 and 11.01.

[3] *Annual Book of ASTM Standards*, Vol 06.02.

[4] *Annual Book of ASTM Standards*, Vol 06.01.

[5] A sponge, 3 by 3¾ by 1¾ in. (75 by 95 by 45 mm), Part No. AG-8116, and a metal holder, Part No. AG-8115, available from BYK-Gardner, Inc., 2435 Linden Lane, Silver Spring, MD 20910 or a sponge, Part No. WA 2222, and metal holder, Part No. WA 2220, available from the Paul N. Gardner Co., 316 N. E. First Street, Pompano Beach, Florida 33060-6699 have been found acceptable for this purpose. An equivalent may be used.

[6] Washability machine, Model AG-8100, available from BYK-Gardner, Inc. or Model WA 2151, available from the Paul N. Gardner Co., have been found suitable for this purpose. Other straight-line wash testers may be adapted to meet the requirements of this test method.

[7] Leneta P-121-10N dull black plastic panels, 17 by 6½ in. by 10 mils (430 by 165 by 0.25 mm), available from the Leneta Co., 15 Whitney Rd., Mahwah, N.J. 07430-3129, are suitable for this purpose. An equivalent may be used.

holder in the form of metal sheets or other flat weights to give a combined weight of 1000 g, including the dry sponge.

NOTE 1—Check the compression of the damp sponge under the 1000-g weight to ensure that the holder does not drag along the panel and tear the film.

8. Procedure

8.1 Clean the top of the glass plate and both sides of the black plastic panel to be sure they are free of specks. Place the black panel on the glass plate and tape one end to the plate. Smooth the panel along the plate to ensure a close fit.

8.2 Stir the material thoroughly and strain, if necessary, to remove all skins and particles. Draw down the coating on the panel. Apply the coating in 3 to 4 s from end to end to prevent pin holes or holidays in the film. Prepare enough panels with each paint for all the projected tests. Air dry all panels in a horizontal position for 7 days in a room maintained at 73 ± 3.5°F (23 ± 2°C) and 50 ± 5 % relative humidity as described in Specification D 3924, or under conditions specifically applicable to the material under test.

NOTE 2—If desired, an extra panel of each paint may be prepared to serve as its unwashed control.

8.3 *Application of Soilants and Stains:*

8.3.1 At the completion of the drying period, tape the coated panel to the glass plate, as directed in 8.1, to ensure uniform application of the soilants and stains. Apply the selected soilants or stains, or both, to the coating film in straight pairs of lines parallel to the length of the panel for the manual method of cleaning, or perpendicular to the length of the panel for the mechanical method of cleaning.

8.3.2 Apply solid soilants or stains using the apparatus shown in Fig. 1. Insert pencil, crayon, pen, or similar items into the appropriately sized hole and secure its position so it extends 1½ in. (40 mm) beyond the panel (see Fig. 1(*a*)). Secure the medium in position with a piece of masking tape (see Fig. 1(*b*)). Put the applicator at one end of the coated plastic panel and place the 100-g weight on the top face of the wooden panel at the end nearest to the marking device, as shown in Fig. 1(*b*), securing it with a piece of tape. Allow the nonweighted end of the applicator to rest on the surface of the film, then hold it by the outer edges and pull it along the entire length of the film (see Fig. 1(*c*)).

NOTE 3—Some soils and stains are prone to smearing. It is advisable to apply them last to the film and protect the first lines with materials such as wax paper or onionskin paper when applying the second and subsequent lines.

8.3.3 Apply liquid stains using hand-held cotton-tipped swabs. Immerse one end of a cotton-tipped swab in an appropriate liquid and allow to remain totally immersed until the cotton tip is saturated (approximately 10 to 15 s). Remove the tip from the liquid and apply the first of two parallel lines to the paint film using the straightedge to assist in drawing the lines. Adjustment of pressure on the cotton tip may be required to provide a line of uniform intensity. Reimmerse the cotton tip in the liquid and then draw the second line. Repeat with a clean or unused cotton tip for each liquid being used. Permit the soilants and stains to dry

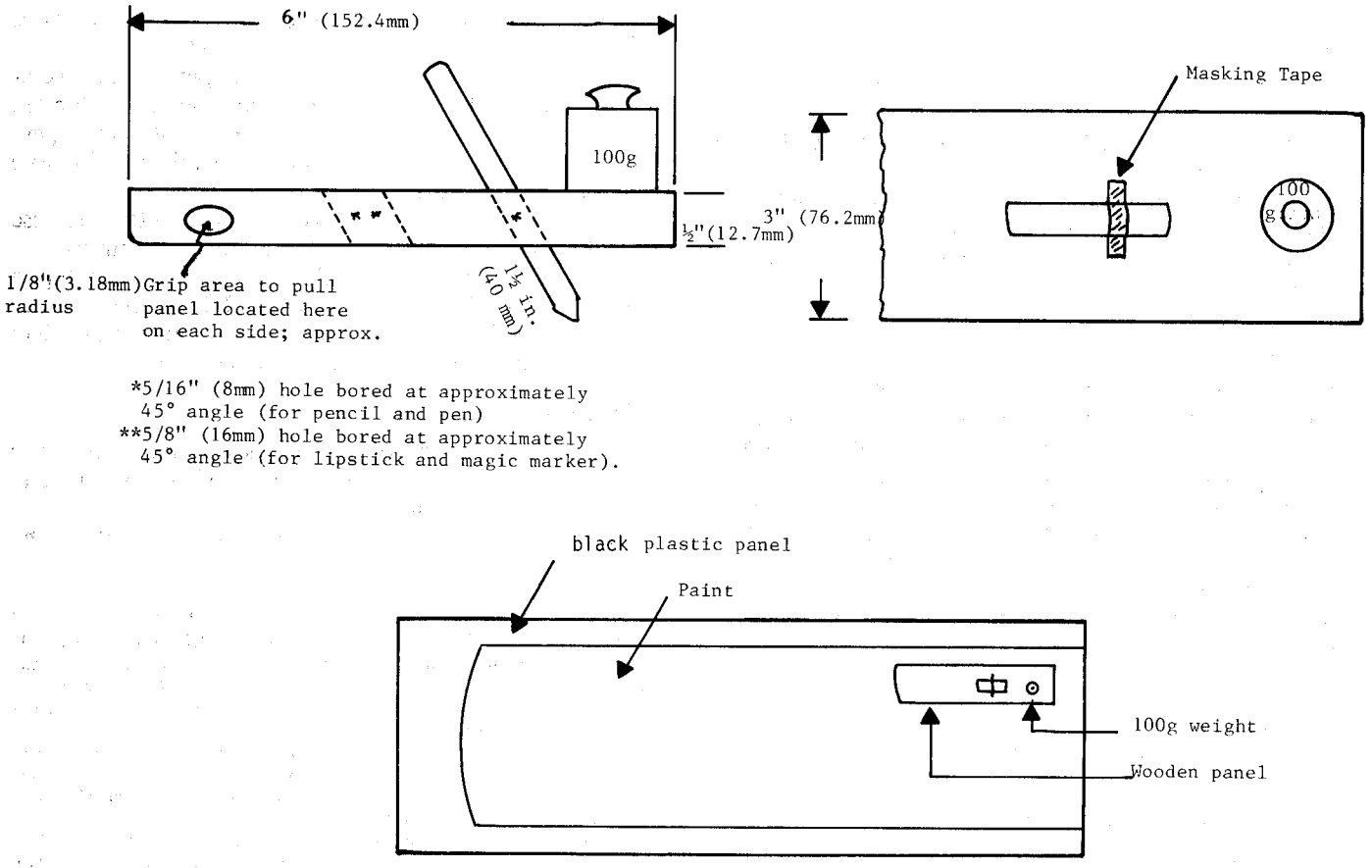


FIG. 1 Solid Soil and Stain Application

at least 1 h under the same temperature and humidity conditions as in 8.2.

8.4 *Washing with a Liquid Cleanser:*

8.4.1 Soak the sponge in tap water at ambient temperature until saturated. Remove the sponge and squeeze with one hand until no more water drips from the sponge. Replace the sponge in the holder and pour 15 ± 1 mL of water on the exposed face of the sponge.

8.4.2 Measure and deliver to the exposed face of the sponge 3 mL of the liquid cleaning medium. Apply 5 mL of water in parallel bands to each soilant and stain line.

8.5 *Washing with a Powder Cleanser:*

8.5.1 Use a separate sponge prepared in accordance with 8.4.1. (Alternatively, thoroughly wash the sponge used until all traces of the liquid cleanser are removed and repeat 8.4.1.)

8.5.2 Weigh 2 g of the powder cleanser and deliver to the exposed face of the sponge. Use a spatula to spread the cleanser until it appears to be wetted by the moisture left in the sponge. Apply 5 mL of water in parallel bands to each soilant and stain line.

8.6 *Manual Method:*

8.6.1 Place the sponge and holder at one end of the panel so that its long axis is perpendicular to the length of the panel (see Fig. 2). Rub the sponge across the panel over the soil or stain lines, exerting minimum downward pressure. Continue rubbing until all the soils or stains are removed or to a maximum of 100 cycles. If all the soils or stains are removed

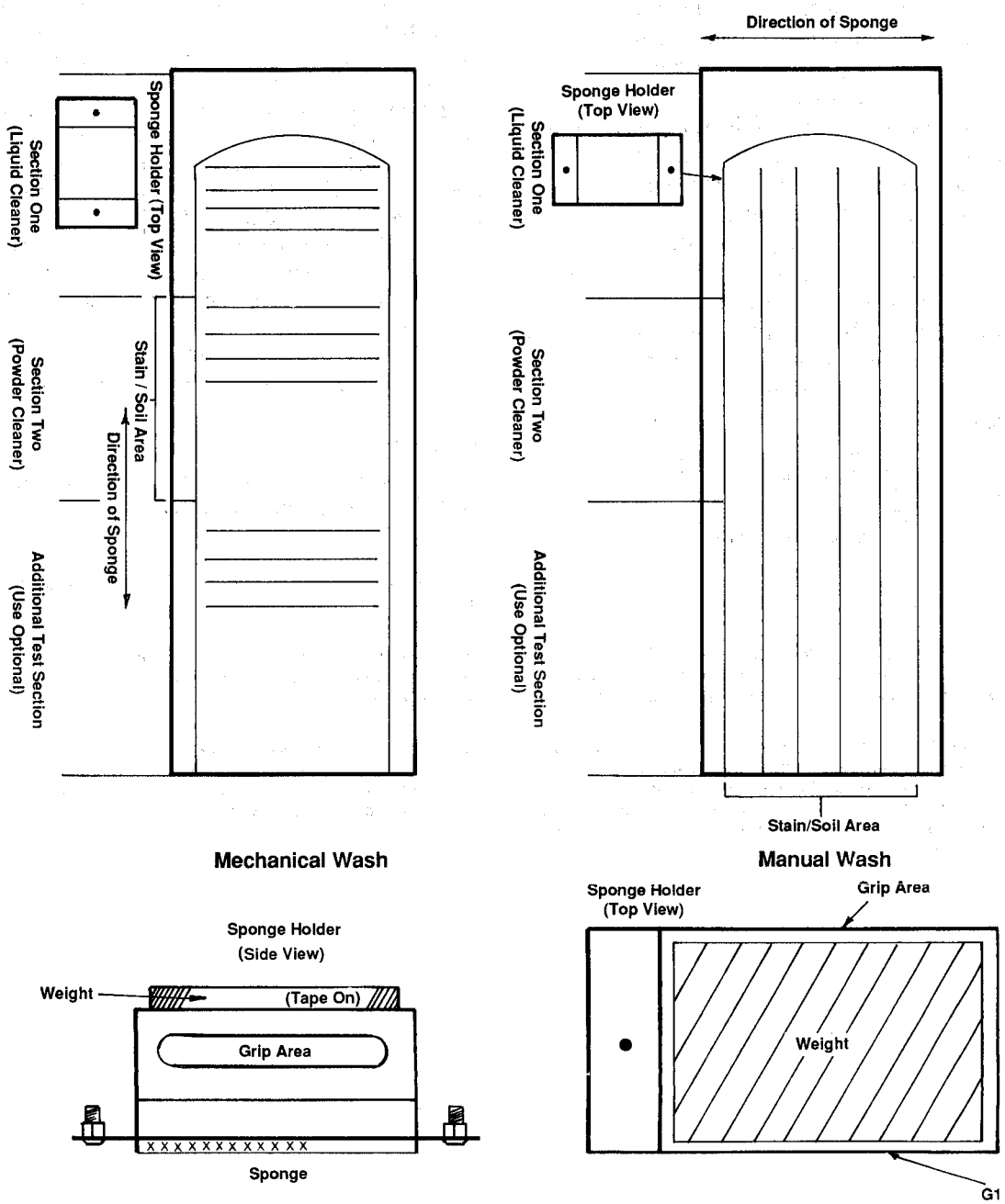


FIG. 2 Panel Layout and Brush Holder Diagram

prior to 100 cycles, stop and record the number of cycles before proceeding to 8.8.

8.7 *Mechanical Method:*

8.7.1 Place the sponge and holder at one end of the panel so that its long axis is parallel to the length of the panel (see Fig. 2). Attach to the cable of the washability machine. Allow the sponge to travel a maximum of 100 cycles. If all the soils or stains are removed prior to 100 cycles, stop and record the number of cycles before proceeding to 8.8.

8.8 Remove the test panel and evaluate the condition of each soil or stain in the path of the sponge and rate as follows:

0—No change from original intensity (depth) of soil or stain,

3—Slight change from original, but readily visible,

5—Moderate change from original, slightly visible,

7—Large change from original, barely visible, and

10—All soil and stain removed.

If a difference exists between a pair of lines, report the lower rating of the pair. When a soil or stain is removed prior to 100 cycles, assign a rating of 10 and note the number of cycles in which each soilant or stain was removed.

8.9 Rinse the panel with running tap water and remove any clinging particles of cleaning medium by gently moving the palm of the hand over the path the sponge followed during the washing cycle. Blot the panel and allow to dry. Rate the washed area relative to the unwashed areas for gloss or color change and erosion as given below:

Gloss Change	Color Change	Erosion
N—None	N—None	N—None
I—Increase	SD—Slightly darker	S—Slight
II—Large increase	CD—Considerably darker	M—Moderate
D—Decrease	SL—Slightly lighter	
DD—Large decrease	CL—Considerably lighter	

9. Report

9.1 Report the following information:

9.1.1 Type of soilant(s), stain(s), washing medium(s) and washing method used and the results obtained in 8.8 and 8.9,

9.1.2 Any soils or stains that were removed in less than 100 cycles, and

9.1.3 Any deviation from the recommended procedure.

10. Precision and Bias[8]

10.1 *Precision:*

10.1.1 *Mechanical Procedure*—In an interlaboratory study of this test method, operators in each of four laboratories applied three types of markings to two panels of each of three coatings covering a wide range of PVC's and evaluated the removability using an abrasive cleaner. The intralaboratory standard deviation was found to be 5.07 cycles with 13 df and the interlaboratory standard deviation is 10.53 cycles with 19 df. Based upon these standard deviations, the following criteria should be used for judging, at the 95 % confidence level, the acceptability of results:

10.1.1.1 *Repeatability*—Two results obtained by the same operator on different panels should be considered suspect if they differ by more than 15.5 cycles.

10.1.1.2 *Reproducibility*—Two results, each the mean of tests on two panels, obtained by operators in different laboratories should be considered suspect if they differ by more than 28.5 cycles.

10.2 *Bias*—This procedure has no bias because the value is defined only in terms of this test method.

11. Keywords

11.1 cleansability; soil/dirt resistance; stain resistance; washability; wet abrasion resistance

[8] Supporting data available from ASTM Headquarters. Request RR: D 01 - 1052.

Designation: D 4838 – 88

Standard Test Method for Determining the Relative Tinting Strength of Chromatic Paints[1]

This standard is issued under the fixed designation D 4838; 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 describes the determination of the absorption tinting strength of a chromatic test paint relative to that of a standard or reference paint of the same chemical type. The procedures are based on dilution of the paints with a standard mixing white paint, followed by instrumental measurement and calculation. Provision is made for correcting the results for small differences in hue or chroma, or both, between the test and reference chromatic paints.

1.2 This test method is intended for the comparison of paints containing the same type of vehicle (acrylic, alkyd, or oil) and single-pigment colorants of the same Colour Index[2] name and number. The amounts of the pigment and of the other components of the paint need not be known.

1.3 *This standard may involve hazardous materials, operations, and equipment. This standard does not purport to address all of the safety problems 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 1640 Test Methods for Drying, Curing, or Film Formation of Organic Coatings at Room Temperature[3]

D 4303 Test Methods for Lightfastness of Pigments Used in Artists' Paints[4]

E 284 Terminology Relating to Appearance of Materials[5]

E 308 Test Method for Computing the Colors of Objects by Using the CIE System[5]

E 1164 Practice for Obtaining Spectrophotometric Data for Object-Color Evaluation[5]

3. Terminology

3.1 *Definitions:*

3.1.1 *tinting strength*—measure of the effectiveness with which a unit quantity of a colorant alters the color of a material. For scattering and absorbing colorants (pigments), both absorption and scattering tinting strength must be specified.

3.1.2 *tinting strength, absorption*—relative change in the absorption properties of a standard white material when a specified amount of an absorbing pigment, black or chromatic, is added to it.

DISCUSSION—This is the common definition of tinting strength; however, this definition of the term can be misleading. For example, the tinting strength of a yellow colorant depends on its scattering as well as its absorption. Its tinting strength as determined from a mixture with white provides no information about its behavior when mixed with low-scattering colorants, such as a black.

3.1.3 *tinting strength, scattering*—relative change in the scattering properties of a standard black material (with no white pigment present) when a specified amount of a white or chromatic scattering pigment is added to it.

3.1.4 For other definitions, see Definitions E 284.

3.2 *Descriptions of Terms Specific to This Standard:*

3.2.1 *drawdown*—a layer of paint deposited on a substrate by use of a drawdown bar to evaluate the characteristics of the paint.

3.2.2 *drawdown bar*—a bar designed to deposit a specified thickness of wet paint film uniformly on a specified test panel or other substrate.

4. Summary of Test Method

4.1 Chromatic paints are diluted with white paint to obtain mixtures that will produce a drawdown having 35 to 45 % reflectance factor at the wavelength of maximum absorption.

4.2 Drawdowns of these mixture paints are produced at complete hiding.

4.3 The drawdowns are measured to obtain tristimulus filter readings *R, G, B* either directly or by computation from CIE tristimulus values *X, Y, Z*.

4.4 One of the samples is designated the standard, and the percents of tinting strength, % *TS*, of the others are calculated relative to that of the standard. Provision is made for correcting this tinting strength for small differences in hue, chroma, or both, between the standard and the test specimen, and for obtaining an average tinting strength and a range.

5. Significance and Use

5.1 Tinting strength may be one factor in judging the relative economic value of paints, since pigment concentration contributes to strength in a major way; other factors are formulation and color development in grinding. The user may also select products for other properties, such as

---

[1] This test method is under the jurisdiction of ASTM Committee D-1 on Paint and Related Coatings and Materials and is the direct responsibility of Subcommittee D01.57 on Artist Paints and Related Materials.

Current edition approved June 24, 1988. Published November 1988.

[2] *Colour Index*, The Society of Dyers and Colourists, London, 1987. Available from the American Association of Textile Chemists and Colorists, P.O. Box 12215, Research Triangle Park, NC 27709.

[3] *Annual Book of ASTM Standards*, Vol 06.03.

[4] *Annual Book of ASTM Standards*, Vol 06.02.

[5] *Annual Book of ASTM Standards*, Vol 06.01.

transparency, that are accompanied by different tinting strengths. The results of this test method may be used for production control or quality comparisons.

5.2 The product with the greatest or the least tinting strength may not be the most desirable for a given artistic use. For example, low tinting strength may lead to the need to use an excessively high pigment concentration to obtain a desired color effect, and this may lead to defects in the dry paint film.

5.3 This test method applies only to single-pigment paints. The tinting strength of paints that contain two or more chromatic pigments with different optical properties cannot be evaluated by this test method.

5.4 The term "similar chemical type" used in 1.1 does not limit the ingredients in the paints to identity, but refers to compatibility in the case of vehicles and to similarity in the case of pigment types.

5.5 While the instrumental evaluation of tinting strength is described, visual comparisons can also be used, with lower precision, and should be made to provide confirmation of the instrumental and computational results.

5.6 If the sample and standard are widely different in appearance when prepared at the same ratio of chromatic to white paint, another sample should be prepared to bring the two closer in appearance, to obtain the most accurate results.

5.7 The quantities of chromatic and white paints mixed must be accurately known, on either a weight or a volume basis, but the concentration of pigment in the chromatic paint need not be known.

5.8 When the paints being compared have the same vehicle and pigment (same Colour Index name and number) the values of uncorrected tinting strength from 9.1 and corrected tinting strength from 9.2 should be nearly the same. If they are not, an average of the two tinting strengths is recommended as the best estimate of the true value, and a range provides a measure of the magnitude of the uncertainty, which is due to differences in hue or chroma, or both, between the paints.

5.9 Strictly speaking, the Kubelka-Munk-type analysis of this test method should not be applied to the tristimulus filter readings used, but only to spectral data. For the purposes of the relative comparisons of this test method, however, the errors introduced by the calculations used cancel to an adequate degree.

6. Apparatus and Materials

6.1 *Laboratory Balance*, top-loading, having a sensitivity of 0.01 g.

6.2 *Drawdown bars*, capable of producing smooth paint films with wet-film thicknesses between 0.003 and 0.010 in. (0.075 and 0.25 mm).[6]

6.3 *Opacity charts*, sealed-paper type with black and white areas.[7]

6.4 *Color-Measuring Instrument*, either a spectrophotometer providing 1931 CIE tristimulus values *X, Y, Z* for CIE standard illuminant *C*, or a tristimulus colorimeter providing either such tristimulus values or colorimeter readings *R, G, B*.

6.5 *Mixing White Paint*, prepared as described in the Specimen Preparation, Mixing Whites for Dilution of Colors section of Test Method D 4303. Alternatively, a commercial titanium-dioxide white artists' paint may be used. The mixing white paint must be made with the same vehicle type (acrylic, alkyd, or oil) as the paints to be tested.

7. Specimen Preparation

7.1 Obtain representative samples of the chromatic paints to be tested. For tube paints, expel the entire contents of the tube and mix thoroughly before sampling.

7.2 Determine the approximate amount of chromatic paint to be added to 20 g of mixing white paint to obtain a drawdown with 35 to 45 % reflectance factor at the wavelength of maximum absorption. If the amount of chromatic paint is not known in advance, consult the tables in Appendix X1. For pigments other than those listed, use as the general guideline the addition of 5 g of chromatic paint containing an inorganic pigment or 1 g of chromatic paint containing an organic pigment to the 20 g of mixing white paint.

NOTE 1—Appendix X1 of Test Method D 4303 describes a method for computing the necessary adjustments in quantities required if additional trials are needed to obtain the desired level of reflectance factor.

7.3 Weigh out the chromatic and mixing white paints to the nearest 0.01 g, and mix thoroughly.

7.4 Prepare drawdowns by placing the paint mixture at one end of an opacity chart and pulling the drawdown bar smoothly through the paint and across the chart. Paste paints should be spread with a spatula or palette knife over the entire chart area to be covered before pulling the bar down the chart.

7.5 Allow the drawdowns to reach the dry-to-touch time as described in the Procedure section of Test Method D 1640. Acrylic paints should dry in air overnight. Alkyd paints may require 5 days to dry. Oil paints may require 2 months to dry.

7.6 Determine whether each drawdown is at complete hiding by measuring the portions of it over the black and over the white areas of the chart to determine tristimulus value Y or colorimeter reading G. If the quotient Y_B/Y_W or G_B/G_W, where the subscripts refer to measurements over black and white, respectively, is greater than 0.98, the drawdown can be considered at complete hiding. If the drawdown is not at complete hiding, prepare a thicker drawdown or a drawdown made with multiple coats of paint, one over another.

NOTE 2—At the required dilution with white, a drawdown bar with an aperture of 0.006 in. (0.15 mm) will usually make a drawdown at complete hiding. In the cases of some acrylic paints and a few oil paints it may be necessary to increase the aperture to 0.010 in. (0.25 mm) to obtain complete hiding. If this leads to a slow-drying film or a film that is wrinkled when dry, multiple coats can be applied by depositing a second 0.006 in. (0.15 mm) coat, drawing down at a right angle to the first coat. After this coat dries, a third coat can be applied if necessary by using a shorter bar that rides over the previous coats.

[6] Suitable drawdown bars can be obtained from the Paul N. Gardner Company, Inc., P.O. Box 10688, Pompano Beach, FL 33061-6688, or BYK-Gardner, Inc., Gardner Laboratory, 2435 Linden Lane, Silver Spring, MD 20910.

[7] Leneta 2A charts, available from the Leneta Co., Box 576, Ho-Ho-Kus, NJ 07423, and the Morest Co., 211 Center St., New York, NY 10013, have been found satisfactory for this purpose.

8. Procedure

8.1 Obtain values of *R, G, B* for each sample by either of the two following procedures.

8.1.1 Measure the drawdown with a spectrophotometer or a tristimulus colorimeter to determine 1931 CIE tristimulus values *X, Y, Z* for CIE standard illuminant *C*. Follow Practice E 1164 and Method E 308. If hemispherical (integrating-sphere) geometry is used, measure with the specular component excluded.

8.1.2 If a colorimeter that is direct reading in *R, G, B* is used, measure these quantities.

8.2 If *X, Y, Z* are measured, calculate *R, G, B* by use of the following equations:

$$R = (X/0.98 - 0.2Z/1.18)/0.8 \quad (1)$$

$$G = Y \quad (2)$$

$$B = Z/1.18 \quad (3)$$

NOTE 3—The use of the 1931 CIE system (and standard observer) and standard illuminant *C* is specified because all known tristimulus colorimeters that are direct reading in *R, G, B* measure for these conditions. If values of *X, Y, Z* are obtained by spectrophotometry, the 1964 CIE system and other CIE standard illuminants may be used. Equations 1 to 3 are specific to the conditions, and must be replaced by the appropriate equations if other conditions are specified.[8] The article referenced also discusses correcting the measured values for surface reflections.

9. Calculation

9.1 Calculate uncorrected relative tinting strength, % TS_{UC} as follows:

9.1.1 Using decimal-fraction values of *R, G, B*, calculate Kubelka-Munk-type ratios of absorption coefficient, *K*, to scattering coefficient, *S*:

$$(K/S)_R = (1 - R)^2/2R \quad (4)$$

$$(K/S)_G = (1 - G)^2/2G \quad (5)$$

$$(K/S)_B = (1 - B)^2/2B \quad (6)$$

9.1.2 Calculate the pigment concentration term C_P:

$$C_P = Q_c/(Q_c + Q_w) \quad (7)$$

where:

Q_c = quantity of chromatic paint, g,
Q_w = quantity of white paint, g.

NOTE 4—If it is desirable to use volume rather than weight as the basis for comparison of tinting strengths, determine the densities of the paints and compute the volumes of the weighed samples. Calculate C_P by use of Eq 7 using volumes instead of weights.

9.1.3 Calculate normalized values of (*K/S*), denoted *N*, as follows:

$$N_R = (K/S)_R/C_P \quad (8)$$

$$N_G = (K/S)_G/C_P \quad (9)$$

$$N_B = (K/S)_B/C_P \quad (10)$$

9.1.4 Select one of the specimens to be denoted the standard and assigned the value of 100 % tinting strength. The tinting strength of the remaining specimens will be determined relative to that of the standard.

9.1.5 Select the value of *N* to be used in the calculation of % TS_{UC} by one of the following three methods:

9.1.5.1 Select *N* based on the visually determined color of the specimen: For blue and green specimens, select N_R; for purple and red specimens, select N_G; and for yellow and orange specimens, select N_B. Relabel the selected value $N1_{SPEC}$ and N_{STD} for the specimens and the standard, respectively. Relabel the remaining two values of *N* as $N2_{SPEC}$ and $N3_{SPEC}$ for the specimens and $N2_{STD}$ and $N3_{STD}$ for the standard.

9.1.5.2 If the specimen color cannot be classified accurately in 9.1.5.1, select the lowest value of *N* as *N*1. The same selection must be made for the standard and all specimens to be compared. Relabel the values of *N* as in 9.1.5.1.

9.1.5.3 If the values of N_R and N_B for the specimen are both low and approximately equal, follow the procedure in Annex A1 to select *N* and calculate the tinting strength.

9.1.6 Calculate % TS_{UC} as follows:

$$\%\ TS_{UC} = 100\ (N1_{SPEC}/N1_{STD}) \quad (11)$$

9.2 Calculate tinting strength corrected for differences in hue and chroma, % TS_C, by use of the following equations:

$$d_{SPEC} = N2_{SPEC} + N3_{SPEC} \quad (12)$$

$$d_{STD} = N2_{STD} + N3_{STD} \quad (13)$$

$$D = (d_{SPEC} - d_{STD})/2 \quad (14)$$

$$\%\ TS_C = 100\ (N1_{SPEC} - D)/N1_{STD} \quad (15)$$

9.3 Calculate average tinting strength, % TS_{AV}, and range *E* as follows:

$$\%\ TS_{AV} = (\%\ TS_{UC} + \%\ TS_C)/2 \quad (16)$$

$$E = \pm\ (\%\ TS_{UC} - \%\ TS_C)/2 \quad (17)$$

10. Report

10.1 Report the following information:

10.1.1 Complete identification of the specimens, including brand and color name, date of manufacture, and lot number if available.

10.1.2 Name of color-measuring instrument used, method of standardization, and other information required in the Report section of Practice E 1164 and Methods E 308.

10.1.3 Date of test.

10.1.4 Test results for % TS_{UC}, % TS_C, or % TS_{AV}, and range.

11. Precision and Bias[9]

11.1 Based on interlaboratory intercomparisons, the results of this test method agree to within ±6 % on an absolute basis.

12. Index Terms

12.1 This test method is indexed under the following terms: artists' paints; chromate coatings; tinting strength.

[8] Johnston-Feller, R. M., and Bailie, C. W., "Determination of the Tinting Strength of Chromatic Pigments," *Journal of Coatings Technology*, Vol 54, No. 692, 1982, pp. 43–56.

[9] Supporting data are available from ASTM Headquarters. Request RR:D01-1057.

ANNEX

(Mandatory Information)

A1. Procedure for Pigments with Two Separated Absorption Maxima

A1. The tinting strength of pigments, such as chromium oxide green, for which both N_R and N_B are low and approximately equal, must be calculated by the following equations:

$$\text{NUM} = (N_{\text{R.SPEC}} + N_{\text{B.SPEC}})/2 \quad \text{(A1.1)}$$

$$\text{DENOM} = (N_{\text{R.STD}} + N_{\text{B.STD}})/2 \quad \text{(A1.2)}$$

$$D = (N_{\text{G.SPEC}} + N_{\text{G.STD}})/2 \quad \text{(A1.3)}$$

$$\%\ TS_{\text{UC}} = 100\ \text{NUM/DENOM} \quad \text{(A1.4)}$$

$$\%\ TS_{\text{C}} = (\text{NUM} - D)/\text{DENOM} \quad \text{(A1.5)}$$

APPENDIX

(Nonmandatory Information)

TABLE X1.1 Approximate Weight of Acrylic Paint to Mix With 20-g of Mixing White Paint

Pigment Name	Colour Index Name	Chromatic Paint, g
Alizarin crimson	PR 83	2.5
Azo yellow medium	PY 74	2.5
Burnt umber	PBr 7	3.0
Cadmium-barium orange	PO 20:1	2.5
Cadmium-barium red medium	PR 108:1	4.0
Cadmium-barium yellow light	PY 35:1	4.0
Cadmium-barium yellow medium	PY 37:1	3.3
Cerulean blue Co-Cr	PB 36	9.0
Cerulean blue Co-Sn	PB 35	10.0
Chromium oxide green	PG 17	4.0
Cobalt blue	PB 28	5.0
Dioxazine purple	PV 23 RS	1.0
Hansa yellow light	PY 3	3.0
Naphthol AS-OL red	PR 9	2.5
Naphthol red light AS-D	PR 14	2.0
Phthalocyanine blue	PB 15	0.4
Phthalocyanine green	PG 7, PG 36	0.5
Raw sienna	PBr 7	4.0
Raw umber	PBr 7	6.0
Red oxide	PR 101	1.0
Ultramarine blue	PB 29	4.0
Yellow oxide	PY 42	4.0

Designation: D 4938 – 89

Standard Test Method for Erosion Testing of Antifouling Paints Using High Velocity Water[1]

This standard is issued under the fixed designation D 4938; 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 the determination of erosion rates for marine antifouling paint systems immersed in flowing natural seawater.

1.2 *This standard may involve hazardous materials, operations, and equipment. This standard does not purport to address all of the safety problems associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.* For a specific hazard statement, see Section 7.

2. Referenced Documents

2.1 *ASTM Standards:*

A 569/A 569M Specification for Steel, Sheet and Strip, Carbon (0.15 Maximum Percent), Hot-Rolled, Commercial Quality[2]

D 823 Test Methods for Producing Films of Uniform Thickness of Paint, Varnish, and Related Products on Test Panels[3]

D 1889 Test Methods for Turbidity of Water[4]

D 2200 Pictorial Surface Preparation Standards for Painting Steel Surfaces[5]

2.2 *U.S. Military Specifications:*[6]

MIL-P-24441 Paint, Epoxy-Polyamide

DOD-P-24647 Paint, Antifouling, Ship Hull (Metric)

DOD-P-24655 Paint, Underwater Hull, Anticorrosion (Metric)

3. Summary of Test Method

3.1 Steel panels coated with the antifouling paint system under evaluation are positioned in a high velocity water channel, similar to the type shown in Figs. 1 to 3, parallel to the path of the flowing water.

3.2 Exposure conditions shall include at least one series of test panels evaluated at the standard water velocity of 12 m/s and shall specify the length of time, temperature, salinity, and pH. Additional velocities may be conducted at the discretion of the customer.

3.3 Color photographs and coating thickness measurements shall be taken prior to exposure, at specified time intervals, and repeated at the end of the test for comparison purposes.

4. Significance and Use

4.1 This test method is intended to measure the erosion rates of ablative antifouling paint systems exposed to flowing water at velocities designed to subject the paint system to shear stresses experienced in service.

4.2 Measurement of erosion rates are necessary to help in the assessment of ablative antifouling paint film thicknesses required for fouling control between scheduled drydockings of ships, in the selection of materials, in producing quality assurance, and in understanding the performance mechanism.

4.3 The test data is intended to serve as a guide for predicting the service life of ablative antifouling paints in order to calculate the necessary paint thickness to fit specified deployment cycles. Erosion rates of antifouling paints in service will vary depending on such factors as: berthing location, geographic area of operation, salinity, pH, and temperature of seawater. It should also be recognized that some areas of the ship are subject to different erosion rates.

4.4 The degree of correlation between results obtained from this test method and shipboard service has not been determined.

5. Apparatus

5.1 *Water Channel:*

5.1.1 High velocity flowing water in a contained channel, similar to the type shown in Figs. 1 to 3, is used to induce hydrodynamic shear stresses on painted panels to determine erosion rates of ablative antifouling paints.

5.1.2 The basic apparatus consists of a four-walled channel, rectangular in cross section, through which natural seawater flows at varying linear velocities to simulate ships' speeds.

5.1.3 All wetted materials supplying seawater to and within the channel shall be nonmetallic with the following exceptions:

5.1.3.1 Channel circulating pump impellers.

5.1.3.2 Thermowells.

5.1.3.3 Channel flow orifice plate.

5.1.4 One section of the channel shall permit testing of the panels at a standard test velocity of 12 m/s. All sections of the channel shall provide flow with fully formed turbulent characteristics. A minimum Reynolds number of 1 000 000 shall be achieved in each velocity test section. The Reynolds number, R, is calculated as follows:

---

[1] This test method is under the jurisdiction of ASTM Committee D-1 on Paint and Related Coatings and Materials and is the direct responsibility of Subcommittee D01.45 on Marine Coatings.

Current edition approved April 28, 1989. Published June 1989.

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

[3] *Annual Book of ASTM Standards*, Vol 06.01.

[4] *Annual Book of ASTM Standards*, Vol 11.01.

[5] *Annual Book of ASTM Standards*, Vol 06.02.

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

$$R = (D \times V \times P)/U$$

where:

D = equivalent diameter = 4 × (area of flowing liquid/wetted perimeter), m,
V = velocity, in m/s,
P = density of medium, kg/m^3, and
U = viscosity, P/s.

For a channel with a rectangular cross section and a test panel placed in the middle of the channel, the equivalent diameter would be calculated as follows:

$$4 \times [(A \times B)/(2A + 2B)]$$

where:

A = width of channel from side wall to panel face, m, and
B = height of channel, m.

5.2 *Erosion Rate Determination*—Erosion rates of ablative antifouling paints are determined by using noneroding reference points and measured in accordance with Section 8 with the following equipment:

5.2.1 Microtome or encapsulating/polishing equipment.

5.2.2 Microscope with photomicrographic capability.

5.3 *Seawater Requirements:*

5.3.1 Seawater will be circulated through the channel at a constant rate permitting testing at different flow velocities as shown in 9.3.

5.3.2 Natural seawater shall be continuously supplied to the channel during operation to eliminate stagnation or concentration effects. During operation of the channel the following data shall be obtained and recorded on a daily basis:

5.3.2.1 Seawater circulating rate.

5.3.2.2 Seawater salinity and pH.

5.3.2.3 Incoming seawater temperature and the channel seawater temperature.

5.3.3 Provisions shall also be made for supplying filtered seawater to the channel. A suitable filter is one which can reduce turbidity to ½ Jackson Turbidity Unit in accordance with Test Method D 1889.

5.3.4 As a minimum, the seawater chemistry in the channel, averaged over the course of the test run, shall be within the limits specified below:

	Maximum	Minimum
Salinity, ppm	35 000	27 000
pH	8.3	7.6

5.4 *Test Panels:*

5.4.1 Steel test panels conforming to Specification A 569/A 569M shall be used in the channel. The panels shall measure 18.75 cm high, 15 cm long, and 1.25 cm thick. The painted test panels shall be subjected to a double sided exposure with both sides exposed to similar hydrodynamic conditions.

5.4.2 Test panels painted in accordance with Test Methods D 823 are positioned vertically and parallel to the flowing water to simulate sheer stresses experienced by paints on the ship's underwater hull.

5.4.3 The coating systems shall be applied in accordance with the manufacturer's instructions for both the anticorrosion and the antifouling paints.

5.5 *Operation*—The channel shall be operated on a continuous basis during the test period except for downtime for panel inspection and seawater filtering system backwashes. The total running time of the test is defined as the total hours of actual channel operation under fully flowing conditions.

6. Application of Paints

6.1 Antifouling paints under evaluation may be applied by spray over a primer from the same manufacturer in accordance with the manufacturer's directions or over 9 mils of epoxy polyamide paint conforming to Military Specification MIL-P-24441 with an appropriate tie-coat if necessary. Application shall be in accordance with Test Methods D 823.

7. Hazards

7.1 Antifouling paints contain toxic materials that could cause skin and eye irritation on contact and adverse physiological effects if ingested or inhaled. In the preparation of panels and the application of various types of antifouling paints, the use of appropriate protective clothing and equipment is required consistent with local, state, and federal government regulations and recognized industrial and technical standards. Spills, overspray, and unused material shall not be flushed down the drain but shall be disposed of as hazardous waste.

8. Procedure

8.1 Abrasive blast a minimum of three test panels for each system being evaluated to near-white metal, Sa 2½ in accordance with Pictorial Standard D 2200, to obtain a 1.0 to 3.0 mils (25 to 75 μm) surface profile.

8.2 Apply an epoxy anticorrosion primer in accordance with Military Specifications DOD-P-24655 and MIL-P-24441, or the manufacturer's recommendations, whichever applies.

8.3 Apply an antifouling topcoat in accordance with Military Specification DOD-P-24647 or the manufacturer's recommendations, whichever applies.

8.4 Apply additional coats of antifouling paint in accordance with Military Specification DOD-P-24647 or the manufacturer's instructions, whichever applies. The last coat shall dry for a minimum of 7 days before any erosion testing.

8.5 Both sides of the painted test surfaces are provided with noneroding reference (NER) points before immersion in the test environment. The NER is an insoluble, tightly adherent vinyl or other suitable, compatible coating 2 ± 0.5 cm/diameter applied in the center of the panel which will blanket a portion of the eroding surface. The NER preserves the original outer surface of the antifouling and thus offers a reference for comparison with the eroded surface during later microscopic examination.

8.6 Take film thickness measurements before and after testing (see 5.2).

8.7 Panels are to be photographed prior to starting the test for comparison with photographs taken at the conclusion of the test.

8.8 A specimen of exposed antifouling paint is carefully removed for examination in a single flake which includes a fragment of the noneroding reference. This specimen is mounted for microscopic analysis in a suitable medium such as paraffin wax or epoxy resin. Care is required to ensure that the specimen is not damaged by solvent attack or heat evolution during this encapsulation.

8.9 Specimens are prepared for examination by micro-

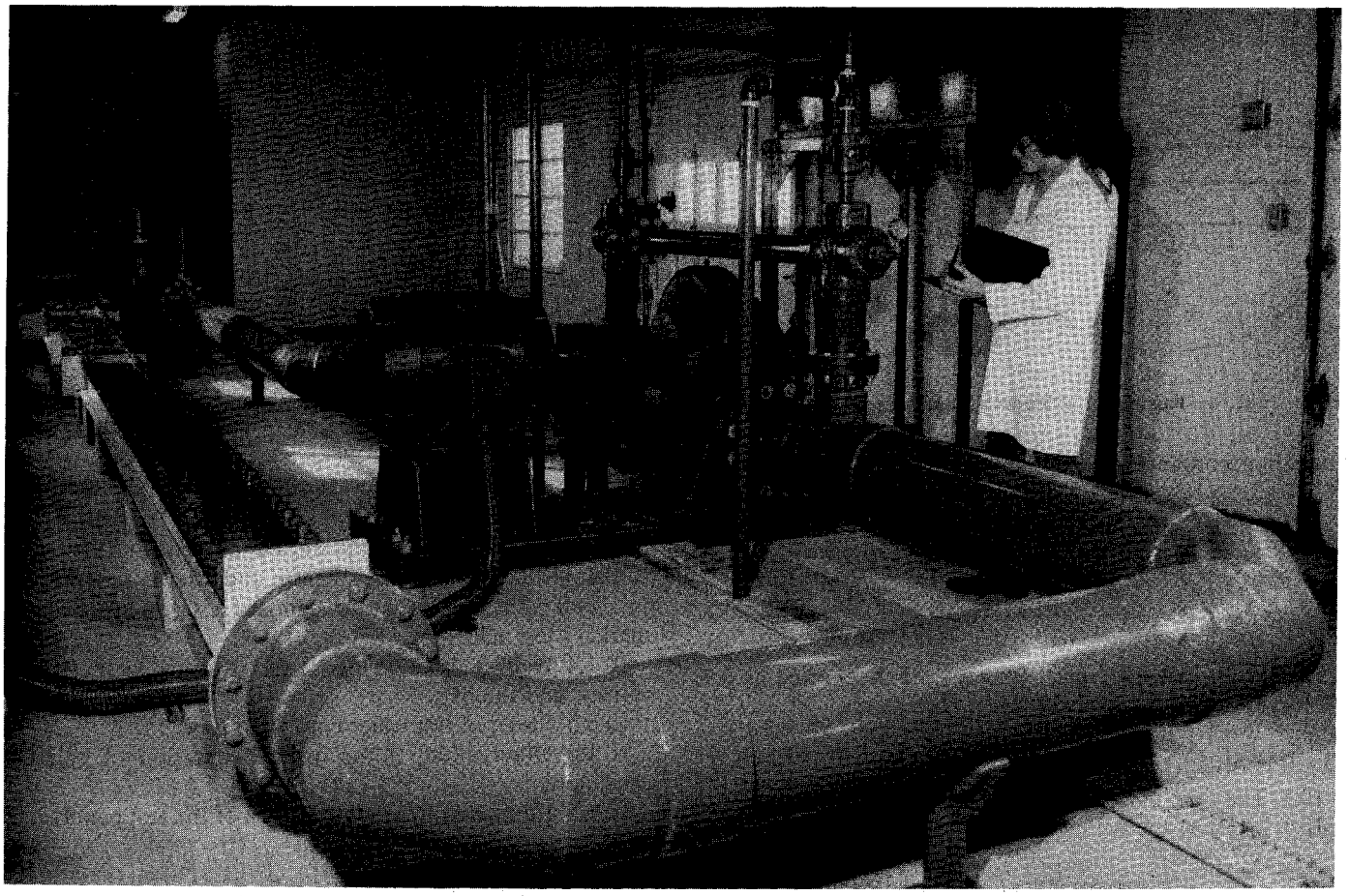


FIG. 1 High Velocity Flow Channel

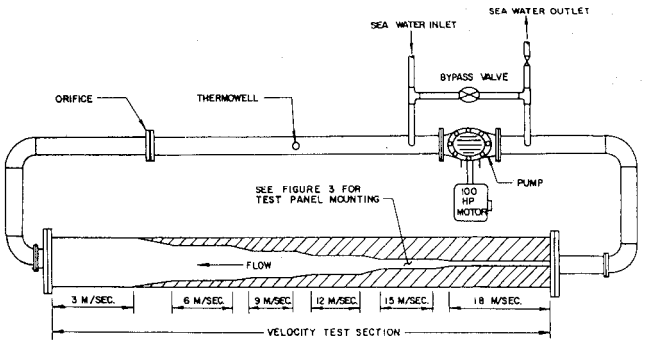
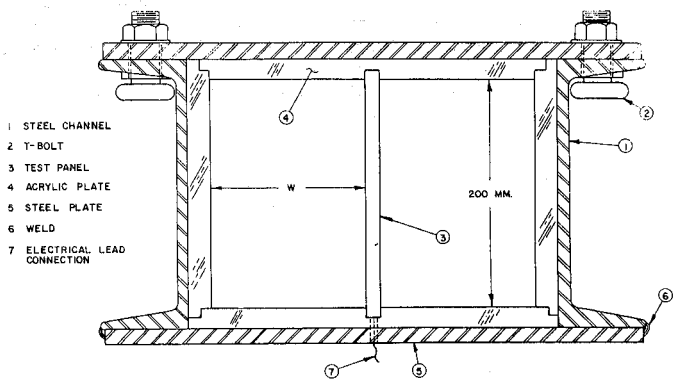


FIG. 2 Simplified Schematic of Flow Channel



W, mm	Velocity, m/s
50	18
60	15
75	12
100	9
150	6
300	3

FIG. 3 Cross-Section View of Test Panel Mounted in Flow Channel (Low Velocity Section)

tome sectioning or by abrasive polishing to a plane surface.

8.10 Subsequent microscopic examination yields the typical image shown in Figs. 4 and 5. The material lost during the duration of the test is clearly shown as measurement *d* in Fig. 4. An actual photomicrograph is shown in Fig. 5.

9. Calculation

9.1 The material loss is expressed as the erosion rate of the ablative antifouling paint.

9.2 The erosion rate is calculated by dividing the micrometers of surface erosion by the duration of the test expressed in months at a specified speed.

9.2.1 *Example*—A 20-μm erosion in 3 months equals 6.7 μm/month.

9.3 The speed of the water in the channel expressed in metres per second is correlated to a ship's speed expressed in

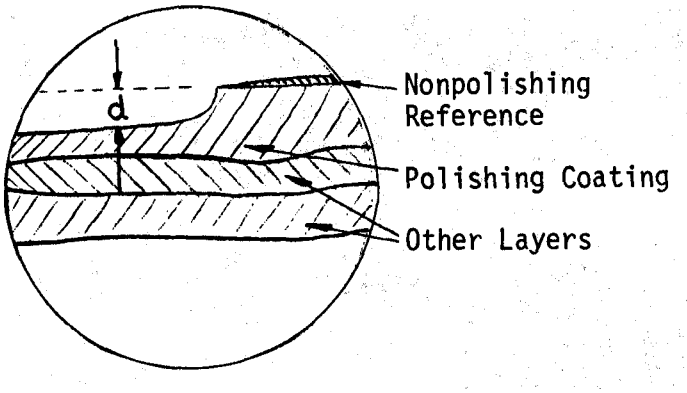


FIG. 4 Illustration of Material Lost During Testing

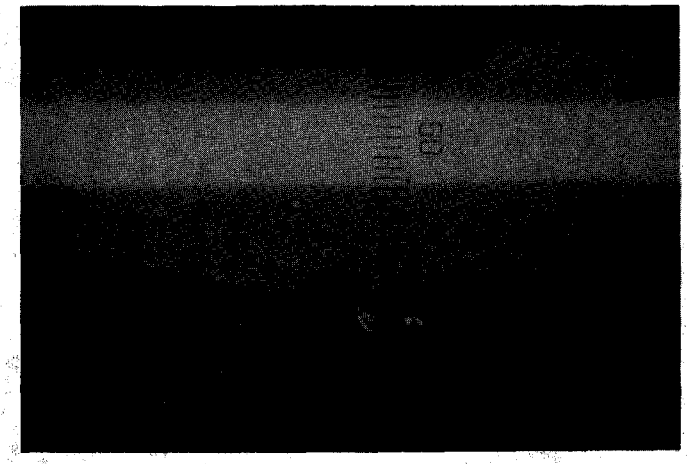


FIG. 5 Actual Microphotograph

knots in accordance with the following table:

Speed in Channel, m/s	Speed, knots
3	5.8
6	11.7
9	17.5
12	23.3
15	29.1
18	35.0

9.3.1 *Example*—A typical erosion rate is reported as 6.7 μm/month at 17.5 knots, etc.

10. Report

10.1 The final test report shall include the following data:

10.1.1 List of the paints tested,

10.1.2 Test duration—date started and date ended,

10.1.3 Thickness readings before and after exposure. Report total paint film loss at the standard test velocity and any auxiliary test velocities,

10.1.4 Daily measurements of the seawater temperature, salinity, and the pH,

10.1.5 Speed of test water correlated to knots,

10.1.6 Observation of the overall condition of painted panel, and

10.1.7 Initial and final photographs of the test panels.

Designation: D 4939 - 89

Standard Test Method for Subjecting Marine Antifouling Coating to Biofouling and Fluid Shear Forces in Natural Seawater[1]

This standard is issued under the fixed designation D 4939; 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 the determination of antifouling performance and reduction of thickness of marine antifouling (AF) coatings by erosion or ablation (see Section 3) under specified conditions of hydrodynamic shear stress in seawater alternated with static exposure in seawater. An antifouling coating system of known performance is included to serve as a control in antifouling studies.

1.2 *This standard may involve hazardous materials, operations, and equipment. This standard does not purport to address all of the safety problems associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.* For a specific hazards statement, see Section 8.

2. Referenced Documents

2.1 *ASTM Standards:*

A 569/A 569M Specification for Steel, Sheet and Strip, Carbon (0.15 Maximum Percent), Hot-Rolled, Commercial Quality[2]

D 1186 Test Methods for Nondestructive Measurement of Dry Film Thickness of Nonmagnetic Coatings Applied to a Ferrous Base[3]

D 2200 Pictorial Surface Preparation Standards for Painting Steel Surfaces[4]

D 3623 Method for Testing Antifouling Panels in Shallow Submergence[4]

2.2 *U.S. Military Specifications:*[5]

MIL-P-24441 Primer, Epoxy (Formula 150, Formula Sheet 24441/1)

MIL-P-15931B Paint, Antifouling, Vinyl, Red (Formula 121/63)

MIL-S-22698A Steel Plate, Carbon, Structural

3. Terminology

3.1 *Descriptions of Terms Specific to This Standard:*

3.1.1 *ablation*—in this test method, the removal or wearing away of the outer layers of coating caused by the combined action of hydrolysis and hydrodynamic shear stress. This action is often, but not necessarily, achieved by the combined effects of hydrolysis and hydrodynamic shear stress.

3.1.2 *hydrolysis*—softens or weakens the outer layers, permitting the hydrodynamic shear stresses gradually to remove them, continually exposing a fresh antifouling surface.

3.1.3 *hydrodynamic shear stress*—the force tangential to the surface resulting from water in contact with and flowing parallel to the surface.

4. Summary of Test Method

4.1 The antifouling coatings to be tested and a control coating are applied to steel panels and exposed in natural seawater at a site where the fouling rate is high. The exposure consists of alternate static and dynamic cycles of typically 30 days each for a total length of time to be specified (such as one or two years) or until some selected degree of fouling is reached. The static exposure is conducted in accordance with Method D 3623 except that the panels are smaller and are preformed to fit a rotating drum. The dynamic exposure consists of subjecting the test panels to a shear stress by rotating the drum underwater at some specified revolution rate; typically, that rate that gives a peripheral speed of 15 knots (7.6 m/s). See Note 1 for an example. Photographs and film thickness measurements (made in accordance with Test Method D 1186) are taken before exposure to seawater and, along with fouling ratings, at intervals during exposure.

NOTE—Consider antifouling paint for a ship about 500 ft in length that cruises at about 20 knots. From Table 2, the column for 20 knots shows the hydrodynamic shear stress, τ varying from 2.01 to 1.40 lbf/ft^2 over a flat plate with approximately the same length as the ship. From Table 1, a rotating drum with a radius of 0.75 ft with a peripheral speed of 15 knots gives a τ of 1.72 lbf/ft^2. To subject the paint to about the same range of τ as on the ship, the paint can be tested on the drum with τ of 1.72 lbf/ft^2. Because τ for the plate (and ships) decreases from the leading to the trailing edge, it is considered adequate to select τ for the drum as the approximate midrange of the plate values matched to the length and cruising speed of the vessels of interest.

5. Significance and Use

5.1 Effective antifouling coatings are essential for the retention of speed and reduction of operating costs of ships. This test method is designed as a screening test to evaluate antifouling coating systems under conditions of hydrodynamic stress caused by water flow alternated with static exposure to a fouling environment. A dynamic test is necessary because of the increasing availability of AF coatings that are designed to ablate in service to expose a fresh antifouling surface. Because no ship is underway continually, a static exposure phase is included to give fouling microorganisms the opportunity to attach under static conditions.

---

[1] This test method is under the jurisdiction of ASTM Committee D-1 on Paint and Related Coatings and Materials and is the direct responsibility of Subcommittee D01.45 on Marine Coatings.

Current edition approved April 28, 1989. Published June 1989.

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

[3] *Annual Book of ASTM Standards*, Vol 06.01.

[4] *Annual Book of ASTM Standards*, Vol 06.02.

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

TABLE 1 Approximate Hydrodynamic Shear Stress, τ, For Rotating Drum Apparatus, lbf/ft² [A]

Drum Radius, ft	Peripheral Speed of Drum, knots					
	10	15	20	22	25	30
0.75	0.82	1.72	2.91	3.48	4.39	6.14
1.0	0.78	1.64	2.78	3.31	4.19	5.86
1.25	0.75	1.58	2.68	3.20	4.05	5.68
1.5	0.73	1.53	2.60	3.11	3.94	5.52

[A] Values calculated as follows:

$\tau = \frac{1}{2} C_f \rho v^2$,

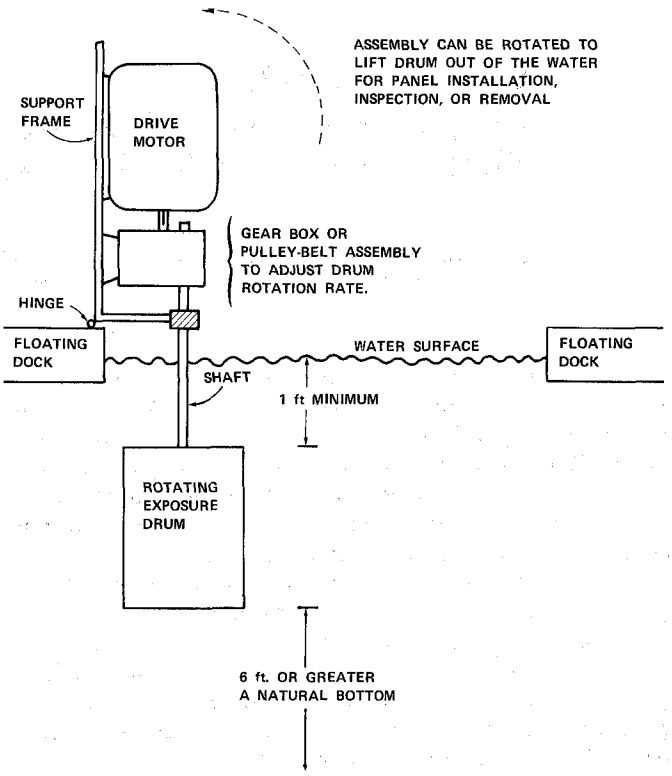
$v = r\omega$

$R = \frac{vr}{\nu}$, Reynolds Number

$\frac{1}{\sqrt{C_f}} = -0.6 + 4.07 \log [R\sqrt{C_f}]$ (from Dorfman, *Hydrodynamic Resistance and the Heat Loss of Rotating Solids*, Oliver and Boyd, London, 1963, p. 176.

where

τ = shear stress on drum surface, lbf/ft²,
ρ = water density = 1.99 slugs,
v = peripheral speed of drum surface, knots,
C_f = shear stress (drag) coefficient,
ω = Rotational speed of drum, radions/s, and
r = drum radius, ft.



NOTE 1—Specific components and arrangements may vary to suit user and site requirements.

NOTE 2—1 ft = 305 mm.

FIG. 1 Rotating Drum Assembly

After an initial 30-day static exposure, alternated 30-day dynamic and static exposures are recommended as a standard cycle. The initial static exposure is selected to represent vessels coming out of drydock and sitting pierside while work is being completed. This gives the paint time to lose any remaining solvents, complete curing, absorb water, and, in general, stabilize to the in-water environment.

5.2 This test method is intended to provide a comparison with a control antifouling coating of known performance in protecting underwater portions of ships' hulls. This test method gives an indication of the performance and anticipated service life of antifouling coatings for use on seagoing vessels. However, the degree of correlation between this test method and service performance has not been determined.

6. Apparatus

6.1 *Rotating Drum Assembly*—The basic system consists of a rotating drum assembly as shown in Fig. 1. The drum diameter and rotational rate shall be calculated to give the desired hydrodynamic shear stress. The drum diameter shall be not less than 18 in. (460 mm).

6.2 *Panels*—The panels shall be made from medium low-carbon steel plate in accordance with Specification A 569/A 569M, ⅛ in. thick by 3 to 6 by 7 to 10 in. (3 mm thick by 80 to 150 by 180 to 250 mm) curved to fit the drum surface as shown in Fig. 2. Panel length must be selected in order to prevent gaps greater than 1/16 in. (1.6 mm).

6.3 *Static Exposure Rack*—The static exposure rack shall provide firm positioning of the specimen panels so that the coated surfaces are held vertically in place in spite of the current and are electrically insulated from metallic contact with the rack or other panels. The rack shall be so positioned that the prevailing tidal currents move parallel to the panel face, and the panels are immersed to a depth of a minimum of 1 ft (0.3 m) and a maximum of 10 ft (3 m). In a rack where panels are stacked front to back, they should be spaced at least 2½ in. (64 mm) apart, with the two end positions filled with blank panels. In a rack where the panels are mounted side by side, the distance between adjacent panels should be not less than ½ in. (13 mm).

7. Materials

7.1 *Control Coating System*—The control antifouling coating system shall consist of the following system unless an alternative control coating system is specified.

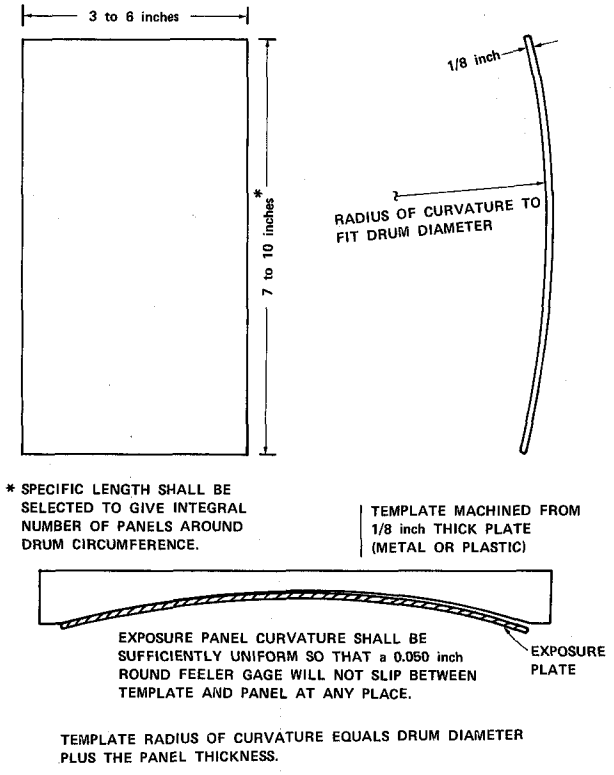
7.1.1 *Polyamide Epoxy Anticorrosive Coating*, conforming to U.S. Military Specification MIL-P-24441 (Navy Formula 150, Type I).

7.1.2 *Vinyl Antifouling Coating*, conforming to U.S. Military Specification MIL-P-15931B (Formula 121/63), B revision only.

7.2 *Test Coating System*—The antifouling coating under test may be applied to the control primer system or to any other suitable anticorrosive primer system agreed upon between the parties concerned. The application procedure is to be in accordance with the manufacturer's instructions.

8. Hazards

8.1 Antifouling paints contain toxic materials that could cause skin and eye irritation on contact and adverse physiological effects if ingested or inhaled. In the preparation of panels and the application of various types of antifouling paints the use of appropriate protective clothing and equipment is required consistent with applicable regulations, and recognized industrial and technical standards. Spills, overspray, and unused material should not be flushed down the drain, but disposed of as hazardous waste.



NOTE—1 in. = 25.4 mm.

FIG. 2 Curved Exposure Panels for Rotating Drum

9. Procedure

9.1 Abrasive blast clean the required number of panels (six panels for each coating system being tested) to near white metal (Grade Sa 2½ of Pictorial Standard D 2200) to obtain a profile from 1 to 1.5 mils (25 to 40 μm).

9.2 On the clean, dry, uncontaminated, blast-cleaned surface apply to each standard panel one coat of epoxy polyamide primer conforming to MIL-P-24441 to give a dry film thickness of approximately 3 mils (75 μm). After about 24 h, (for temperatures above 70°F and below 90°F), apply a second coat of the primer to the panels. After a second 24-h period, apply the third coating of primer to give a total dry film thickness of approximately 9 mils (230 μm).

9.3 Apply the vinyl antifouling coating conforming to MIL-P-15931B before the final coat of epoxy paint has hardened. The epoxy should be slightly tacky when the first coat of the topcoat is applied. If the epoxy is hard (usually after 8 h) apply a tack or mist coat of 1 to 2 mils wet film thickness and allow to dry to a slightly tacky state before applying the first coat of the topcoat. Allowing a minimum of 2 h and a maximum of 24 h drying after the first coat, apply the second coat of the antifouling coating conforming to MIL-P-15931B to give a nominal dry film thickness of the antifouling paint of 4 mils (100 μm).

9.4 Before immersion permit the second coat of antifouling coating to dry a minimum of 24 h or until fully cured in accordance with the manufacturer's recommendations and a maximum of one month, the latter time allowing for shipping the panels to the immersion site. Measure dry film thickness at ten locations on the panel in accordance with Test Methods D 1186 prior to immersion at the site. To accurately locate the thickness measurement locations on the panels for repeated measurements, use a mask with two rows of five holes equally spaced over the surface.

9.5 Exposure consists of alternating static and dynamic phases at an immersion site with a high incidence of fouling (that is fouling resistance of 50 % or less determined in accordance with Method D 3623) as indicated by attachments to a dark nontoxic surface such as slate.

9.5.1 Place the panels on the stationary exposure racks, handling them only by the edges, and expose them in accordance with Method D 3623. Static exposure may be accomplished by leaving the panels attached to the drum and not rotating it. The time the panels are out of the water must be kept to a minimum. When any panels are removed from the stationary racks or the rotating drum, they are to be kept in containers of seawater except during actual rating, photography, or thickness measurement. If the time out of water exceeds 10 min, this fact should be recorded and reported.

9.5.2 Subject the test panels to dynamic exposure by mounting them on the drum and rotating it at a peripheral speed calculated from the values and formulas given in Tables 1 and 2 as agreed upon between the parties concerned.

9.6 Evaluate the antifouling panels for surface fouling and physical condition of the film system at the end of each exposure or as agreed upon between the parties concerned. Record the evaluation on the report form in Fig. 3.

9.6.1 *Fouling on Surface*—Rate the fouling present on that portion of the antifouling test surface that is intact at the time of inspection in accordance with Method D 3623. Ignore fouling present on the substrate or on anticorrosive undercoats. Barnacles, polychaetes, coelenterates, etc. that are immature or loosely attached should be so reported in the appropriate space on the report form (see Fig. 3). Report fouling by initial algal germination, low-form algae, and diatoms as "algal slime." Report absorbed organic and inorganic chemicals, trapped silt and detritus, and other unidentified slimes as "silt."

9.6.2 *Physical Condition*—Rate the condition of coating films in accordance with 10.2. Record qualitative descriptions of film deterioration and discoloration in the appropriate column in Fig. 3 unless otherwise specified. Indicate deterioration of anticorrosive (AC) undercoats, when evident, by the notation "AC." For example, "Peeling antifouling film (AF) from AC" or "Chipping, AC from steel." For ablative coating with fouling-free areas, measure total coating thickness in accordance with Test Methods D 1186 using the mask to locate measurement spots. If the panel surface is free of fouling, measure thickness at all ten locations given on the mask. If any locations are obstructed by fouling, note this fact and do not make measurements at that spot.

9.7 Record the start and stop dates of each of the static and dynamic exposures. Record each of the inspection dates. During the exposures, record the range of water depth, temperature, salinity, pH, and water solids content at intervals using the methods agreed upon by the parties concerned.

9.8 Document the exposure results as follows:

9.8.1 Take color photographs and coating film thickness at ten locations marked by the mask in accordance with Test Methods D 1186 prior to immersion. Repeat the film thickness measurement at the end of the first static exposure

Behavior Report of Experimental Surfaces

Origin:
Series:
Base:
Size:

Place of Immersion:
Depth of Immersion:
Date Immersed:
Date Inspected:
Inspected by:

Test Surface No.	Fouling on Surface	Physical Condition	Percent Ratings			
			FR	AF	AC	OP
	Barn: EB: Others:					
	Barn: EB : Others:					
	Barn: EB: Others:					
	Barn: EB: Others:					
	Barn: EB: Others:					
	Barn: EB: Others:					
	Barn: EB: Others:					

NOTE—Fouling is reported as found on the more heavily fouled surface. Solitary forms are reported numerically; colonial forms by percent surface covered. Abbreviations: algae (Al); barnacles (Barn); encrusting bryozoans (EB); hydroids (Hyd); tunicates (Tun); completely fouled (CF); coelenterates (CO); filamentous bryozoans (FB); molluscs (Mol); polychaetes (PC).

FIG. 3 Report Form

to allow for film swelling and to provide a reference for the amount of paint thickness lost during the subsequent dynamic exposures.

9.8.2 At the end of each phase, take color photographs of each set (six panels including color chart), determine coating dry (or cured) film thickness in accordance with Test Methods D 1186 prior to the first and after each succeeding dynamic-exposure phase, and determine fouling rating in accordance with Method D 3623.

10. Calculation

10.1 *Fouling Resistance (FR)*—Calculate the fouling resistance in accordance with Method D 3623 except do not normalize the results.

10.2 *Physical Change:*

10.2.1 *Antifouling Film (AF)*—Award an antifouling test surface having no physical defects a rating of 100. Subtract the percent surface affected by film defects from 100 to obtain the rating for imperfect films.

10.2.2 *Anticorrosive Film (AC)*—Obtain the rating in accordance with the procedure in 10.2.1.

10.3 *Overall Performance (OP)*—For overall performance, award the panel the lowest percent rating of the three preceding values: FR, AF, and AC.

10.4 *Paint Thickness*—Average the initial ten film thickness readings per panel made after the first static exposure; average the final thickness readings after the last exposure. Compute the average thickness loss by subtracting the average final thickness from the average initial thickness. Calculate the number of months over which the film thickness loss occurred.

11. Report

11.1 Report the following information:

11.1.1 The results of the immersion test in terms of fouling resistance and overall performance for both the material under test and the control system.

11.1.2 The initial and final film thickness for each panel, the film thickness loss, and the months over which the loss occurred.

11.1.3 The place, depth, and date of immersion; whether mounted from a dock, a floating raft, or in a man-made flow tank; the drum diameter and r/min; the date the panels were removed and inspected; the panel size; the panel identification number; and the range of the water temperature, salinity, pH, and water solids content on a monthly basis. A census of the fouling on a nontoxic surface taken each month for the period of exposure must be included in the report. Color photographs of the fouling and coating are to be taken at the end of each exposure or as specified.

12. Precision and Bias

12.1 Precision and bias cannot be determined. Only a

limited number of test facilities[6] have constructed this apparatus and utilized this test procedure to date. Furthermore, the test method was developed and used only for prototype testing. This means few specimens of a kind have been tested or are likely to be tested with results suitable for analysis available in the next few years. Also, since there is no acceptable reference material suitable for determining the bias for this procedure, no statement on bias is being made.

[6] Facilities that have constructed this apparatus include Miami Marine Research Inc., 547 West Ave., Miami Beach, FL 33139 and Battelle Columbus Laboratories, Florida Marine Research Facility, 4928 Sailfish Drive, Ponce Inlet, Daytona Beach, FL 32019.

Designation: D 4940 - 89

Standard Test Method for Conductimetric Analysis of Water Soluble Ionic Contamination of Blasting Abrasives[1]

This standard is issued under the fixed designation D 4940; 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 describes a procedure for rapid evaluation of abrasives for the presence of ionic contamination by determining the total concentration of water soluble ionic contaminants by means of a conductivity test.

1.2 This test method does not identify the ionic species present nor provide quantitative results on each species.

1.3 This test method is based on a volume comparison among abrasives of similar sizes. A volume comparison is more closely related to surface area of the abrasives than is a weight comparison.

1.4 *This standard may involve hazardous materials, operations, and equipment. This standard does not purport to address all of the safety problems 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 1193 Specification for Reagent Water[2]

E 832 Specification for Laboratory Filter Papers[3]

3. Summary of Test Method

3.1 Abrasive and pure water are combined into a slurry that is stirred to leach the soluble salts from the abrasive. This slurry is filtered and conductance of the filtrate is measured. The conductivity, which is related to the concentration of soluble ionic materials contaminating the abrasive surface, is calculated from the conductance and the cell constant.

4. Significance and Use

4.1 By-product abrasives manufactured from slags that are air cooled or quenched with pure water, normally contain low concentrations of ionic materials as do mined mineral abrasives. However, slags quenched with seawater or other contaminated water, contain high amounts of ionic material as does seashore sand. This contamination of the abrasive can transfer to the steel surfaces being blasted, where it may accelerate corrosion. This test is useful in establishing the cleanliness of the abrasive at the jobsite.

4.2 This test method provides a value that indicates the concentration of total water soluble ions in accordance with their electrolytic mobility. Thus, it provides an indication of ionic corrosion potential.

NOTE 1—A typical value of conductivity for a high level of contamination is 500 μmho/cm. A typical value for a low level of contamination is 50 μmho/cm.

5. Apparatus

5.1 *Conductivity Bridge and Cell*—Any commercial conductivity bridge and conductivity cell having a range of at least 5 μmho/cm to 1 000 000 μmho/cm and temperature compensation capability is satisfactory. Either a dip-type, pipet-type, or cup-type cell may be used. A means of adjusting for temperature or controlling the temperature is essential. While some instruments have an adjustment to compensate for temperature, one means is to use a 25°C constant temperature bath. Another method is to stir the solution with a clean thermometer while the vessel is warmed or cooled by an external source.

NOTE 2—If temperature compensation or control is not followed correctly, an error of approximately 2 % per degree of temperature deviation from 25°C can be introduced. The deviation of conductivity with temperature in the range of 18°C is reported to be 0.0216 % per degree for chloride ions and 0.0227 % per degree for sulfate ions.

5.2 *Filter Paper*, conforming to Specification E 832, Type 1, Class C, to keep silt from fouling the surfaces of the conductivity cell.

6. Reagents and Materials

6.1 *Purity of Reagents*—Reagent grade chemicals shall be used in all tests. Unless otherwise indicated, it is intended that all reagents conform to the specifications of the Committee on Analytical Reagents of the American Chemical Society where such specifications are available.[4] Other grades may be used, provided it is first ascertained that the reagent is of sufficiently high purity to permit its use without lessening the accuracy of the determination.

6.2 *Purity of Water*—Unless otherwise indicated, references to water shall be understood to mean reagent water as defined by Type IV of Specification D 1193.

6.3 *Potassium Chloride* (KCl or 0.02 N KCl solution).

---

[1] This specification is under the jurisdiction of ASTM Committee D-1 on Paint and Related Coatings and Materials and is the direct responsibility of Subcommittee D01.46 on Industrial Protective Coatings.

Current edition approved April 28, 1989. Published June 1989.

[2] *Annual Book of ASTM Standards*, Vol 06.01 and 11.01.

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

[4] "Reagent Chemicals, American Chemical Society Specifications," Am. Chemical Soc., Washington, DC. For suggestions on the testing of reagents not listed by the American Chemical Society, see "Reagent Chemicals and Standards," by Joseph Rosin, D. Van Nostrand Co., Inc., New York, NY, and the "United States Pharmacopeia."

7. Sampling

7.1 Sampling shall be as follows unless otherwise agreed upon between the purchaser and the seller. Take two 1-L samples of abrasive at random from different packages of each lot, batch, day's pack, or other unit of production in the shipment. When no markings distinguishing between units of production appear, take samples from the different packages in the ratio of two samples for each 10 000 lb (5000 kg), except that for shipments of less than 10 000 lb, take two samples. Test the samples separately.

8. Calibration and Standardization

8.1 *Determination of Cell Constant:*

8.1.1 The conductivity cell will come with a predetermined constant. This constant should be checked periodically, one method being as follows:

8.1.1.1 Prepare a standard solution such as a 0.0005 *N* solution of KCl by diluting a 0.02 *N* KCl solution with water or by dissolving 0.0372 g of KCl (heated before weighing for 1 h at 105°C) in water, followed by dilution to 1 L. Cool and measure the conductance at 25°C as described in Section 9. Calculate the cell constant, K_{25}, as follows:

$$K_{25} = (C_s/C_m)$$

where:

C_m = conductance, measured at 25°C (see 10.1), μmho, and
C_s = conductivity, 72 μmho/cm (from Table 1).

NOTE 3—In general the cell constant is not greatly affected by variations in the strength of the KCl solution, but, for greater accuracy, measurements should be made at or near the specific conductivity of the solution to be measured and at values that utilize the middle range of the scale of the conductivity bridge, using the same multiplier tap.

8.1.2 Table 1 gives values of specific conductivities for corresponding KCl solution concentrations which are useful for abrasive testing.

9. Procedure

9.1 *Preparation of a Slurry Filtrate:*

9.1.1 Rinse beakers, stirring rods, and funnels with reagent water until tests show the rinse water has a conductivity of 5.0 μmho/cm or less.

9.1.2 Add 300 mL of water to 300 mL of abrasive and stir for 1 min with a stirring rod. Let stand for 8 min and then stir again for 1 min.

9.1.3 Filter sufficient supernatant liquid for tests, discarding the first 10 mL of the filtrate. The amount of supernatant liquid filtered shall be sufficient to cover the cell.

9.1.4 Rinse the conductivity cell in reagent water until the rinse water is a cleanliness of 5.0 μmho/cm or less.

9.1.5 Rinse the conductivity cell two or three times with the filtrate then determine conductance at 25°C in accordance with the operating instructions of the instrument. Use successive portions of the sample until a constant value is obtained.

TABLE 1 Specific Conductivities for Potassium Chloride (KCl) Concentrations at 25°C

Normality	Heated, Dry KCl/Reagent Water Solution, g/L	KCl Conductivity, μmho/cm
0.0005	0.0373	72
0.001	0.0746	147
0.005	0.3728	718
0.01	0.7455	1414

10. Calculation

10.1 Calculate the specific conductivity of the abrasive as follows:

$$C_s = C_m \times K_{25}$$

11. Report

11.1 Report the following information:

11.1.1 The calibration value of the cell constant (both as measured and as predetermined and supplied with the conductivity cell), the date, and the name of the person checking the calibration.

11.1.2 The material, date, readings and mean in μmho/cm along with name of person conducting the tests and identification of the apparatus.

12. Precision and Bias[5]

12.1 *Precision*—On the basis of five replicate interlaboratory tests of this test method in which three operators in three laboratories analyzed, in duplicate, six blasting abrasives containing ionogenic contamination, the within-laboratory coefficient of variation after rejecting results from one set of replicate tests as outliers, was found to be 1.7 % with 20 degrees of freedom (df) and the between-laboratory standard deviation coefficient of variation was found to be 7.4 % with 15 df. Based on these coefficients, the following criteria should be used for judging the acceptability of results at the 95 % confidence level:

12.1.1 *Repeatability*—Two results, each the mean of two runs obtained by the same operator should be considered suspect if they differ by more than 5 % relative.

12.1.2 *Reproducibility*—Two results, each the mean of two runs, obtained by operators in different laboratories should be considered suspect if they differ by more than 22 % relative.

12.2 *Bias:*

12.2.1 Bias can be present because of the mobility of various ions. The hydrogen ion has a much greater mobility than the hydroxyl ion or other ions so that at low pH's the conductivity will be relatively higher than at high pH's for the same ionic concentration. However, the bias introduced by this factor is in the proper direction. That is, high conductivity due to a lower pH of the contamination would normally indicate greater corrosion potential.

12.2.2 A bias may be introduced by extraneous contamination or from reduced sensitivity of instruments for low levels of contamination in the range of conductivity between 0 and 30 μmho/cm.

13. Keywords

13.1 ionogenic; contamination; steel surfaces; abrasive; blasting; conductimetric; analysis; interlaboratory testing; precision; chloride; conductivity; salts.

[5] Supporting data available from ASTM Headquarters. Request RR: D01-1061.

Designation: D 4941 – 89

Standard Practice for Preparing Drawdowns of Artists' Paste Paints[1]

This standard is issued under the fixed designation D 4941; 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 production of uniform films of artists' tube paints and other nonflowing pigmented paints using paint applicators designed for less viscous paints.

1.2 Information on how to achieve opaque specimens from these paints is included.

1.3 *This standard may involve hazardous materials, operations, and equipment. This standard does not purport to address all of the safety problems 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 16 Terminology Relating to Paint, Varnish, Lacquer, and Related Products[2]

D 4838 Test Method for Determining the Relative Tinting Strength of Chromatic Paints[3]

E 1164 Practice for Obtaining Spectrophotometric Data for Object-Color Evaluation[2]

3. Terminology

3.1 *Definitions*—See Terminology D 16 for definitions of terms used in this practice.

3.2 *Descriptions of Terms Specific to This Standard:*

3.2.1 *drawdown bar*—a metal applicator with a specified gap designed to deposit a wet paint film uniformly on a specified test panel (for example, an opacity chart) or other substrate.

3.2.2 *drawdown*—a layer of paint deposited on a substrate by use of a drawdown bar for the evaluation of paint characteristics.

4. Summary of Practice

4.1 The paint is spread over the area of the test panel to be covered by the drawdown and the bar is pulled down with pressure just sufficient to avoid lifting of the bar from the chart surface.

4.2 Test panels are allowed to dry in a dust-free environment.

4.3 If complete hiding (opacity) is needed and not produced by a single paint film, a second film is applied at a 90° angle to the first. If required, additional layers may be applied using a narrower drawdown bar.

5. Significance and Use

5.1 Quality standards for artists' paints require the evaluation of various appearance characteristics of paint films. Tinting strength determination (Test Method D 4838) specifically requires the preparation of drawdowns for colorimetric measurement. Other evaluations such as color designation, transparency, gloss, and color difference measurements also require drawdown samples.

5.2 Artists' tube paints have a paste consistency that makes the use of traditional film application methods difficult, especially for drying oil paints.

5.3 Artists' paints vary in two properties important to the preparation of films, that is, transparency and drying time. Colorimetric determination and some other types of evaluation require paint specimens that completely hide the substrate. Very transparent paints require such a thick film to produce complete hiding that drying times is excessively long or the specimen surface is blemished. When complete hiding is necessary, this practice is designed to provide opaque films without these defects through application of a series of thin film.

6. Apparatus

6.1 *Drawdown Bars*, two, of different widths with a clearance of 0.006 in. (0.152 mm). Recommended widths are 3 in. (7.6 cm) and 6 in. (15.2 cm). The second bar is required to prepare drawdowns with more than two layers. Wire wound drawdown bars have been found to be unsuitable.[4]

6.2 *Drawdown Charts*, sealed paper type, half black and half white if transparency is being evaluated or opacity is necessary.[5]

7. Procedure

7.1 Attach chart to a firm, smooth, level plane surface using tape, a vacuum plate, or a clamp. Label the chart with the identity of the specimen and other data as required.

7.2 Mix paint sample thoroughly using two spatulas. Tube paints that have separated should be expelled completely and mixed.

NOTE 1—The use of coated freezer wrapping paper as a mixing surface simplifies clean up. The same paper can be used for weighing

[1] This specification is under the jurisdiction of ASTM Committee D-1 on Paint and Related Coatings and Materials and is the direct responsibility of Subcommittee D01.57 on Artist Paints and Related Materials

Current edition approved April 28, 1989. Published June 1989.

[2] *Annual Book of ASTM Standards*, Vol 06.01.

[3] *Annual Book of ASTM Standards*, Vol 06.02.

[4] Suitable drawdown bars can be obtained from the Paul N. Gardner Co., P.O. Box 10688, Pompano Beach, FL 33061-6688; or BYK-Gardner, Inc., Gardner Laboratory, 2435 Linden Lane, Silver Spring, MD 20910.

[5] Suitable charts can be obtained from The Leneta Co., Box 576, Ho-Ho-Kus, NJ 07423.

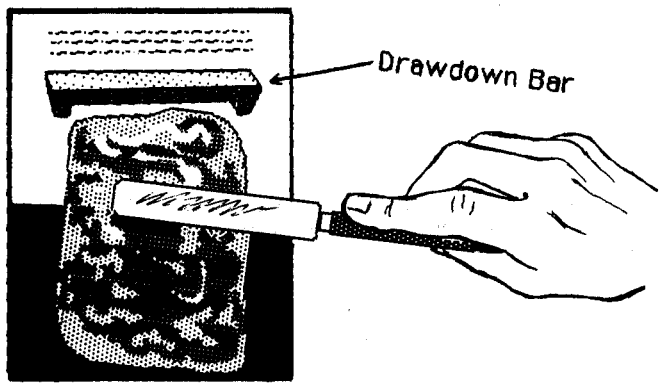


FIG. 1 Preparation for Drawdown

specimens when required as in the tinting strength determination (Test Method D 4838).

7.3 Using a spatula, spread the paint, in a thickness exceeding the bar's gap clearance, over the entire area to be covered by the drawdown. Do not cover the area to be contacted by the supporting feet of the wider of the two bars. Starting at the top of the chart and using the wider bar, draw the bar down over the paint in an even motion applying sufficient pressure to ensure that the resistance of the viscous paint does not raise the feet of the bar from the surface. When using oil paints the motion should be slow enough to allow for the high viscosity. Acrylic paints, which have short drying times, should be applied immediately after mixing to avoid premature film formation.

7.4 After drying in a horizontal position for 15 min, specimens may be hung in a vertical position in a dust-free area to complete the drying. Allow 24 h for acrylic and alkyd paints and 48 h or longer for oil paints until dry to touch.

7.5 Examine the specimen for surface defects and discard if unacceptable.

7.6 If complete hiding is required, compare, either visually or instrumentally, the lightness of the paint on the black portion of the chart with that on the white. For instrumental evaluation, follow the procedures given in Practice E 1164 to determine CIE Y for each portion, then calculate the contrast ratio of the paint film on the two portions of the chart (CIE Y_{black}/CIE Y_{white}). A contrast ratio of 0.98 or higher is considered opaque.

7.6.1 If opacity is not sufficient, rotate the chart through a 90° angle and deposit a second film using the wider bar to repeat the procedure in 7.3 through 7.5. If additional layers are required, repeat this sequence using the narrower bar. Be careful each time that the feet of the drawdown bar ride on the surface of the combined lower layers. See Figs. 1 and 2.

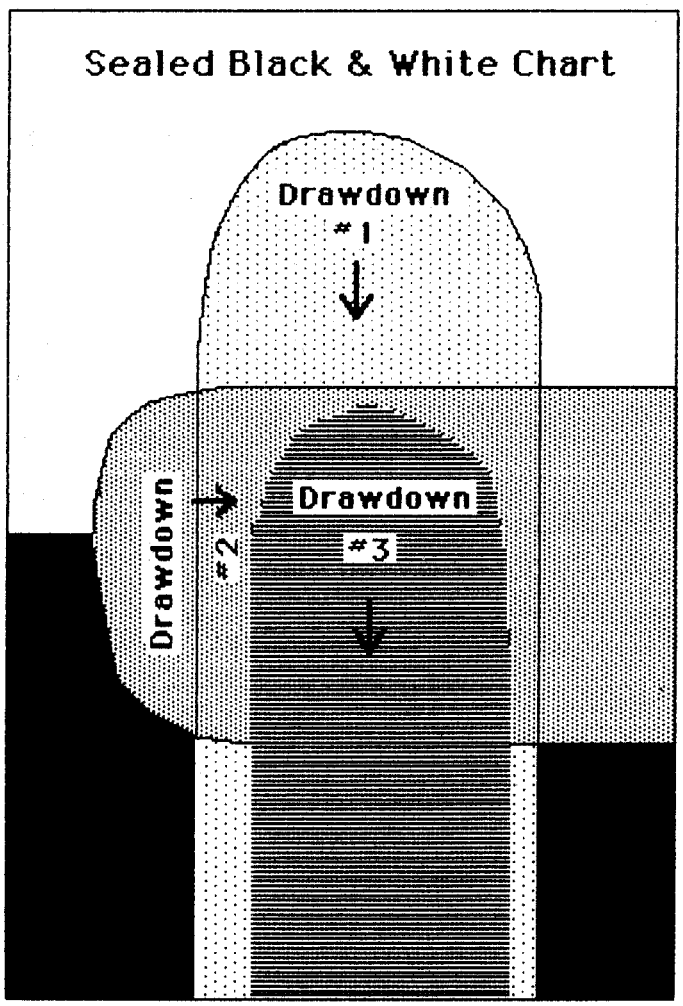


FIG. 2 Three Overlapping Drawdowns

NOTE 2—The most transparent paints studied were found to require three coats; however, in some instances, such as with alizarin crimson oil paint, it may not be practical to obtain complete hiding.

Designation: D 4942 – 89

Standard Test Methods for Water Pickup of Lithographic Printing Inks and Vehicles in a Laboratory Mixer[1]

This standard is issued under the fixed designation D 4942; 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 cover two procedures for determining the amount of water picked up by lithographic printing inks in a laboratory mixer.

1.2 Test Method A covers single-point water pickup; Test Method B covers the rate of water pickup. Both test methods are applicable to any printing ink and vehicle intended for the lithographic printing process.

1.3 *This standard may involve hazardous materials, operations, and equipment. This standard does not purport to address all of the safety problems 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. Summary of Test Method

2.1 These test methods utilize a laboratory mixer for beating water or other agreed upon fluid into the test ink.

2.2 For single-point water pickup (Test Method A), 50 mL of water is normally added to 50 g of ink and mixed in for 5 min. The water picked up is determined from volumetric measurements of free water.

2.3 For rate of water pickup (Test Method B), water is added to 50 g of ink in increments of 20 mL and mixed in for 1 min or more over a cumulative time period totaling 10 min. The water taken up by the ink after each mixing interval is determined gravimetrically.

3. Significance and Use

3.1 The lithographic printing process requires that some dampening solution be emulsified into the ink. These test methods provide a rapid means for determining water pickup under laboratory conditions. Test results may be useful for specification acceptance between the supplier and the customer.

3.2 In order that results be comparable, the tests must be run at the same temperature and with the same type and quantity of liquid added prior to mixing.

3.3 The emulsions obtained in these test methods are of larger particle size than those typically produced in printing nips. Because of these and other variables in the printing process, water pickup results do not by themselves predict lithographic printing performance.

4. Apparatus

4.1 *Laboratory Mixer*,[2] such as a Duke Ink-Water Emulsification Tester[2] equipped with a stainless steel specimen bowl 83 mm wide and 88 mm high, mixer blades that rotate at 90 r/min, and a timing device.

4.2 *Balance*, accurate to 0.1 g, 600-g capacity.

4.3 *Palette knives*, two.

4.4 *Thermometer*, quick response.

4.5 *pH Meter* (optional).

4.6 *Conductivity Meter* (optional).

4.7 *Graduated Cylinder*, 50 or 100-mL.

5. Reagents and Materials

5.1 *Water*—Deionized or distilled water, preferably having a pH of 5.0 to 7.0 (100 to 200 mL per sample); alternatively, fountain solution or other aqueous medium as agreed upon between the supplier and the customer may be used.

5.2 *Cleanup Materials*—Naptha and rags or tissues.

6. Test Specimen

6.1 A minimum of 100 g is sufficient for two determinations. Before removing ink from the can, stir or otherwise ensure that the ink specimen is representative. Close the can and replace sealing tape immediately after each ink removal.

7. Conditioning

7.1 Condition the instrument, water, and ink samples in a constant temperature room or bath, preferably at 23 ± 1°C.

7.2 Prior to use, check the alignment of the mixer blades. With the power switch of the mixer in the off position, set the clean bowl into the turntable and engage the locking pin firmly into the slot in the side of the turntable. Tilt the mixer head back and insert the blades, marked left and right, into their respective holders. Lower the mixer head. If the blades hit the side or bottom of the bowl, return the instrument to the manufacturer for realignment.

8. Test Method A—Single Point Water Pickup (by Volumetry)

8.1 Program the counter of the mixer for 5 min mixing time (450 revolutions).

8.2 *Optional*—If the first run of the day, pour test water into a beaker. Measure pH, conductivity, and temperature at the beginning of testing.

8.3 Weigh or tare the clean dry mixing bowl. Add 50 ±

[1] This test method is under the jurisdiction of ASTM Committee D-1 on Paint and Related Coatings and Materials and is the direct responsibility of Subcommittee D01.56 on Printing Inks.

Current edition approved April 28, 1989. Published June 1989.

[2] Available from Duke Custom Systems, 8371 Highway 49, Pleasant View, TN 37146.

0.1 g of the ink to the center of the bowl.

8.4 Pour 50 mL of water (from 8.2) into a graduated cylinder. If the ink is expected to pick up more than 100 % water, use 100 mL of water. Adjust the volume to ±0.5 mL. Add the entire contents to the bowl.

8.5 With the mixer head tilted back insert the clean blades, marked left and right, into their respective holders. Lock the bowl on the turntable. Lower the mixer head. Press the counter reset button, making sure that 450 is displayed on the face of the counter.

8.6 Turn the mixer on. Examine contents of the bowl as mixing progresses. If 50 mL of water had been added and all of it disappears into the ink, stop, discard the ink in the bowl, clean up, and start over from 8.3, adding 100 mL of water in 8.4. The latter quantity must also be used for all other inks in the series under study.

NOTE 1—With some inks, water pickup is affected by the amount of water added prior to mixing. When 50 mL is insufficient, do not simply add another 50 mL during the run, as test results may differ significantly from those obtained by adding 100 mL at the outset.

8.7 When the mixer stops, turn the power switch off. Tilt the head out of the ink, detach the mixing blades, and add to the bowl.

8.8 Remove the bowl from the turntable and, holding the blades at the side of the bowl, decant the free water into a graduated cylinder. Run the blades *very slowly* through the ink in the bowl. Decant additional free water into the cylinder.

NOTE 2—Do not knock the bowl to force free water from the surface. Always handle the bowl gently to avoid breaking the emulsion.

8.9 Record the returned water level to 0.5 mL.

8.10 *Optional*—Measure the temperature, pH, and conductivity of the returned water. Note the appearance of the water and the consistency of the ink and the appearance of the returned water.

8.11 Discard ink left in the bowl. Clean the bowl and the mixer blades with tissue wetted with naphtha. Discard the returned water and rinse the cylinder clean.

8.12 Repeat 8.3 through 8.10 with a second specimen of the same ink.

9. Test Method B—Rate of Water Pickup (by Gravimetry)

9.1 Program the counter for the first interval of the mixing cycle.

NOTE 3—A commonly used cycle is 1-min intervals (90 revolutions) times ten determinations. Intervals need not be uniform, for example, 1, 2, 3, 5, and 10 min (90 times 3 plus 180 plus 450 revolutions).

9.2 *Optional*—Measure water properties in accordance with 8.2.

9.3 Weigh or tare the clean dry mixing bowl and blades on the balance. Add 50 ± 0.1 g of ink to the center of the bowl.

9.4 Lock the bowl on the platform of the mixer. With the mixer head raised, carefully insert the blades into their respective holders. If ink on one blade touches the upper parts of the other blade or the side of the bowl, carefully remove the ink with two palette knives and transfer to the bottom of the bowl. Lower the mixer head.

9.5 Pour 100 mL of water (from 8.2) into a beaker. Meter out 20 mL and add to the bowl.

9.6 Press the counter reset button, making sure that the desired number of revolutions is displayed on the face of the counter. Turn the mixer on. Examine the contents of the bowl as mixing progresses. If all liquid disappears into the ink, add more as needed to maintain a layer of excess water on the surface of the ink.

NOTE 4—Few specimens will take up more than 20 mL of water within a 1-min mixing interval. If a high-water pickup specimen is being run and the mixing interval is longer than 1 min, another 20 mL should be added prior to each subsequent minute of mixing time.

9.7 When the mixer stops, turn the power switch off. Detach the mixing blades and add to the bowl.

9.8 Remove the bowl from the turntable and, holding the blades at the side of the bowl, decant the free water into the beaker containing the unused water. Run the blades *very slowly* through the ink in the bowl. Decant additional free water into the beaker (see Note 2).

9.9 Weigh the mixing bowl and contents, including the blades.

9.10 Using a palette knife, transfer the ink from the walls to the center of the bowl. Return the bowl to the mixer. Replace the blades as in 8.4.

9.11 For the next mixing interval, swirl the beaker in order to mix the returned and unused water. Meter out 20 mL and add to the bowl. Press the counter reset (or change the counter) and turn the power on. Add more water if needed to maintain an excess layer (see Note 4).

9.12 When the mixer stops, repeat 9.7 through 9.11 until the cumulative mixing time totals at least 10 min.

9.13 *Optional*—At the end of the run, make measurements in accordance with 8.10.

9.14 Discard the ink left in the bowl. Clean the bowl and the mixer blades with tissue wetted with naphtha. Discard returned water and rinse the beaker clean.

9.15 Repeat 9.3 through 9.14 with another specimen of the same ink.

10. Calculation

10.1 Calculate water pickup, P, as follows:

10.1.1 *Test Method A—Volumetric:*

$$P = (V_1 - V_2) \times 2$$

where:

P = water pickup, % or mL water/100 g ink,
V_1 = volume of water added, mL, and
V_2 = volume of returned water, mL.

10.1.2 *Test Method B—Gravimetric:*

$$P = (W - S) \times 2$$

where:

P = water pickup, % or g water/100 g ink,
W = weight of the specimen plus water picked up after each mixing interval, g, and
S = weight of initial specimen, g.

NOTE 5—The conversion from water pickup of the ink to water content, C, of the emulsion is $C = P/(100 + P)$. Units are percent or grams of water per 100 grams of emulsion.

11. Report

11.1 Report the following information:

11.1.1 The percent water pickup to the nearest whole number as the mean of the two determinations, the cumulative mixing time, and a description of the water used for

testing (for example, tap water, deionized water, or type of fountain solution).

11.1.2 If rate of water pickup was determined, plot the percent of water pickup versus the cumulative mixing time.

11.1.3 *Optional*—The mean temperature, changes in pH, conductivity, appearance of the water, and the change in consistency of the ink.

12. Precision and Bias

12.1 *Precision:*

12.1.1 *Test Method A*—An interlaboratory study of single-point water pickup by Test Method A was conducted in which one operator in each of eleven laboratories tested in duplicate on each of two days three lithographic printing inks ranging in 5-min water pickup from 50 to 65 %. One company was found to be an outlier and was deleted from the analysis. The within laboratory pooled standard deviation was found to be 1.58 % absolute (millilitre of water per 100 grams of ink) at 9 degrees of freedom (df), and the between laboratories pooled standard deviation was 7.1 % absolute at 30 df. Based on these standard deviations, the following criteria should be used for judging the acceptability of results at the 95 % confidence level:

12.1.1.1 *Repeatability*—Two results, each the mean of two runs obtained by one operator, should be considered suspect if they differ by more than 4.5 % absolute.

12.1.1.2 *Reproducibility*—Two results, each the mean of two runs obtained by operators in different laboratories, should be considered suspect if they differ by more than 20 % absolute.

12.1.2 *Test Method B*—In an interlaboratory study of rate of water pickup by Test Method B, water pickup values at 2½, 5, 7½ and 10 min were determined twice on one day by one operator in each of nine laboratories on six inks. The inks ranged in water pickup from 40 to 52 % at 2½ min and from 65 to 100 % at 10 min. After rejecting 12 out of 156 replicated test values as outliers, the within laboratory pooled standard deviation was found to be 1.58 % absolute (grams of water per 100 grams ink) with 97 df and the between laboratory standard deviation 3.73 % absolute with 86 df. Based on these standard deviations, the following criteria should be used for judging the acceptability of results at the 95 % confidence level:

12.1.2.1 *Repeatability*—Repeatability cannot be determined as both runs were conducted on the same day.

12.1.2.2 *Reproducibility*—Two water pickup curves, each the mean of two runs, obtained by operators in different laboratories should be considered suspect if they differ by more than 10.5 % absolute.

12.2 *Bias*—Bias cannot be determined because there are no standard materials. The poorer interlaboratory precision of Test Method A compared to Test Method B is believed to be caused by the fact that the gross quantity of water added at one time is picked up as large globules which make it difficult for different operators to release free water in the same manner.

13. Keywords

13.1 lithographic printing inks; printing inks; inks; vehicles; water pickup; water content; emulsification; fountain solution; mixers

Designation: D 4946 - 89ε1

Standard Test Method for Blocking Resistance of Architectural Paints[1]

This standard is issued under the fixed designation D 4946; 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.

ε1 NOTE—Paragraphs 6.5, 7.2, and 7.5 were editorially corrected in October 1990.

1. Scope

1.1 This test method describes an accelerated procedure for evaluating the face-to-face blocking resistance of trades sales paints. This is not to be confused with blocking resistance Test Method D 3003 which is concerned with blocking of industrial coatings on metal substrates, nor with Test Method D 2793 which is concerned specifically with wood product finishes and reports results on a satisfactory or not satisfactory basis, rather than by the degree of blocking tendency as in this test method.

1.2 *This standard may involve hazardous materials, operations, and equipment. This standard does not purport to address all of the safety problems 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 2793 Test Method for Block Resistance of Organic Coatings on Wood Substrates[2]

D 3003 Test Method for Pressure Mottling and Blocking Resistance of Organic Coatings on Metal Substrates[2]

3. Terminology

3.1 *Definition:*

3.1.1 *blocking*—The undesirable sticking together of two painted surfaces when pressed together or placed in contact with each other for an extended period of time.

4. Summary of Test Method

4.1 Dried paint films are placed face-to-face and a pressure of about 1.8 psi (127 g/cm^2) is applied. These paint films are put into an oven for 30 min to make the test more stringent. After cooling, the blocked panels are peeled apart. The degree of blocking is rated subjectively for tack or seal using a series of standard descriptive terms corresponding to numerical ASTM values of 10 to 0.

5. Significance and Use

5.1 Dry paint often comes in contact with itself especially in window and door areas and, depending on its hardness, the pressure, temperature, humidity, and duration of time the surfaces are in contact, sometimes sticks to itself (blocks). This stringent test method can be used to compare and rate subjectively the resistance of paints to blocking.

6. Apparatus

6.1 *Conditioned Room*, at 65 to 85°F (18 to 29.5°C) and 40 to 60 % relative humidity.

6.2 *Sealed Paper Test Charts*, approximately 7.5 by 11 in. (190 by 280 mm).[3]

6.3 *Applicator Blade*, 5 to 6 in. (13 to 15 cm) wide, 6 mil clearance.

6.4 *Oven*, 115 to 125°F (48 to 52°C).

6.5 *Rubber Stoppers*, No. 8, 1.25 in. (3.2 cm) smaller diameter.

6.6 *Weights*, 1000 g.

6.7 *Scissors.*

6.8 *Aluminum Tray or Pan*, flat.

7. Procedure

7.1 Cast the paint to be tested on a sealed test chart using the applicator blade. Condition coated panels in the conditioned room for seven days. All painted panels should be kept free of grease, oil, or fingerprints since these will affect block resistance.

7.2 After the panels have been conditioned, cut out six 1½ by 1½-in. (3.8 by 3.8-cm) sections from the painted chart. Start the cut at least ½ in. (1.3 cm) away from the edge of the drawdown.

7.3 Place the cut sections with the paint surfaces face-to-face for each paint to be tested.

7.4 The weights, stoppers, and tray should be temperature equilibrated in the oven prior to running the test.

7.5 Place the face-to-face specimens in the oven on a flat aluminum tray. Place a No. 8 stopper on top, with the small diameter in contact with the specimens, then place a 1000-g weight on top of the stopper. This results in a pressure of 1.8 psi (127 g/cm) on the specimens. One weight and stopper is to be used for each specimen to be tested. It is recommended that "pass" and "fail" paint controls be used in each test run and that the tests be run in triplicate.

7.6 After exactly 30 min, take the stoppers and weights off the test specimens and remove them from the oven. Allow them to cool for ½ h in the conditioned room before determining the block resistance.

---

[1] This test method is under the jurisdiction of ASTM Committee D-1 on Paint and Related Coatings and Materials and is the direct responsibility of Subcommittee D01.42 on Architectural Finishes.

Current edition approved May 26, 1989. Published July 1989.

[2] *Annual Book of ASTM Standards*, Vol 06.02.

[3] Form WB available from The Leneta Co., P.O. Box 86, Ho-Ho-Kus, NJ 07423 has been found satisfactory for this purpose.

7.7 After cooling, separate the specimens by peeling them apart with a slow and steady force at about 180° from each other forming a "*T*" pattern during beginning of the separation. It is necessary to put the specimen next to the ear while separating to actually hear the degree of tack. Rate for blocking resistance on a scale of 0 to 10 (see 8.2).

8. Interpretation of Results

8.1 Blocking resistance is rated on a scale of 10 to 0, which corresponds to a subjective tack (sound of separation when peeled) or seal (the complete sticking together) rating determined by the operator. This rating system is defined in 8.2 in the appropriate descriptive terms. The degree of seal is the estimated area on the specimens where the paint surfaces adhere and some of the paper tears away from the chart when peeled.

8.2 *Blocking Resistance Ratings:*

Blocking Resistance Numerical Ratings	Type of Separation	Performance
10	no tack	perfect
9	trace tack	excellent
8	very slight tack	very good
7	very slight to slight tack	good to very good
6	slight tack	good
5	moderate tack	fair
4	very tacky; no seal	poor to fair
3	5 to 25 % seal	poor
2	25 to 50 % seal	poor
1	50 to 75 % seal	very poor
0	75 to 100 % seal	very poor

9. Report

9.1 Report the blocking resistance rating determined in accordance with 8.2.

10. Precision

10.1 Data are unavailable for a conventional precision statement. However, based on actual laboratory experience, with experienced operators, the repeatability is estimated to be plus or minus one blocking resistance unit. Numerical values may differ from operator to operator but relative ranking should be about the same. As in many tests the precision improves with practice.

11. Keywords

11.1 blocking; blocking resistance; sticking; tack

Designation: D 4958 – 91

Standard Test Method for Comparison of the Brush Drag of Latex Paints[1]

This standard is issued under the fixed designation D 4958; 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 is a standardized brushout procedure for comparing the brush drag of architectural type latex paints.

1.2 With slight modifications this test method is also applicable to solvent paints.

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

2. Referenced Documents

2.1 *ASTM Standards:*

D 1475 Test Method for Density of Paint, Varnish, Lacquer and Related Products[2]

D 3924 Specification for Standard Environment for Conditioning and Testing Paint, Varnish, Lacquer and Related Materials[2]

D 3925 Practice for Sampling Liquid Paints and Related Pigmented Coatings[2]

D 4287 Test Method for High-Shear Viscosity Using the ICI Cone/Plate Viscometer[2]

3. Terminology

3.1 *Definitions*—See *Paint/Coatings Dictionary*[3] for definition of terms used in this test method.

3.1.1 *brush-drag*— resistance encountered when applying a coating by brush.

4. Summary of Test Method

4.1 A 2-in. (50-mm) polyester brush is used to apply the test paint on a 1.076-ft^2 (1000-cm^2) test area. The application is made at a spreading rate of 400 ft^2/gal (9.82 m^2/L) and is completed in 30 to 35 s. The degree of brush drag is rated subjectively using a series of standard descriptive terms corresponding to numerical values of 1 to 10. The rank order of a set of samples is thereby established.

5. Significance and Use

5.1 As the brush drag of a paint increases, any natural tendency on the part of the painter to overspread the paint is reduced. When all other factors are held constant, increased brush drag will result in greater film thickness with consequent improvement in durability and hiding. Conversely, sometimes it might be preferred to have a lesser degree of brush drag for easier application (that is, the amount of time and effort in applying a paint to a specific area is reduced with a lesser degree of brush drag).

5.2 This test method provides a standardized brushout procedure for the evaluation of brush drag as an alternative to customary informal ad hoc procedures. Its objective is to maximize the reliability and precision with which this characteristic may be determined.

NOTE 1—The brush drag of paints is directly related to their high-shear viscosity. There is generally good rank order agreement between results obtained by this method and Test Method D 4287. The sensitivity of this brushout method has been found sufficient to distinguish between brushabilities corresponding to high-shear viscosity differences not lower than 0.3 poise (0.03 Pa.s). Round robin data show that rank order agreement between the brushout and viscometric methods is poor when latex and solvent paints are part of the same comparison group. This is the result of these two paint types having markedly different rheological properties that affect the relative perception of brush drag.[4]

6. Apparatus

6.1 *Brush*, 2-in. (50-mm) polyester filament, 2¾-in. (70-mm) length-out, 9/16 in. (14 mm) thick, with a chiseled tip.

NOTE 2—All tests of a given series of paints, within or between laboratories, should be carried out with commercially identical brushes.

6.2 *Stopwatch.*

6.3 *Balance*, capable of weighing accurately to 0.1 g.

6.4 *Test charts*, with a sealed surface, having 1.076 ft^2 (1000 cm^2) of test area.[5]

7. Sampling and Conditioning

7.1 Sample in accordance with Practice D 3925.

7.2 Condition the samples in accordance with the Conditioning and Testing section of Specification D 3924.

7.3 All testing should be performed under the same conditions.

8. Procedure

8.1 Do not change operators during the running of a series of specimens, since this will invalidate any conclusions as to rank order.

8.2 Determine the density in pounds per gallon of the paint sample in accordance with Test Method D 1475.

---

[1] This test method is under the jurisdiction of ASTM Committee D-1 on Paint and Related Coatings and Materials and is the direct responsibility of Subcommittee D01.42 on Architectural Finishes.

Current edition approved Oct. 15, 1991. Published December 1991. Originally published as D 4958 – 89. Last previous edition D 4958 – 89.

[2] *Annual Book of ASTM Standards*, Vol 06.01.

[3] Available from Federation of Societies for Coatings Technology, 492 Norristown Rd., Blue Bell, PA 19422.

[4] Supoporting data are available from ASTM Headquarters. Request RR: D01-1072.

[5] Leneta Form 8H-BW, obtainable from The Leneta Co., P.O. Box 86, Ho-Ho-Kus, NJ 07423, has been found satisfactory for this purpose.

8.3 Multiply the density by 1.221 to obtain the weight of paint in grams to apply on the specified test chart to obtain a spreading rate of 400 ft^2/gal (9.82 m^2/L).

8.4 *Conditioning of the Brush:*

8.4.1 Soak the brush in clean water, then spin rapidly to remove the water from the bristles as completely as possible.

8.4.2 In order to equalize the amount of paint contained on the brush, dip the brush into the can to take up a normal brush load and paint out approximately ½ ft^2 (0.05 m^2) of a reasonably well sealed surface (for example, any previously painted test chart).

8.4.3 Repeat 8.4.2 utilizing another dry surface.

8.5 Place the test chart on the balance and weigh the correct amount of paint as calculated in 8.3 directly onto the center of the card.

8.6 Immediately tape the card onto a hard, flat surface, start the stopwatch, and proceed to spread the paint using the previously conditioned 2-in. (50-mm) brush. Using long, steady brush strokes, alternately parallel and perpendicular to the edge of the chart, cover the test area uniformly and completely in 30 to 35 s.

8.7 Immediately assign and record a brush drag rating according to the following series of qualitative descriptive terms, first characterizing it by a verbal description, and then by the corresponding number.

1—Very slight
2—Slight
3—Slight to moderate
4—Moderate
5—Moderate to considerable
6—Considerable
7—Considerable to pronounced
8—Pronounced
9—Very pronounced
10—Extreme

8.8 Thoroughly clean the brush with warm water and spin it to remove excess water between tests.

8.9 Repeat 8.2 through 8.8 for each specimen in the set and rate the specimen as the mean of the two results.

8.10 If more than one specimen has the same rating, brush out the similarly rated specimens again, in close comparison. If small differences are perceived, then indicate these by assigning intermediate decimal values. If no difference is found then the original ratings stand.

9. Interpretation of Results

9.1 Tabulate the paints in order of their brush drag ratings, showing verbal descriptions and numerical ratings in separate columns.

9.2 In a fourth rank order column, rank the paints from 1 to *n* (least to most brush drag), where *n* is the total number of paints in the series.

9.3 Paints with the same qualitative ratings should be assigned multiple rank numbers, with the mean of those numbers shown in parentheses, for example, 3 to 4 (3.5), 5 to 7 (6). The mean ranking value (in parentheses) is used to calculate an average ranking value when the same series of paints is ranked by more than one operator.

10. Report

10.1 Report the brush drag ranking as determined in Section 9.

11. Precision and Bias

11.1 In an interlaboratory study of this test method in which five coatings varying widely in brush drag were ranked by one operator in each of nine laboratories, two operators in one laboratory, and three operators in another laboratory, the coefficient of concordance (agreement in ranking) was found to be 0.84, reflecting the fact that seven of the fourteen operators agreed perfectly and four others reversed one of two adjacent pairs. The coefficient is statistically significant at the 99.9 % confidence level.

11.2 Bias has not been determined for this test method.

12. Keywords

12.1 brush drag; high shear viscosity; brushability; ease of brushing; drag

Designation: D 4960 – 89

Standard Test Method for Evaluation of Color for Thermoplastic Traffic Marking Materials[1]

This standard is issued under the fixed designation D 4960; 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 the instrumental determination of color of thermoplastic traffic marking materials in the CIE 1931 system.

1.2 *This standard may involve hazardous materials, operations, and equipment. This standard does not purport to address all of the safety problems 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 883 Terminology Relating to Plastics[2]

E 97 Test Method for Directional Reflectance Factor, 45-Deg 0-Deg, of Opaque Specimens by Broad-Band Filter Reflectometry[3]

E 179 Practice for Selection of Geometric Conditions for Measurement of Reflectance and Transmission Properties of Materials[3]

E 284 Terminology of Appearance[3]

E 308 Test Method for Computing the Colors of Objects by Using the CIE System[3]

E 1164 Practice for Obtaining Spectrophotometric Data for Object-Color Evaluation[3]

F 412 Terminology Relating to Plastic Piping Systems[4]

3. Terminology

3.1 *Definitions*—Definitions are in accordance with Terminology D 883, E 284 and F 412, unless otherwise indicated.

3.2 *Descriptions of Terms Specific to This Standard:*

3.2.1 *thermochromism*—a color hue change that takes place in the thermoplastic material due to temperature changes.

3.2.2 *thermoplastic traffic marking material*—a highly filled 100 % total solids highway marking material that when heated to a molten state can be extruded or sprayed onto a road surface and when cooled forms a solid, durable delineator.

4. Summary of Test Method

4.1 The thermoplastic specimen is prepared for this test by melting a sample to its application temperature under continuous agitation and then pouring it into a TFE-fluorocarbon coated pan, to form a patty of approximately 3 in. (7.6 cm) in diameter. The patty is allowed to cool to room temperature before measuring the color. Color measurements are made on the flat side or the top side of the thermoplastic patty.

NOTE 1—No significant color differences are encountered in reading the top or bottom of the patty.

5. Significance and Use

5.1 This test method provides a standard procedure for the determination of color of thermoplastic traffic marking materials. This test method can be used in conjunction with specifications to determine the uniformity of thermoplastic traffic marking materials from batch to batch and that produced by various suppliers.

5.2 There is a slight variation in color standards and colorimeters. This test method is only applicable when results are reported with the instrument model designation and white color calibration standard identification information.

6. Sampling

6.1 Samples may be obtained by an appropriate quartering or riffle sampling method where deemed necessary considering the physical form of the material.

7. Apparatus

7.1 *Agitator Blade*, 6 in. (15 cm) long with a ½-in. (1-cm) steel shaft and a 1¾ by 1 by ⅛-in. (4.5 by 2.5 by 0.3-cm) straight horizontal steel blade.

7.2 *Drill Press*, or other apparatus capable of agitating the thermoplastic marking material in the electric pots at 600 to 700 r/min during meltdown to the application temperature.

7.3 *Heating Equipment:*

7.3.1 *Gravity Convection Oven*, capable of maintaining 260°C, for melting the thermoplastic traffic marking.

7.3.2 *Hot Plate*, capable of maintaining 537°C.

7.3.3 *Insulated Electric Pots*, for heating and melting the thermoplastic traffic marking materials.

7.4 *Color Measuring Instrument*, conforming to all requirements of Test Method E 97, Practices E 179 and E 1164, and Method E 308 (geometry 45°/0°, illuminant C, 2° observer).

7.5 *Spatulas*, for stirring the thermoplastic traffic marking

---

[1] This test method is under the jurisdiction of ASTM Committee D-1 on Paint and Related Coatings and Materials and is under the direct responsibility of Subcommittee D01.44 on Traffic Coatings.

Current edition approved June 30, 1989. Published August 1989.

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

[3] *Annual Book of ASTM Standards*, Vol 06.01.

[4] *Annual Book of ASTM Standards*, Vol 08.04.

during meltdown on the hot plate or in the gravity convection oven.

7.6 *TFE-fluorocarbon Baking Pans or Uncoated Pint Can Lids*, for forming 3-in. (7.6-cm) diameter patties.

8. Procedure

8.1 Taking care to prevent scorching of the material, melt a 1000 ± 50-g sample of the thermoplastic marking material to a temperature of 218°C under continuous agitation, by one of the following means:

8.1.1 On a hot plate set at 537°C and using a spatula as the means of agitation.

8.1.2 In an insulated electric pot with a heat setting sufficient to reach the test temperature and with agitation of 600 to 700 r/min from an electric drill press or other suitable means.

8.1.3 In an oven set at 260°C with agitation by stirring with a spatula after the first 15 min and thereafter at 15-min intervals. The first stirring at 15 min is critical to prevent scorching of the thermoplastic marking material. The sample must be completely wet in on the first stir to ensure even melting and complete blending of the components of the thermoplastic material.

8.2 Pour the thermoplastic sample into a clean, TFE-fluorocarbon-lined pan, to form a 3-in. (7.6-cm) diameter patty. If a TFE-fluorocarbon pan is not available, pour the sample into an uncoated pint tin lid to form a 3-in. diameter patty. Before pouring the patty, the sample must be agitated well to prevent settling of the components and to provide a smooth homogeneous surface for color measurement.

8.3 Allow the patty to cool to room temperature for a minimum of 30 min and not to exceed 45 min.

NOTE 2—A 30 ± 5-min conditioning of the patty negates the initial effects of thermochromism.

8.4 Calibrate the color measuring instrument with a white calibration color standard according to the instructions supplied by the manufacturer.

8.5 Remove the patty from the TFE-fluorocarbon pan and read the color measurement values from the flat smooth side. If a pint tin lid is used then read the top of the patty. Without removing the patty from the sample port immediately take three readings. Record only the third reading for each Y, x, and y value to further compensate for any thermochromism of the thermoplastic marking material.

8.6 A small port adapter, if available, for the color measuring instrument of approximately 3/4 in. (19 mm) may be used to negate the effects of geometry and texture when reading the patties. This will measure in between small surface imperfections characteristic of thermoplastic traffic marking.

9. Report

9.1 Report the following information:

9.1.1 The formula code, batch number, formula type, and color for each patty read,

9.1.2 The type of color measuring instrument used and the identification of the white color calibration standard, and

9.1.3 The exact cooling period and values Y, x and y for each sample.

10. Precision and Bias

10.1 No general statement of precision can be made because of lack of sufficient data at this time.

10.2 No statement of bias can be prepared for this test method since there is no absolute test method for use as a comparative basis.

11. Keywords

11.1 thermoplastic traffic marking; color measurement.

Designation: D 5007 - 89

Standard Test Method for Wet-to-Dry Hiding Change[1]

This standard is issued under the fixed designation D 5007; 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 the determination of the change in hiding power of an architectural coating during drying, by visual evaluation of the wet and dry film.

1.2 This test method is not recommended for colors other than white and tints.

1.3 *This standard may involve hazardous materials, operations, and equipment. This standard does not purport to address all of the safety problems 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 2805 Test Method for Hiding Power of Paints by Reflectometry[2]

D 3924 Specification for Standard Environment for Conditioning and Testing Paint, Varnish, Lacquer, and Related Materials[2]

3. Terminology

3.1 *Descriptions of Terms Specific to This Standard:*

3.1.1 *hiding index, h_S*—the Spreading Index at a standard film opacity. In this test method the latter is a visual contrast standard prepared by applying a semi-opaque white coating on a black and white hiding-power chart to give a contrast ratio of 0.98 which is just short of complete hiding, and is the conventional so-called *full hiding* end point in photometric hiding-power methods such as Test Method D 2805. Refer to the hiding indices of the wet and dry films as h_{SW} and h_{SD} respectively.

3.1.1.1 *Discussion*—Since this test method is intended to measure hiding-power difference rather than hiding power itself, a 98 % contrast ratio standard is not required. It is necessary only that the same standard be used for measuring both wet and dry films. See 3.1.8.1. For this purpose the standard needs to lie within the contrast range of both the wet and dry stripes, which will be true of the 98 % contrast-ratio standard for most commercial paints. With paints of unusually low hiding, a lower contrast standard may be required, which can be simply one of the stripes taken from a drawdown of the test paint.

3.1.2 *hiding power*—the spreading rate of a paint applied uniformly on a standard black and white hiding power chart to give a standard degree of contrast just short of complete hiding.

3.1.2.1 *Discussion*—In reflectometry the standard contrast for hiding power measurements is generally accepted as the contrast ratio $C = 0.98$, which with white and light tinted coatings is equivalent to a visual color difference of about 0.75 CIELAB units. That amount of color difference can reasonably be described as "just-short-of complete-hiding." Since this is a visual method it employs a visual comparator as a standard, which is a hiding power chart with a white coating applied at a contrast ratio of 0.98.

3.1.3 *logicator*—a multi-notch applicator with clearances, and corresponding wet film thicknesses and spreading rates, in equal percentage steps.

3.1.4 *logicator scale*—a scale whose values are in direct, linear relationship with the logarithms of corresponding spreading rates. A specified change in scale value represents the same percentage change in spreading rate over any part of such a scale.

3.1.5 *spreading index, h*—the spreading rate expressed in logicator scale units (LU) as described in 3.1.4 and 4.1.7.

3.1.6 *spreading rate, H*—the area covered per unit quantity of coating. (In this test method the quantity is volumetric).

3.1.7 *TG19 logicator*—a logicator designed for this test method with eight notches numbered at four-unit intervals on a scale from 20 to 48, the notch clearances ranging from 2.65 to 10.4 mils (67 to 264 μm) corresponding to wet film thicknesses from 1.46 to 5.7 mils (37 to 145 μm) and spreading rates from 280 to 1100 ft^2/gal (6.9 to 27 m^2/L), with one scale unit representing a change of 5 % and the four-unit interval between notches a cumulative change of 21.55 % in the clearance and corresponding film thicknesses and spreading rates. Refer to this scale unit as a logicator unit (LU). (See Fig. 1.)

3.1.7.1 *Discussion*—The percentage difference between notches is calculated as $(1.05^4 - 1) \times 100 = 21.55$. This percentage is applicable precisely to the notch clearances and approximately to their related wet-film thicknesses and spreading rates. The detailed relationships between scalar value and the notch clearance, wet film thickness, and spreading rate are given in Tables 1 and 2.

3.1.8 *wet-to-dry hiding change* (WDHC)—the difference in the Hiding Index of a paint between the wet and the dry state, expressed in logicator units (LU) as follows:

$$\text{WDHC} = \Delta h_S = h_{SD} - h_{SW}$$

3.1.8.1 *Discussion*—The WDHC is unchanged if the contrast level of the hiding standard is varied, because the resultant changes in the two hiding power values will be proportional and their ratio therefore constant.

[1] This test method is under the jurisdiction of ASTM Committee D-1 on Paint and Related Coatings and Materials and is the direct responsibility of Subcommittee D01.42 on Architectural Finishes.

Current edition approved October 27, 1989. Published December 1989.

[2] *Annual Book of ASTM Standards*, Vol 06.01.

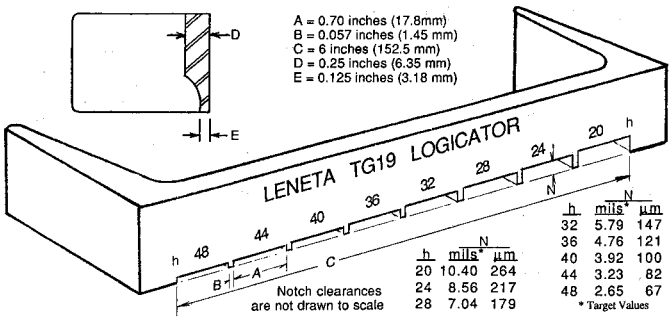


FIG. 1 Diagram of the Leneta TG19 Logicator

3.1.8.2 *Discussion*—The WDHC is unaffected by deviations from the estimated film thickness/clearance ratio T/N (see Note, Table 1), because the ratio of the two recalculated hiding-power values is unchanged.

4. Summary of Test Method

4.1 The test paint is applied with a TG19 Logicator on a logicator test chart (see 6.2 and Fig. 2) and the drawdown examined in comparison with an agreed hiding standard immediately after application and again after drying.

4.2 The scale numbers of the wet and dry stripes that match the standard in contrast are recorded as the Wet Hiding Index, h_{SW}, and the Dry Hiding Index h_{SD}.

4.3 The difference between the wet and dry hiding indices is recorded as the wet-to-dry hiding change WDHC.

4.4 If desired, the percent change in hiding power corresponding to the WDHC value is calculated and reported.

5. Significance and Use

5.1 Many architectural paints, particularly white and light tints, change significantly in film opacity as they dry. An increase in hiding is sometimes associated with porosity and poor film integrity with conventionally formulated coatings. A decrease can result in a disappointing paint job. The wet-to-dry hiding change is therefore a property of great practical importance.

5.2 This test method can be used in paint specifications and as a short, simple procedure for evaluation and quality control.

6. Apparatus

6.1 *TG19 Logicator*[3]—A multi-notch, varied-clearance applicator designed specifically for this test method (see 3.1.7 and Fig. 1).

6.2 *Logicator Test Charts*[3]—Black and white hiding charts with a chevron-stripe pattern and scale numbers printed at the top corresponding to the paint stripes applied by the Logicator (see Fig. 2).

6.3 *Vacuum Plate*, for holding the chart flat while the drawdown is made.

6.4 *Visual Hiding Standard*[4]—A narrow stripe cut from a logicator test chart on which a durable glossy white coating had been applied to obtain a contrast ratio of 0.98. The stripe is mounted on a blank card for convenient handling, as illustrated in Fig. 3.

TABLE 1 Equations Relating the Logicator Scale Value or Spreading Index, *h*, to the Notch Clearance, *N*, Wet Film Thickness, *T*, and Spreading Rate, *H*

NOTE—The relationships involving T and H are based on a presumed T/N ratio of 0.55, which ratio is approximate and somewhat variable, depending on coating rheology, drawdown technique, and clearance.

Inch-Pound Units (mils, ft^2/gal):	*Metric Units* (μm, m^2/L):
$N = 1.05^{68-h} = 27.6 \div 1.05^h$	$N = 25.4 \times 1.05^{68-h} = 701 \div 1.05^h$
$h = 68 - 47.2 \log N$	$h = 134.3 - 47.2 \log N$
$T = 0.55\ N = 15.18 \div 1.05^h$	$T = 0.55\ N = 385.5 \div 1.05^h$
$h = 55.75 - 47.2 \log T$	$h = 122.05 - 47.2 \log T$
$H = 105.7 \times 1.05^h$	$H = 2.594 \times 1.05^h$
$h = 47.2 \log H - 95.52$	$h = 47.2 \log H - 19.54$

7. Procedure

7.1 Prepare a hiding standard as described in 6.4, or use the standard supplied with the logicator test charts.

NOTE 1—Strong colors were measured according to this test method using standards prepared with the self-same coatings. Some measurements were also made using the regular white standard. Due to poor correlation in these tests it was decided to exclude strong colors from the scope of the test method. However, should measurements with such colors be attempted anyway, it is of interest to note that the white standard apparently served as well for that purpose as a standard made with the identical color.

7.2 Place a test chart on the vacuum plate. Then place the logicator at the top of the chart with its arms extending toward the operator.

7.3 Spread about 6 mL of the test paint evenly in front of the logicator, then draw down the full length of the chart (about 10 in. (254 mm)) at a uniform speed such that the total drawdown time is about 2.5 to 3 s.

7.4 Promptly after film application, determine the Wet Hiding Index (h_{SW}) in accordance with 7.5.

7.5 *Observation of the Hiding Index (h_s):*

7.5.1 Place the chart vertically in a well-illuminated glare-free location.

7.5.2 Hold the hiding standard next to the chart and identify by number the stripe that the standard matches in contrast. This number is the Hiding Index.

7.5.3 If there is no exact match and it is difficult to decide which of two adjacent stripes is matched more closely, record their mean as the Hiding Index. However, if the standard is perceived as closer to one or the other of the two stripes, then report the Hiding Index as one more than the lower or one less than the higher, as the case may be.

7.6 Immediately after determining the Wet Hiding Index (h_{SW}), place the drawdown horizontally in a well-ventilated, dust-free location, as specified in Specification D 3924, and allow to dry for 40 to 48 h. Then repeat 7.5 to determine the Dry Hiding Index (h_{SD}).

7.7 Make drawdowns in triplicate and calculate the mean index value to 0.1 units. Individual values that deviate from the mean by more than 1.5 units should be discarded and the test repeated.

8. Calculation

8.1 Subtract the Wet Hiding Index, h_{SW} from the Dry

[3] Available from The Leneta Company, P.O. Box 86, Ho-Ho-Kus, NJ 07423.

[4] A white standard of this description is supplied with the TG19 Logicator Test Charts.

TABLE 2 Logicator Scale Relationships Calculated from Equations in Table 1

Index[A]	Clearance		Film Thickness[C]		Spreading Rate[C]		Index[A]	Clearance		Film Thickness[C]		Spreading Rate[C]	
h	mils[B]	μm	mils	μm	ft²/gal	m²/L	*h*	mils[B]	μm	mils	μm	ft²/gal	m²/L
20	**10.40**	**264**	**5.72**	**145**	**280**	**6.88**	**36**	**4.76**	**121**	**2.62**	**67**	**612**	**15.0**
21	9.90	252	5.44	138	294	7.23	37	4.54	115	2.50	63	643	15.8
22	9.43	240	5.19	132	309	7.59	38	4.32	110	2.38	60	675	16.6
23	8.98	228	4.94	126	325	7.97	39	4.12	105	2.26	58	709	17.4
24	**8.56**	**217**	**4.71**	**120**	**341**	**8.37**	**40**	**3.92**	**100**	**2.16**	**55**	**744**	**18.3**
25	8.15	207	4.48	114	358	8.78	41	3.73	95	2.05	52	781	19.2
26	7.76	197	4.27	108	376	9.22	42	3.56	90	1.96	50	820	20.1
27	7.39	188	4.07	103	395	9.68	43	3.38	86	1.86	47	861	21.1
28	**7.04**	**179**	**3.87**	**98**	**414**	**10.2**	**44**	**3.23**	**82**	**1.77**	**45**	**904**	**22.2**
29	6.70	170	3.69	94	435	10.7	45	3.07	78	1.69	43	950	23.3
30	6.38	162	3.51	89	457	11.2	46	2.93	74	1.61	41	997	24.5
31	6.08	154	3.34	85	480	11.8	47	2.79	71	1.53	39	1047	25.7
32	**5.79**	**147**	**3.19**	**81**	**504**	**12.4**	**48**	**2.65**	**67**	**1.46**	**37**	**1100**	**27.0**
33	5.52	140	3.03	77	529	13.0							
34	5.25	133	2.89	73	555	13.6							
35	5.00	127	2.75	70	583	14.3							

[A] Boldface values refer to notches in TG19 Logicator.
[B] Target values are significant to one decimal place.
[C] Based on wet film thickness estimated at 55 % of clearance.

Hiding Index, h_{SD} to obtain the wet-to-dry hiding change (WDHC), Δh_S, as follows:

$$\text{WDHC} = \Delta h_S = h_{SD} - h_{SW}$$

The value for WDHC is positive for an increase and negative for a decrease in hiding. To avoid possible misunderstanding write the sign of the change (+ or −) *in every case.*

8.2 If desired, calculate the corresponding percent change in wet-to-dry hiding power as follows:

$$\text{WDHC\%} = (1.05^{\text{WDHC}} - 1) \times 100$$

9. Report

9.1 Report the following information:

9.1.1 The Wet-to-Dry Hiding Change (WDHC) in logicator units (LU) to one decimal place, as described in 8.1, and

9.2 If desired, the percent change in conventional hiding power (WDHC%), calculated as shown in 8.2.

10. Precision and Bias

10.1 In an interlaboratory study of this test method, two operators in each of two laboratories and one operator in each of six laboratories, tested in triplicate five coatings with a wide range in wet-to-dry hiding change. Since the test was not repeated the repeatability data is only for replicates. On this basis the intralaboratory standard deviation was 0.77 LU with 85 df and the interlaboratory standard deviation was 1.97 LU with 39 df. Based on these standard deviations the following criteria should be used for judging the acceptability of results at the 95 % confidence level:

10.1.1 *Repeatability (Replicate)*—Three replicates by the same operator should be considered suspect if they differ by more than 2.6 LU.

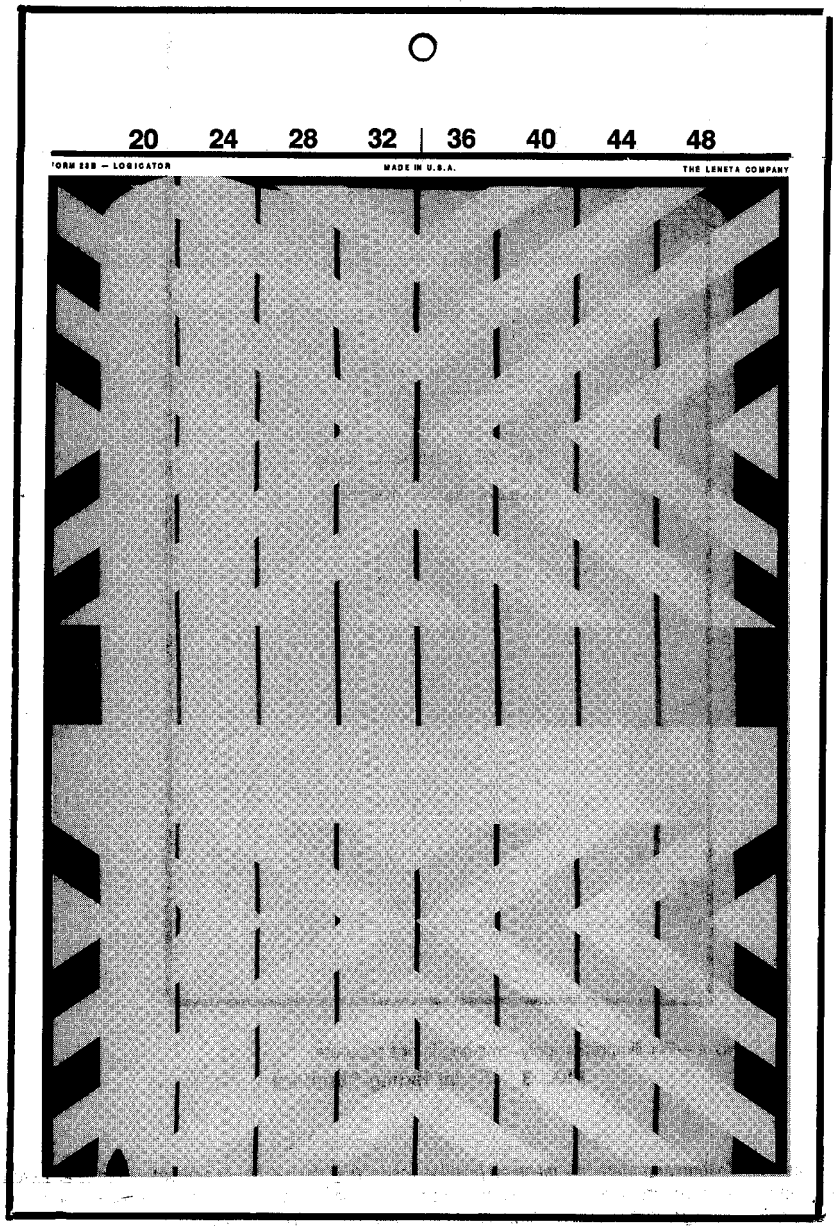
10.1.2 *Reproducibility*—Two results, each the mean of triplicates, obtained by different operators should be considered suspect if they differ by more than 5.7 LU.

10.2 *Bias*—This test method has no bias because there is no criterion for the property it measures more valid than the test method itself.

NOTE 2—In the statistical analysis results were discarded on the following basis: (*1*) all results from one operator who appeared to be less sensitive than the other operators in detecting differences among triplicates, (*2*) one replicate result from one laboratory because the triplicate range was significantly higher than for other laboratories, and (*3*) all three results from the same laboratory for another paint, because the mean differed significantly from other means for that paint.

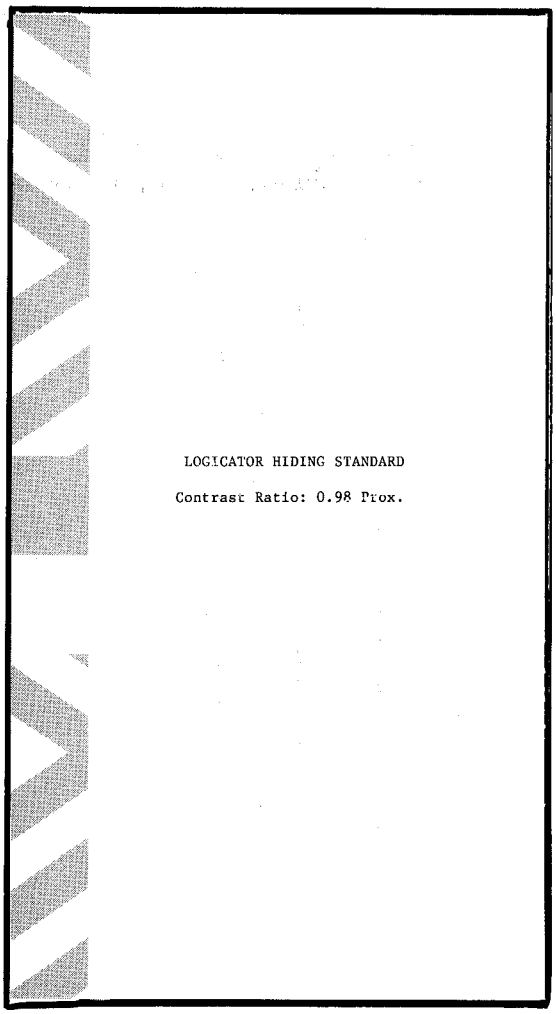
11. Keywords

11.1 hiding power; wet-to-dry hiding change



NOTE—For illustration only. Shading is not accurate.

FIG. 2 Logicator Test Application



NOTE—For illustration only. Shading is not accurate.

FIG. 3 Visual Hiding Standard

Designation: D 5009 – 89

Standard Test Method for Evaluating and Comparing Transfer Efficiency Under Laboratory Conditions[1]

This standard is issued under the fixed designation D 5009; 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 the evaluation and comparison of the transfer efficiency of spray-applied coatings under controlled laboratory conditions.

1.2 This test method has been shown to yield excellent intralaboratory reproducibility. Interlaboratory precision is poorer and is highly dependent on closely controlled air flow in the spray booth, the rate at which the paint is delivered to the part, and other variables suggested in the test method.

1.3 *Limitations:*

1.3.1 This laboratory procedure only indicates the direction of the effect of spray variables on transfer efficiency. The magnitude of the effect is determined only by specific plant experience.

NOTE 1—This laboratory procedure requires specific equipment and procedures. For those laboratories that do not have access to the type of equipment required a more general laboratory procedure is being prepared as Procedure B.

1.4 *This standard may involve hazardous materials, operations, and equipment. This standard does not purport to address all of the safety problems associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.* For specific hazard statements, see Section 7 and Notes 2 and 3.

2. Referenced Documents

2.1 *ASTM Standards:*

D 1200 Test Method for Viscosity by Ford Viscosity Cup[2]

D 2369 Test Method for Volatile Content of Coatings[2]

D 3925 Practice for Sampling Liquid Paints and Related Pigmented Coatings[2]

2.2 *National Fire Protection Association Documents*[3]

NFPA 33 Spray Application Using Flammable and Combustible Materials

NFPA 86 Standard for Ovens and Furnaces

3. Terminology

3.1 *Descriptions of Terms Specific to This Standard:*

3.1.1 *conveyor speed*—the speed of the conveyor in centimeters per minute during the test.

3.1.2 *fluid mass flow rate*—the mass flow rate of paint in grams per minute during the test.

3.1.3 *mass of foil*—the weight of each target foil in grams before being painted.

3.1.4 *mass of foil plus paint solids*—the weight of each target foil in grams after being painted and baked.

3.1.5 *mass of paint solids*—the difference in the mass of the foils before painting and the mass of the foils after painting and baking. This is the sum of the mass of the foil plus paint solids less the sum of the mass of the foil.

3.1.6 *transfer efficiency*—the ratio of the mass of the paint solids deposited on the foil to the mass of the paint solids sprayed during the test expressed as a percent.

3.1.7 *weight percent solids*—the solids content in percent of the total weight of a sample of the paint used during the test.

4. Summary of Test Method

4.1 Metal panels covered with preweighed aluminum foil are conveyed in a spraybooth past a fixed spraygun. The coated foils are then baked to remove volatile matter. The transfer efficiency is calculated on a weight basis using the solids content and quantity of the paint sprayed and the amount of solids on the coated aluminum foil target.

5. Significance and Use

5.1 Subject to the limitations listed above, the procedure can be used as a research tool to optimize spray equipment and paint formulations as well as to study the relative effect on transfer efficiency of changing operating variables, spray application equipment, and types of coatings.

6. Apparatus

6.1 *Laboratory Scale*, accurate to ±0.001 g for weight percent solids determination.

6.2 *Platform Scale*, accurate, or equivalent, to ±0.01 g for mass of foil, mass of foil plus paint, and mass flow rate instrumentation calibration.

6.3 *Mass Flow Rate Meter*, or mass flow rate determination method, accurate to ±2 % of the mass flow rate to be used during the test.

6.4 *Conveyor Timer* or conveyor timing method, accurate to ±1 % of the conveyor speed to be used during the test. The equipment may consist of photoelectric cells or limit switches used in conjunction with a digital timer or timing marks on the conveyor used in conjunction with a stopwatch. Take at least two readings with a stopwatch and average the readings.

6.5 *Targets*, consisting of a set of ten steel panels 6 in. (15.2 cm) wide by 0.0625 in. (0.15875 cm) with 0.25-in.

[1] This test method is under the jurisdiction of ASTM Committee D-1 on Paint and Related Coatings and Materials and is the direct responsibility of Subcommittee D01.55 on Factory-Applied Coatings on Preformed Products.

Current edition approved October 27, 1989. Published December 1989.

[2] *Annual Book of ASTM Standards*, Vol 06.01.

[3] Available from National Fire Protection Assn., Battery March Park, Quincy, MA 02269.

(0.635-cm) radius corners. A minimum panel length of 48 in. (121.9 cm) should be used. The length of the panel should be set so that a minimum of 12 in. (30.4 cm) above and below the spray pattern is achieved.

6.5.1 It is essential to do this so that the entire height of the spray pattern is effectively captured.

6.6 *Aluminum Foil*, medium temper or equivalent, 1.5 mil (0.0037 cm) thick.

6.7 *Back-Draw Water Wash Spray Booth*, or equivalent. The booth should be a minimum of 6 ft (1.8 m) wide and capable of up to 120 ft/min (0.61 m/s) air velocity in the middle at the plane of the target. If a dry filter booth is used, filters should be changed as necessary to maintain uniform air velocity.

6.8 *Adjustable Rate Overhead Conveyor System*, capable of hanging targets as specified, and capable of up to 40 ft/min (0.20 m/s) or the maximum speed desired by the user.

6.9 *Forced Draft Curing Oven*, of sufficient size for curing targets, and capable of achieving and maintaining the cure temperatures specified by the paint supplier. All ovens should conform to NFPA 86.

6.10 *Curing Rack.*

6.11 *Stopwatch.*

6.12 *Air Velocity Measurement Equipment.*

6.13 *Humidity and Temperature Measurement Equipment.*

6.14 *Compressed Air Supply.*

7. Hazards

7.1 For specific hazard information and guidance, consult the supplier's Material Safety Data Sheet (MSDS) for the materials used.

8. Procedure

8.1 Set up the spray apparatus paint supply and the mass flow measurement equipment in accordance with the manufacturer's instructions.

8.1.1 In accordance with Chapter 9-11 of NFPA 33, all electrically conductive objects in the spray area, except those objects required by the process to be at high voltage, shall be adequately grounded.

8.2 Agitate paint in a closed container at least 30 min before any paint samples are taken.

8.3 Using an airtight container take a paint grab sample from the paint pot in accordance with Practice D 3925.

8.4 Determine and record the following from the paint sample:

8.4.1 Viscosity determined in accordance with Test Method D 1200.

8.4.2 Weight percent solids determined in accordance with Test Method D 2369. If the baking temperature in Test Method D 2369 is inadequate, use the manufacturers recommended cure schedule.

8.4.3 Resistivity for the samples being applied electrostatically (An ASTM method is under development).

8.5 Set up the conveyor speed measuring equipment.

8.6 Cut the aluminum foil to dimensions of 15 in. (38 cm) by approximately 50 in. (127 cm) or 2 in. (5 cm) longer than the length of the target panel.

8.7 Consecutively number each precut foil strip before weighing using a permanent marking pen.

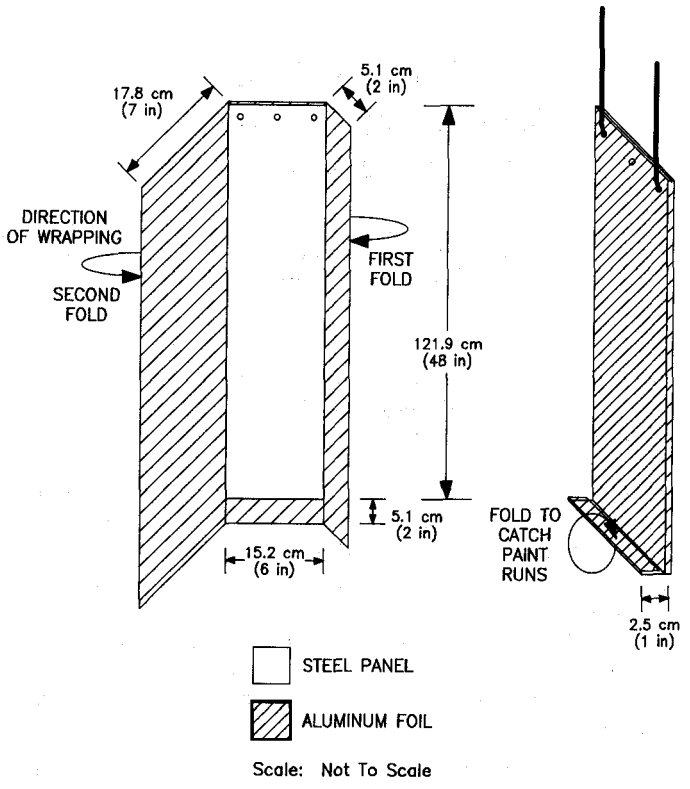


FIG. 1 Foil Attachment Technique

8.8 Weigh each test foil strip and record the uncoated weight and the foil number.

8.9 Attach the preweighed, labeled test foil to six targets using the technique shown in Fig. 1. Attach the unlabeled foil on four scavenger targets as shown in Fig. 1.

8.10 Mount the foil covered targets in consecutive order as shown in Fig. 2, with the foil seam on each target facing away from the spray gun.

8.10.1 If electrostatic equipment is being used the resistance shall be less than 1 by 10^6 Ω between the target and the earth ground in accordance with Chapter 9-8 of NFPA 33.

8.11 Adjust the following equipment operating parameters to the values desired for testing:

8.11.1 Paint fluid pressure (kilopascals) at spray gun.

8.11.2 Atomizing air pressure (kilopascals) at spray gun.

8.11.3 Rotating atomizer head speed (revolutions per minute) with and without paint fluid flow.

8.11.4 Operating voltage (kilovolts) if electrostatic equipment is used.

8.11.5 Ambient air temperature (degree Celsius).

8.11.6 Paint fluid temperature (degree Celsius).

8.11.7 Booth air velocity (feet per minute).

8.11.8 Relative humidity (percent).

8.11.9 Spray gun to target distance (centimeters).

NOTE 2: **Precaution**—If electrostatic equipment is being used, the gun-to-target distance shall be at least twice the sparking distance in accordance with Chapter 9-7 of NFPA 33.

8.11.10 Conveyor speed (centimeters per second).

8.11.11 Fluid mass flow rate (grams per minute).

8.11.12 Set the cure time and temperature in accordance with the manufacturer's instructions.

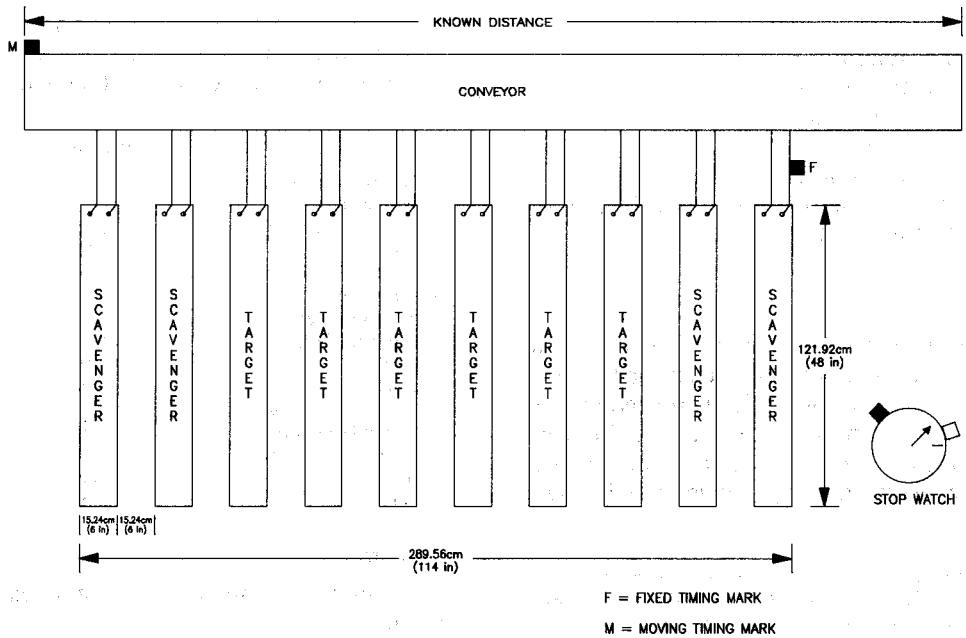


FIG. 2 Target Configuration for Transfer Efficiency Determination

8.12 For electrostatic spray equipment, measure the operating voltage and adjust it according to the manufacturer's instructions.

8.13 Turn on the spray booth and conveyor. At least 15 s before the first scavenger target passes in front of the gun, turn on the paint spray equipment. Maintain uniform paint flow during the test.

8.13.1 If mass flow measurement is used, begin the flow measurement at the leading edge of the first scavenger target and stop the mass flow measurement at the trailing edge of the last scavenger target.

8.13.2 If mass flow measurement equipment is not available use the following technique. Just before turning on the spray booth and the conveyor, spray the gun into a preweighed covered plastic container for a minimum of 30 s.

NOTE 3: **Precaution**—In addition to other precautions, turn off all high voltage to electrostatic spray guns to prevent personal injury.

8.13.3 Immediately weigh the container with paint, calculate the flow rate, and record the result. Just after turning off the spray booth and conveyor, repeat this procedure. Average the two results to obtain the average flow rate for the test.

NOTE 4—A gallon plastic bottle with the top cut off to conveniently fit around the front of the gun is recommended to use with the above procedure. A large plastic beaker covered with plastic wrap with a hole punched in the center of the plastic wrap works also.

Turn off all air sources to the spray gun before using the above procedure to prevent paint splattering out of the container.

8.14 Record the following data:

8.14.1 *Application Equipment:*

8.14.1.1 Paint fluid pressure (kilopascals) at the spray gun,

8.14.1.2 Atomizing air pressure (kilopascals) at the spray gun,

8.14.1.3 Rotating atomizer head speed (revolutions per minute) with and without paint fluid flow, and

8.14.1.4 Operating voltage (kilovolts) if electrostatic equipment is used.

8.14.2 *Spray Booth and Conveyor:*

8.14.2.1 Ambient temperature (degrees Celsius),

8.14.2.2 Paint fluid temperature (degrees Celsius),

8.14.2.3 Booth air velocity (foot per minute),

8.14.2.4 Relative humidity (percent),

8.14.2.5 Spray gun to target distance (centimeters),

8.14.2.6 Conveyor speed (centimeters per minute), and

8.14.2.7 Fluid mass flow rate (grams per minute).

8.15 After the paint flow and the conveyor are stopped, remove the painted targets from the conveyor and ensure that no paint is lost. Measure the wet film thickness to ensure that the proper amount of paint has been applied and record the wet film thickness.

8.16 Securely hang the coated targets on oven racks so all painted surfaces are exposed for uniform drying. Insert the racks into the oven and bake at the recommended manufacturer's cure schedule.

8.17 Remove the targets from the oven and let cool.

8.18 Remove the foil from each target, weigh and record the coated weight, the foil number, the percent vertical film coverage, and the dry film thickness at the center of the spray pattern.

8.19 The mass of the paint solids deposited is the difference in the total weight of the foils before painting and the total weight of the foils after painting and baking.

9. Calculation

9.1 Calculate the transfer efficiency using the following equation:

$$T = (100 \times C \times P)/(F \times S \times W)$$

where:

T = transfer efficiency, %
C = conveyor speed, cm/min,
P = mass of paint solids deposited, g,
F = fluid delivery rate, g/min,
S = weight percent solids expressed as a decimal, and
W = effective target width, 30.48 cm.

10. Report

10.1 Report the following information:
10.1.1 Transfer efficiency results,
10.1.2 Type of spray equipment,
10.1.3 Type of paint applied,
10.1.4 Paint application conditions, and
10.1.5 Conditions of test other than those specified in the procedure section of this test method.

11. Precision

11.1 This test method is derived from a study and report of transfer efficiency measurements conducted for the U. S. Environmental Protection Agency.[4] The procedure described was subjected to round-robin evaluation following ASTM guidelines. The procedure was used at eight laboratories and results were obtained using conventional airless, electrostatic air spray, and conventional air spray equipment. Statistical treatment of the results for the test sites and spray equipment type (gun) yields the following transfer efficiency results:

Type of Gun	Variance	Standard Deviation
Conventional airless:		
Within laboratory	1.22	1.10
Between laboratory	26.41	...
Gun	6.22	...
Total	33.85	5.82
Electrostatic Air Spray:		
Within laboratory	3.63	1.91
Between laboratory	72.02	
Gun	13.01	
Total	88.66	9.42
Conventional Air Spray:		
Within laboratory	2.30	1.50
Between laboratory	42.90	
Gun	0.88	
Total	46.08	6.79

12. Keywords

12.1 laboratory method; spray applied coatings; transfer efficiency

[4] *Development of Proposed Standard Test Method for Spray Painting Transfer Efficiency*, Vols I and II, *EPA Publication Nos. EPA-600/2-88-026a* and *EPA-600/2-88-026b*, Environmental Protection Agency, Research Triangle Park, NC.

Designation: D 5010 - 92

Standard Guide for Testing Printing Inks and Related Materials[1]

This standard is issued under the fixed designation D 5010; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

1. Scope

1.1 This guide covers a list of test methods, practices, and specifications that can be used for the testing and evaluation of printing inks, printed ink films, and substrates used in their production (see Table 1).

1.2 This guide includes methods that were developed to test paints, paint films, and substrates, but may be adapted for use in testing printing inks and printed matter. Tests on raw materials and analytical methods in general have not been included.

NOTE 1—For the purpose of this guide, clear coatings such as overprint varnishes are classed as printing inks.

1.3 Other ASTM standards not specified here may also be applicable.

2. Terminology

2.1 *Definitions:*

2.1.1 *printing ink*—a colored or pigmented liquid or paste composition that dries to a solid film after application as a thin layer by printing machinery.

2.1.1.1 *Discussion*—Printing inks may contain vehicles, colorants, waxes, solvents, and other additives. Bulk inks are tested for dispersion, tinting strength, density, heat and storage stability, rheology, and printing properties.

2.1.2 *printed ink film*—thin layer of a printing ink deposited onto a substrate by means of a laboratory or production printing press, occasionally by a drawdown or roll-out technique. Printed matter is the usual medium by which inks are tested for appearance properties, drying, and resistance to various agents.

2.1.3 *printing substrate*—material onto which ink is deposited in the production of printed matter. Printing substrates include paper, paperboard, plastic film, glass, and metallic surfaces. In this guide, standards relating to substrates are largely restricted to properties associated with appearance and printability.

3. Test Categories

3.1 For convenience in selection, the test methods, practices, and specifications, listed in this guide are classified into three groups by type of printing process and in subgroups indicating whether the test is conducted on a bulk ink, a printed ink film, or a substrate (see Table 2). The group is given in the left column preceding the test method reference. The classification are a follows:

3.1.1 *Group 1—Applicable in General:*
Class A—Bulk inks.
Class B—Printed ink films.
Class C—Substrates.

3.1.2 *Group 2—Applicable to Low Viscosity or Liquid Inks Associated With Flexography or Gravure:*
Class A—Bulk inks.
Class B—Printed ink films.
Class C—Substrates.

3.1.3 *Group 3—Applicable to High Viscosity or Paste Inks Associated With Letterpress, Lithography, or Silk Screen:*
Class A—Bulk inks.
Class B—Printed ink films.
Class C—Substrates.

4. Precision and Bias

4.1 If available, precision for each test method listed can be found in the latest revision of that test method.

5. Keywords

5.1 printed matter; printing inks; printing substrates; test methods and practices (tabulation of)

---

[1] This guide is under the jurisdiction of the ASTM Committee D-1 on Paint and Related Coatings and Materials and is the direct responsibility of Subcommittee D01.56 on Printing Inks.

Current edition approved Oct. 15, 1992. Published December 1992. Originally published as D 5010 - 91. Last previous edition D 5010 - 91.

TABLE 1 Numerical Listing of Ink-Related Standards

ASTM Designation	Volume	Title
D 16	06.01	Terminology Relating to Paint, Varnish, Lacquer, and Related Products
D 56	05.03	Test Method for Flash Point by Tag Closed Tester
	06.04	
D 93	04.09	Test Method for Flash Point by Pensky-Martin Closed Tester
	05.01	
	06.04	
D 185	06.03	Test Methods for Coarse Particles in Pigments, Pastes, and Paints
D 344	06.01	Test Method for Relative Dry Hiding Power of Paints by the Visual Evaluation of Brushouts
D 523	06.01	Test Method for Specular Gloss
D 528	15.09	Test Method for Machine Direction of Paper and Paperboard
D 562	06.01	Test Method for Consistency of Paints Using the Stormer Viscometer
D 644	15.09	Test Method for Moisture Content of Paper and Paperboard by Oven Drying
D 685	15.09	Method for Conditioning Paper and Paperboard Products for Testing
D 724	15.09	Test Method for Surface Wettability of Paper (Angle-of-Contact Method)
D 780	15.09	Test Method for Printing Ink Permeation of Paper (Castor Oil Test)
D 869	06.02	Test Method for Evaluating the Degree of Settling of Paint
D 918	15.09	Test Method for Blocking Resistance of Paper and Paperboard
D 971	05.01	Test Method for Interfacial Tension of Oil Against Water by the Ring Method
D 1200	06.01	Test Method for Viscosity by Ford Viscosity Cup
D 1210	06.01	Test Method for Fineness of Dispersion of Pigment-Vehicle Systems
D 1259	06.01	Test Methods for Nonvolatile Content of Resin Solutions
D 1310	05.01	Test Method for Flash Point and Fire Point of Liquids by Tag Open-Cup Apparatus
	06.04	
D 1316	06.02	Test Method for Fineness of Grind of Printing Inks by the NPIRI Grindometer
D 1331	15.04	Test Methods for Surface and Interfacial Tension of Solutions of Surface-Active Agents
D 1353	06.04	Test Method for Nonvolatile Matter in Volatile Solvents for Use in Paint, Varnish, Lacquer, and Related Products
D 1474	06.01	Test Methods for Indentation Hardness of Organic Coatings
D 1475	06.01	Test Method for Density of Paint, Varnish, Lacquer, and Related Products
D 1535	06.01	Test Method for Specifying Color by the Munsell System
D 1544	06.01	Test Method for Color of Transparent Liquids (Gardner Color Scale)
D 1545	06.03	Test Method for Viscosity of Transparent Liquids by Bubble Time Method
D 1590	11.01	Test Methods for Surface Tension of Water and Waste Water
D 1640	06.03	Test Methods for Drying, Curing, or Film Formation of Organic Coatings at Room Temperature
D 1644	06.01	Test Methods for Nonvolatile Content of Varnishes
D 1647	06.03	Test Methods for Resistance of Dried Films of Varnishes to Water and Alkali
D 1653	06.01	Test Methods for Water Vapor Permeability of Organic Coating Films
D 1725	06.03	Test Method for Viscosity of Resin Solutions
D 1729	06.01	Practice for Visual Evaluation of Color Differences of Opaque Materials
D 1849	06.02	Test Method for Package Stability of Paint
D 1963	06.03	Test Method for Specific Gravity of Drying Oils, Varnishes, Resins, and Related Materials at 25/25°C
D 2066	06.02	Test Methods for Relative Tinting Strength of Printing Ink Dispersions
D 2067	06.02	Test Method for Coarse Particles in Printing Ink Dispersions
D 2091	06.02	Test Method for Print Resistance of Lacquers
D 2196	06.01	Test Methods for Rheological Properties of Non-Newtonian Materials by Rotational (Brookfield) Viscometer
D 2243	06.02	Test Method for Freeze-Thaw Resistance of Water-Borne Coatings
D 2244	06.01	Test Method for Calculation of Color Differences from Instrumentally Measured Color Coordinates
D 2248	06.01	Practice for Detergent Resistance of Organic Finishes
D 2337	06.02	Test Method for Freeze-Thaw Stability of Multicolor Lacquers
D 2369	06.01	Test Method for Volatile Content of Coatings
D 2482	15.09	Method for Wax Pick Test for Surface Strength of Paper
D 2574	06.01	Test Method for Resistance of Emulsion Paints in the Container to Attack by Microorganisms
D 2578	08.02	Test Method for Wetting Tension of Polyethylene and Polypropylene Films
D 2616	06.01	Test Method for Evaluation of Visual Color Difference with a Gray Scale
D 2620	06.02	Test Method for Light Stability of Clear Coatings
D 2794	06.01	Test Method for Resistance of Organic Coatings to the Effects of Rapid Deformation (Impact)
D 2805	06.01	Test Method for Hiding Power of Paints by Reflectometry
D 3134	06.01	Practice for Establishing Color and Gloss Tolerances
D 3258	06.02	Test Method for Porosity of Paint Films
D 3278	06.01	Test Methods for Flash Point of Liquids by Setaflash Closed-Cup Apparatus
D 3359	06.01	Test Methods for Measuring Adhesion by Tape Test
D 3363	06.01	Test Method for Film Hardness by Pencil Test
D 3424	06.02	Test Methods of Evaluating the Lightfastness and Weatherability of Printed Matter
D 3732	06.02	Practice for Reporting Cure Times of Ultraviolet-Cured Coatings
D 3792	06.01	Test Method for Water Content of Water-Reducible Paints by Direct Injection into a Gas Chromatograph
D 3825	05.03	Test Method for Dynamic Surface Tension by the Fast Bubble Technique
D 3828	05.03	Test Method for Flash Point by Setaflash Closed Tester
D 3924	06.01	Specification for Standard Environment for Conditioning and Testing Paint, Varnish, Lacquers, and Related Materials
D 3925	06.01	Practice for Sampling Liquid Paints and Related Pigmented Coatings
D 3928	06.02	Test Method for Evaluation of Gloss or Sheen Uniformity
D 3934	06.01	Test Method for Flash/No Flash Test—Equilibrium Method by a Closed-Cup Apparatus

TABLE 1 *Continued*

ASTM Designation	Volume	Title
D 3960	06.01	Practice for Determining Volatile Organic Compound (VOC) Content of Paints and Related Coatings
D 4017	06.01	Test Method for Water in Paints and Paint Materials by Karl Fischer Method
D 4040	06.02	Test Method for Viscosity of Printing Inks and Vehicles by the Falling-Rod Viscometer
D 4060	06.01	Test Method for Abrasion Resistance of Organic Coatings by the Taber Abraser
D 4086	06.01	Practice for Visual Evaluation of Metamerism
D 4141	06.01	Practice for Conducting Accelerated Outdoor Exposure Tests of Coatings
D 4144	06.02	Method for Estimating Package Stability of Coatings for Ultraviolet Curing
D 4212	06.01	Test Method for Viscosity by Dip-Type Viscosity Cups
D 4287	06.01	Test Method for High-Shear Viscosity Using the ICI Cone/Plate Viscometer
D 4302	06.02	Specification for Artists' Oil, Resin-Oil, and Alkyd Paints
D 4359	06.01	Test Method for Determining Whether a Material is a Liquid or a Solid
D 4361	06.01	Test Method for Apparent Tack of Printing Inks and Vehicles by the Inkometer
D 4366	06.01	Test Methods for Hardness of Organic Coatings by Pendulum Damping Tests
D 4449	06.01	Test Method for Visual Evaluation of Gloss Differences Between Surfaces of Similar Appearance
D 4459	08.03	Practice for Operating an Accelerated Lightfastness Xenon-Arc-Type (Water Cooled) Light-Exposure Apparatus for the Exposure of Plastics for Indoor Applications
D 4518	06.01	Test Methods for Measuring Static Friction of Coating Surfaces
D 4541	06.02	Test Method for Pull-Off Strength of Coatings Using Portable Adhesion Testers
D 4674	08.03	Test Method for Accelerated Testing for Color Stability of Plastics Exposed to Indoor Fluorescent Light and Window-Filtered Daylight
D 4713	06.02	Test Methods for Nonvolatile Content of Printing Inks, Resin Solutions, and Vehicles
D 4758	06.03	Test Method for Nonvolatile Content of Latexes
D 4942	06.02	Test Methods for Water Pickup of Lithographic Printing Inks and Vehicles in a Laboratory Mixer
D 5039	15.09	Methods for Identification of Wire Side of Paper
D 5067	06.02	Specification for Artists' Watercolor Paints
D 5098	06.02	Specification for Artists' Acrylic Emulsion Paints
D 5181	06.02	Test Method for Abrasion Resistance of Printed Matter by the GA-CAT Comprehensive Abrasion Tester
E 97	06.01	Test Method for Directional Reflectance Factor, 45-deg 0-deg, of Opaque Specimens by Broad-Band Filter Reflectometry (Withdrawn 1992: Replaced by Test Method E 1347)
E 284	06.01	Terminology of Appearance
E 308	06.01	Test Method for Computing the Colors of Objects by Using the CIE System
E 313	06.01	Test Method for Indexes of Whiteness and Yellowness of Near-White, Opaque Materials
E 429	06.01	Method for Measurement and Calculation of Reflecting Characteristics of Metallic Surfaces Using Integrating Sphere Instruments
E 430	06.01	Method for Measurement of Gloss of High-Gloss Surfaces by Goniophotometry
E 691	06.04	Practice for Conducting an Interlaboratory Study to Determine the Precision of a Test Method
E 805	06.01	Practice for Identification of Instrumental Methods of Color and Color-Difference Measurement of Materials
E 991	06.01	Practice for Color Measurement of Fluorescent Specimens
E 1331	06.01	Test Method for Reflectance Factor and Color by Spectrophotometry Using Hemispherical Geometry
E 1347	06.01	Test Method for Color and Color Difference Measurement of Object-Color Specimens by Tristimulus (Filter) Colorimetry
E 1349	06.01	Test Method for Reflectance Factor and Color by Spectrophotometry Using Bidirectional Geometry
F 34	15.09	Test Method for Liquid Extraction of Flexible Barrier Materials
F 149	15.09	Definitions of Terms Relating to Optical Character Recognition
F 151	15.09	Test Method for Residual Solvents in Flexible Barrier Materials
F 372	15.09	Test Method for Water Vapor Transmission of Flexible Barrier Materials Using an Infrared Detector Technique
F 413	15.09	Practice for Preparation of an Offset Duplicator for Use in Functional Testing of Lithographic Copy Products
F 425	15.09	Definitions of Terms Relating to Lithographic Copy Products
F 909	15.09	Definitions of Terms Relating to Printers
F 1125	15.09	Terminology of Image Quality in Impact Printing Systems
G 7	06.01	Practice for Atmospheric Environmental Exposure Testing of Nonmetallic Materials
G 23	06.01	Practice for Operating Light-Exposure Apparatus (Carbon-Arc Type) With and Without Water for Exposure of Nonmetallic Materials
G 24	06.01	Practice for Conducting Exposures to Daylight Filtered Through Glass
G 26	06.01	Practice for Operating Light-Exposure Apparatus (Xenon-Arc Type) With and Without Water for Exposure of Nonmetallic Materials

TABLE 2 Index of Standards by Property

Group	Topic	ASTM Designation	ASTM Volume No.
	Testing in General		
1ABC	Terminology Relating to Paint, Varnish, Lacquer, and Related Products	D 16	06.01
1C	Conditioning Paper and Paperboard Products for Testing	D 685	15.09
1ABC	Conditioning and Testing Paint, Varnish, Lacquer, and Related Materials, Standard Environment for	D 3924	06.01
1A	Determining Whether a Material is a Liquid or a Solid	D 4359	06.01
1ABC	Interlaboratory Study to Determine the Precision of a Test Method	E 691	06.04 08.03 06.01
1A	Sampling Liquid Paints and Related Pigmented Coatings	D 3925	06.01
	Appearance Properties		
1ABC	Terminology Relating to Appearance of Materials	E 284	06.01
	Color and Reflectance		
1ABC	Calculation of Color Differences From Instrumentally Measured Coordinates	D 2244	06.01
1ABC	Color and Color-Difference by Tristimulus (Filter) Colorimetry	E 1347	06.01
1ABC	Color of Fluorescent Specimens	E 991	06.01
1A	Color of Transparent Liquids (Gardner Color Scale)	D 1544	06.01
1ABC	Computing the Color of Objects by the CIE System	E 308	06.01
1ABC	Directional Reflectance Factor, 45-deg 0-deg, of Opaque Specimens by Broad-Band Filter Reflectometry (Withdrawn 1992: Replaced by Test Method E 1347)	E 97	06.01
1ABC	Establishing Color and Gloss Tolerances	D 3134	06.01
1ABC	Identification of Instrumental Methods of Color or Color-Difference Measurement of Materials	E 805	06.01
1ABC	Reflectance Factor and Color by Spectrophotometry Using Bidirectional Geometry	E 1349	06.01
1ABC	Reflectance Factor and Color by Spectrophotometry Using Hemispherical Geometry	E 1331	06.01
1C	Reflecting Characteristics of Metallic Surfaces Using Integrating-Sphere Instruments	E 429	06.01
1ABC	Specifying Color by the Munsell System	D 1535	06.01
1ABC	Visual Color Difference With a Gray Scale	D 2616	06.01
1ABC	Visual Evaluation of Color Differences of Opaque Materials	D 1729	06.01
1ABC	Visual Evaluation of Metamerism	D 4086	06.01
1C	Whiteness and Yellowness of Near-White Opaque Materials	E 313	06.01
	Gloss		
1ABC	Gloss of High-Gloss Surfaces by Goniophotometry	E 430	06.01
1ABC	Specular Gloss (20°, 60°, 85°)	D 523	06.01
1ABC	Visual Evaluation of Gloss Differences Between Surfaces of Similar Appearance	D 4449	06.01
1ABC	Visual Evaluation of Gloss or Sheen Uniformity	D 3928	06.02
	Opacity and Strength		
1B	Hiding Power of Paints by Reflectometry	D 2805	06.01
1B	Relative Hiding Power of Paints by the Visual Evaluation of Brushouts	D 344	06.01
3A	Relative Tinting Strength of Printing Ink Dispersions	D 2066	06.02
	Other Optical Properties		
1B	Definitions of Terms Relating to Optical Character Recognition	F 149	15.09
1B	Terminology of Image Quality in Impact Printing Systems	F 1125	15.09
	Chemical Resistance		
1B	Detergent Resistance of Organic Finishes	D 2248	06.01
1B	Resistance of Dried Films of Varnishes to Water and Alkali	D 1647	06.03
	Density		
1A	Density of Paint, Varnish, Lacquer, and Related Products	D 1475	06.01
1A	Specific Gravity of Drying Oils, Varnishes, Resins, and Related Materials at 25/25°C	D 1963	06.03
	Dispersion		
1A	Coarse Particles in Pigments, Pastes, and Paints	D 185	06.03
1A	Coarse Particles in Printing Ink Dispersions	D 2067	06.02
1A	Fineness of Dispersion of Pigment-Vehicle Systems	D 1210	06.01
1A	Fineness of Grind of Printing Inks by the NPIRI Grindometer	D 1316	06.02
	Drying		
1B	Drying, Curing, or Film Formation of Organic Coatings at Room Temperature	D 1640	06.03
1B	Reporting Cure Times of Ultraviolet-Cured Coatings	D 3732	06.02

TABLE 2 *Continued*

Group	Topic	ASTM Designation	ASTM Volume No.
	Heat Stability		
1A	Flash/No Flash Test—Equilibrium Method by a Closed-Cup Apparatus	D 3934	06.01
1A	Flash Point by Pensky-Martin Closed Tester	D 93	04.09 05.01 06.04
1A	Flash Point of Liquids by Setaflash Closed-Cup Apparatus	D 3278	06.01
1A	Flash Point by Setaflash Closed Tester	D 3828	05.03
1A	Flash Point by Tag Closed Tester	D 56	05.01 06.04
1C	Moisture Content of Paper and Paperboard by Oven Drying	D 644	15.09
1A	Flash Point and Fire Point by Tag Open-Cup Apparatus	D 1310	05.01 06.04
2A	Nonvolatile Content of Latexes	D 4758	06.03
1A	Nonvolatile Content in Printing Inks, Resin Solutions, and Vehicles	D 4713	06.02
1A	Nonvolatile Content of Resin Solutions	D 1259	06.01
1A	Nonvolatile Content of Varnishes	D 1644	06.01
1A	Nonvolatile Matter in Volatile Solvents for Use in Paint, Varnish, Lacquer, and Related Products	D 1353	06.03
1A	Volatile Content of Coatings	D 2369	06.01
1A	Volatile Organic Compound (VOC) Content of Paints and Related Coatings	D 3960	06.01
	Light and Weather Fastness		
1B	Accelerated Outdoor Exposure Test of Coatings	D 4141	06.01
1B	Accelerated Testing for Color Stability of Plastics Exposed to Indoor Fluorescent Lighting and Window-Filtered Daylight	D 4674	08.03
1B	Atmospheric Environmental Exposure Testing of Nonmetallic Materials	G 7	06.01
1B	Light Stability of Clear Coatings	D 2620	06.02
1B	Lightfastness of Printed Matter	D 3424	06.02
1B	Natural Light Exposures Under Glass	G 24	06.01
1B	Operating an Accelerated Lightfastness Xenon-Arc-Type (Water Cooled) Light-Exposure Apparatus for the Exposure of Plastics for Indoor Applications	D 4459	08.03
1B	Operating Light-Exposure Apparatus (Carbon-Arc Type) With and Without Water for Exposure of Nonmetallic Materials	G 23	06.01
1B	Operating Light-Exposure Apparatus (Xenon-Arc Type) With and Without Water for Exposure of Nonmetallic Materials	G 26	06.01
1B	Specification for (Lightfastness of) Artists' Oil, Resin-Oil, and Alkyd Paints	D 4302	06.02
1B	Specification for (Lightfastness of) Artists' Watercolor Paints	D 5067	06.02
1B	Specification for (Lightfastness of) Artists' Acrylic Emulsion Paints	D 5098	06.02
	Physical Strength and Resistance (Nonchemical)		
1B	Abrasion Resistance of Organic Coatings by Taber Abraser	D 4060	06.01
1B	Abrasion Resistance of Printed Matter by the GA CAT Comprehensive Abrasion Tester	D 5181	06.02
1B	Adhesion by Tape Test	D 3359	06.01
1B	Film Hardness (of Organic Coatings) by Pencil Test	D 3363	06.01
1B	Hardness of Organic Coatings by Pendulum Damping Test	D 4366	06.01
1B	Indentation Hardness of Organic Coatings	D 1474	06.01
1B	Print (Imprint) Resistance of Lacquers	D 2091	06.02
1B	Pull-off Strength of Coatings Using Portable Adhesion Tester	D 4541	06.02
1B	Resistance of Organic Coatings to the Effects of Rapid Deformation (Impact)	D 2794	06.01
1B	Static Friction of Coating Surfaces	D 4518	06.01
	Porosity and Permeability		
1B	Porosity of Paint Films	D 3258	06.02
1B	Water Vapor Permeability of Organic Coating Films	D 1653	06.01
2C	Water Vapor Transmission Rate of Flexible Barrier Materials Using an Infrared Detection Technique	F 372	15.09
	Printing Properties		
3A	Definitions of Terms Relating to Lithographic Copy Products	F 425	15.09
1B	Definitions of Terms Relating to Printers	F 909	15.09
1C	Blocking Resistance of Paper and Paperboard	D 918	15.09
1C	Machine Direction of Paper and Paperboard	D 528	15.09
3AC	Preparation of an Offset Duplicator for Use in Functional Testing of Lithographic Copy Products	F 413	15.09
1C	Printing Ink Permeation of Paper (Castor Oil Test)	D 780	15.09
3A	Water Pickup of Lithographic Printing Inks and Vehicles in a Laboratory Mixer	D 4942	06.02
3C	Wax Pick Test for Surface Strength of Paper	D 2482	15.09
1C	Wire Side of Paper	D 5039	15.09

TABLE 2 *Continued*

Group	Topic	ASTM Designation	ASTM Volume No.
	Rheology		
3A	Apparent Tack of Printing Inks and Vehicles by the Inkometer	D 4361	06.01
1A	Consistency of Paints Using the Stormer Viscometer	D 562	06.01
1A	High-Shear Viscosity Using the ICI Cone/Plate Viscometer	D 4287	06.01
1A	Rheological Properties of Non-Newtonian Materials by Rotational (Brookfield) Viscometer	D 2196	06.01
2A	Viscosity by Dip-Type Viscosity Cups	D 4212	06.01
1A	Viscosity by Ford Viscosity Cup	D 1200	06.01
3A	Viscosity of Printing Inks and Vehicles by the Falling-Rod Viscometer	D 4040	06.02
1A	Viscosity of Resin Solutions	D 1725	06.03
1A	Viscosity of Transparent Liquids by Bubble Time Method	D 1545	06.03
	Storage Stability		
1A	Degree of Settling of Paint	D 869	06.02
2A	Freeze-Thaw Resistance of Water-Borne Paints	D 2243	06.02
1A	Freeze-Thaw Stability of Multicolor Lacquers	D 2337	06.02
1A	Package Stability of Coatings for Ultraviolet Curing	D 4144	06.02
1A	Package Stability of Paint	D 1849	06.02
2A	Resistance of Emulsion Paints in the Container to Attack by Microorganisms	D 2574	06.01
	Surface Chemistry		
1A	Dynamic Surface Tension by the Fast Bubble Technique	D 3825	05.03
1A	Interfacial Tension of Oil Against Water by the Ring Method	D 971	05.01
1A	Surface and Interfacial Tension of Solutions of Surface-Active Agents	D 1331	15.04
1A	Surface Tension of Water and Waste Water	D 1590	11.01
1C	Surface Wettability of Paper (Angle-of-Contact Method)	D 724	15.09
2C	Wetting Tension of Polyethylene and Polypropylene Films	D 2578	08.02
	Special Analytical Tests		
2C	Liquid Extraction of Flexible Barrier Materials	F 34	15.09
2C	Residual Solvents in Flexible Barrier Materials	F 151	15.09
1A	Water Content of Water-Reducible Paints by Direct Injection into a Gas Chromatograph	D 3792	06.01
1A	Water in Paints and Paint Materials by Karl Fischer Method	D 4017	06.01

Designation: D 5043 - 90

Standard Test Methods for Field Identification of Coatings[1]

This standard is issued under the fixed designation D 5043; 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 cover procedures and portable apparatus for determining the generic type of coating films most likely to be encountered on structures. The coating can either be weathered from exposure or be freshly applied.

1.2 Most commonly used coatings can be divided into the broad categories and subgroups shown in Table 1 on the basis of the nonvolatile component (generic types) of their vehicle (film forming resin, binder). Although the curing of some coatings involves more than one process and coatings may contain more than one type of resin, they can usually be assigned to one of the basic classes and generic types listed in Table 1.

1.3 For field exposed coatings, it is suggested that these test methods be used as part of a complete evaluation of a coated surface as it is frequently helpful to consider the environment of exposure and how the coating has performed in the environment when drawing conclusions from these tests.

1.4 These test methods will not result in the identification of components of a coating beyond general classification of the coating by generic type and are not appropriate if more detailed analysis is required, for example, as a part of failure analysis or to identify between different manufacturers of the same type of coating. They also may not be definitive enough to identify complex systems that include multiple layers of different generic types of coatings.

1.5 The evaluation of results is quite subjective. Practice and experience are required to minimize misinterpretation. Repeat tests may be required.

1.6 None of the tests is to be taken alone as grounds for identifying the generic type. Only the combination of results from several or all of the tests are to be used in conclusions regarding generic types.

1.7 *This standard does not purport to address all of the safety problems associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.* For specific hazard statements, see Notes 8, 9, and 11.

2. Summary of Test Methods

2.1 Samples of coatings films are tested with solvents and chemicals and subjected to pyrolysis to provide evidence of their generic type. Figure 1 shows a flow chart for suggested order of tests and classification of results.

3. Significance and Use

3.1 Information about the generic type of coating on a surface is required to select compatible coatings for repainting and can be used when evaluating the performance of a coating in an environment in decisions on upgrading or replacing a coating system. These test methods provide information on generic type, can be performed in the field by personnel with limited laboratory experience, and require a minimum of equipment and materials.

4. Sampling

4.1 The sample of coating can be obtained by chipping or scraping with a knife or by sanding and then brushing the material into a specimen container or clean envelope. Care should be taken not to cut into substrates, such as plastic or asphalt, that contain polymeric or bituminous materials. Small portions of untreated wood, masonry, or steel do not ordinarily interfere with the tests. Some tests can be conducted directly on the coating surface. If a liquid sample of coating is to be evaluated, a film of the coating should first be cast on a glass plate or similar surface from which it can conveniently be removed after drying.

NOTE 1—To develop familiarity with the subjective evaluations that follow, it is good practice to make films of known resin composition by applying control paints to glass plates or similar surfaces from which they can be readily removed after drying.

5. Pyrolysis

5.1 *Summary of Test Method*—A sample of coating placed in a small test tube is burned over a hot flame. The way the coating burns and the odor and other characteristics of the fume generated are recorded. The Beilstein test identifies the presence of chlorinated and other halogens. In coatings, chlorine-containing material is most often encountered. For coatings *not* containing halogens, the odor is recorded.

5.2 *Apparatus:*

5.2.1 *Flame Source*, including butane or propane utility torch. (Lighters do not provide a hot enough flame.)

5.2.2 *Test Tubes*—A suitable size is 10 by 75 mm (disposable culture tubes).

5.2.3 *Copper Wire*—A length of single-strand 16 to 18 gauge. AWG copper electrical wire, stripped of insulation sufficiently far that melted insulation cannot interfere with the test, is satisfactory. Leave about 6 in. of insulation as a heat insulator or provide a wrapping or handle for protection from heat.

5.2.4 *Lead Acetate Paper.*

5.2.5 *Test Tube Clamp.*

5.3 *Procedure:*

5.3.1 Put a small specimen of coating, preferably of one

[1] These test methods are under the jurisdiction of ASTM Committee D-1 on Paint and Related Coatings and Materials and are the direct responsibility of Subcommittee D01.46 on Industrial Protective Coatings.

Current edition approved April 27, 1990. Published June 1990.

TABLE 1 Classification of Coatings Frequently Used

Basic Class	Examples
Air-drying or baking (oxidizing) paint and enamel	unmodified drying oil
	oleoresinous (oil-modified, alkyd, epoxy ester, phenolic and other resins)
Lacquer (drying by solvent evaporation)	vinyl (poly(vinyl chloride-vinyl acetate))
	poly(vinyl butyral)
	chlorinated rubber
	styrene-butadiene rubber and similar rubbers
	bituminous (coal tar, asphalt)
	cellulose nitrate
Latex (drying by evaporation of water)	poly(vinyl acetate)
	acrylic
	styrenated acrylic
Chemically curing single package and multi-component coating	epoxy
	bituminous epoxy
	urethane
	polyester
Inorganic	silicates and cement
Miscellaneous	flame-sprayed
	silicones

piece, in the test tube and hold the tube briefly in the hot flame. Limit flame contact to the end of the test tube immediately around the specimen. As the specimen begins to burn, observe the nature of deterioration and identify coating type as follows:

Observation	Identification
No change in shape; possible change in color; continued heating causes sample to glow red	inorganic
Rapid deterioration, almost explosive in nature	cellulose nitrate, or similar
Swelling	some vinyl-type coatings

NOTE 2—Melting, bubbling, and charring are common with most generic types and not definitive.

5.3.2 Continue heating until fume (smoke) fills the test tube. Most fumes are white or near-white; slight condensation of a clear liquid on the upper test tube wall is sometimes observed. Other observations and identifications include:

Observation	Identification
Dark fume; clear brown liquid condensate	possibly epoxy
Very dark, possibly sooty fume; dark condensate	bituminous

NOTE 3—Bituminous coatings may be asphalt, coal tar, or combinations. The test is not definitive.

NOTE 4—Silicone coatings will form an ash upon pyrolysis at 800°C. Such temperatures are outside the scope of this test.

5.3.3 *Beilstein Test*—Conduct the Beilstein test by first heating the bare copper wire in the flame until no color is imparted to the flame. Insert the heated wire into hot fume in the test tube briefly (1 to 2 s). Withdraw the copper wire from the test tube and immediately hold it in the flame again. Observe the flame over the copper wire for color and make identifications as follows:

Observation	Identification
No color	no chlorine or chloride (or other halogen) content
Traces of green color	chloride contaminants from environment or minor component of coating
Strong green color	chlorinated resin or chlorinated resin modifier

With practice, the intensity of the green flame can be used to determine whether the chlorine containing component is major or minor.

5.3.3.1 *Example 1*—A very intense, relatively long-lasting *repeatable* green flame indicates chlorinated rubber or vinyl coating.

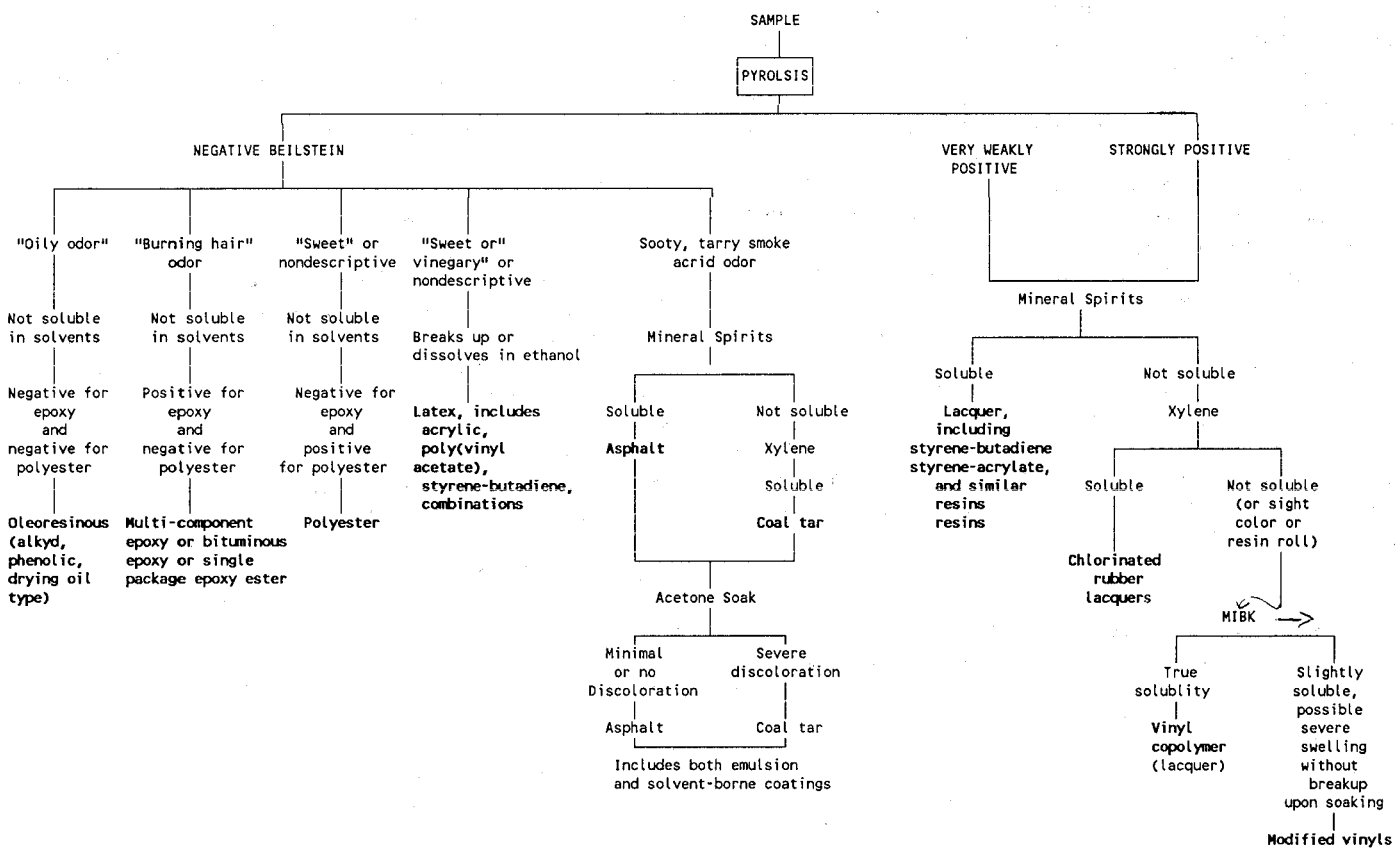


FIG. 1 Suggested Test Flow Chart for Coatings Identification

5.3.3.2 *Example 2*—An intense or moderately intense relatively short-lived green flame, which may or may not be repeated, indicates chlorinated plasticizer in a nonchlorinated resin binder.

NOTE 5—Although fluorinated resins also give a positive Beilstein test, they are less likely to be encountered in industrial applications than chlorinated resins.

NOTE 6—If the sample includes hydrated material, for example, concrete or plaster, water will be liberated by burning and will condense on the wall of the test tube. Halogen liberated from the paint will be absorbed into the condensate. The copper wire must be brought into contact with the condensate to avoid a false negative.

NOTE 7—Those experienced with the Beilstein test may prefer to run it on a specimen not subjected to pyrolysis.

5.3.4 *Odor Test*—Conduct the odor test *only* if the Beilstein test is negative (no green flame).

NOTE 8: **Warning**—Hot chlorine or fluorine-containing fumes are extremely irritating and potentially hazardous. Tip the test tube so that the fumes flow toward the open end of the tube. Gently wave a hand over the mouth of the test tube and carefully smell the odor of the fumes as they dissipate from the mouth of the test tube. Avoid overexposure to the fumes.

5.3.4.1 Indications are subjective, but the following classes can be assigned:

Observation	Identification
Oily	oleoresinous
Very sweet	acrylic latex
Vinegary; acetic acid	poly(vinyl acetate)
Burning hair	epoxy, epoxy ester, bituminous epoxy
Burning rubber	polysulfide
No strong odor	inorganic, cementitious
Acrid (biting) odor, with sooty or tarry smoke	bituminous

5.3.5 Use the lead acetate paper to verify the presence of a sulfide component by holding a piece of moistened lead acetate paper over or in the mouth of the test tube. A sulfur-containing component is present if the paper rapidly darkens.

6. Solubility Tests

6.1 Chemically cured, inorganic, and aged oleoresinous coatings are not resoluble in the solvents originally used in producing the coatings. Lacquers and some latex coatings are resoluble and the strength of the solvent required to cause the coating to dissolve can be used to classify the coating.

6.2 *Reagents*—Solvents used, listed in order of increasing power of solvency (that is, ability to dissolve a resin), are as follows:

6.2.1 *Denatured Ethanol (Ethyl Alcohol):*

6.2.2 *Mineral Spirits (Petroleum Spirits)*—Aliphatic hydrocarbon solvent with typical Kauri-Butanol value (KB) of 25 to 45.

6.2.3 *Xylene (Xylol)*—Aromatic hydrocarbon solvent with typical KB of 98.

6.2.4 *Methyl Isobutyl Ketone (MIBK, 4-Methyl-2-Pentanone).*

6.2.5 *Acetone (Dimethyl Ketone, 2-Propanone).*

6.3 *Procedure:*

6.3.1 Although a stirring rod or a gloved finger-tip can be used, the test is best done by a finger-rub technique on the coating film itself. The sensations perceptible by touch are valuable in interpreting results. Alternatively, the solubility tests may be done by soaking portions of the film in solvents, in which case porcelain spot plates and glass stirring rods can be used.

NOTE 9: **Warning**—These solvents can cause skin irritation and dermatitis. Minimize time of contact of solvents with skin and discontinue use if irritation occurs.

6.3.2 *Finger-Rub Test*—Beginning with ethanol, dampen a fingertip and rub the surface of the film briskly in a circular motion 5 to 10 mm (¼ to ½ in.) in diameter. Renew the test solvent frequently as required. Continue rubbing at least 30 s or until definite effects are observed. Continue with each solvent in increasing power of solvency by cleaning the fingertip in each succeeding solvent before using that test solvent and selecting a new spot on the film or an untested chip of paint for each solvent used.

NOTE 10—If the coating film on the test surface is chalky, the first finger-rub test done with ethanol will liberate much of the chalk, which will dry quickly on the finger as a powder. Repeating the test will reveal much less or no color and the test surface will appear unchanged. If chalk is liberated, use ethanol to clean the test spot for subsequent solvent tests.

6.3.3 *Solvent-Soak Test*—The full series of solvents can be run concurrently. Place five chips in a spot plate dish and pour a small amount of each solvent over one of the chips. Periodically stir the solvent and rub the chip with a stirring rod until definite changes occur. Add additional solvent, if necessary due to evaporation, and observe extent of discoloration of the solvent and whether the chip softens, breaks apart, swells, dissolves, or a combination thereof. Note whether a color different from the color of the topcoat is imparted to the solvent, indicating dissolution of an intermediate or primer coat. If portions of the chip dissolve or discolor the solvent, soak up the solvent with a paper towel and add fresh solvent if undissolved chip remains. If no further effect occurs, wash the remainder of the chip by gentle swirling, soak up the solvent, allow the chip to dry, and proceed with pyrolysis or other tests.

NOTE 11: **Precaution**—Do not attempt to burn a solvent-wet chip or heat solvent in a test tube, as the liquid may suddenly boil, possibly causing burns or loss of specimen.

6.3.4 Observe the effects of rubbing or soaking and classify as follows (the results for the soaking test are more difficult to interpret than for the finger-rub test):

6.3.4.1 No effect or small amount of color transfer to the fingertip or rod (due to chalk or film surface abrasion while rubbing).

6.3.4.2 Softening of the film, with resin rolling into small balls under the fingertip or rod.

6.3.4.3 True solubility with film dissolving, becoming sticky, and transferring in relatively large liquified quantity to the fingertip or rod.

6.3.5 Succeeding layers in a coating system may be individually tested if they are visually different; for example, colored topcoat, white or grey intermediate coat, and brown or red primer coat. To test visually different layers, repeatedly rub the spot with an effective solvent and wipe away dissolved coating periodically until a sublayer of different color is clean, then continue the test with the effective solvent on the sublayer. If that solvent is ineffective, repeat the test on the same spot with the next stronger solvent in the series. If that solvent is effective, repeat the test on a new

specimen or area, and when the sublayer is uncovered, allow the solvent to evaporate, then test the coating with the weakest solvent in the series, continuing up the series until solubility is again observed. If a sublayer of coating is not affected by any solvent in the series, that layer may be separated and collected by chipping or scraping for a pyrolysis test.

6.4 *Interpretation of Results:*

6.4.1 *No Effect with Any Solvent*—Chemically cured, oxidized (aged) oleoresinous, or inorganic.

NOTE 12—With prolonged contact, oleoresinous coatings may soften and wrinkle. Absence of wrinkling, however, is not indicative of absence of oleoresinous coatings.

6.4.2 *Breaks Up or Dissolves in Ethanol*—Latex coating or poly(vinyl butyral).

NOTE 13—Latex coatings are normally not soluble in mineral spirits and are only slightly affected in the short time of the test by xylene and MIBK (resulting in surface slickness). Ethanol will not dissolve any other common coating type in this test, but it may affect considerable color transfer from weathered epoxy films. Bituminous emulsions do not break up or dissolve in ethanol.

6.4.3 *Dissolves in Mineral Spirits*—Asphalt coatings and lacquer coatings other than chlorinated rubber and vinyls. Susceptible resins include styrene-butadiene, styrene-acrylate, and similar resins, but do not include polymers such as neoprene which are not normally used in solvent solution coatings.

NOTE 14—Lacquer coatings other than chlorinated rubber and vinyl may contain chlorinated plasticizers that give a positive Beilstein test.

NOTE 15—Some coal tar coatings strongly discolor mineral spirits but are not significantly dissolved by the solvent.

6.4.4 *Dissolves in Xylene but Not in Mineral Spirits*—Coal tar coatings and chlorinated rubber-based coatings. Frequently associated with solution of a chlorinated rubber resin is the ability of the resin to "string" between surface of the film and finger when the finger is pulled away from the film.

6.4.5 *Dissolves in MIBK but Not in Xylene*—Poly(vinyl chloride-vinyl acetate) solution coatings.

NOTE 16—Vinyls may soften with resultant "resin roll" in the finger-rub test with xylene. Some vinyls, modified with polymers such as polyethylene, may not readily dissolve in MIBK, but feel slick with strong color transfer in the finger-rub test and may swell up to 2½ times without dissolving in the MIBK soak test. They may also feel similarly slick with some color transfer in xylene.

NOTE 17—Latex binders merely soften in the short time the test is run.

6.5 It may be possible to further differentiate between asphalt and coal tar coatings using acetone. Soak a chip of bituminous coating in a test tube of acetone for several minutes. Agitate gently and observe for extent of discoloration. Asphalts only very slightly discolor acetone while coal tars strongly discolor it, but there can be intermediate degrees of discoloration that do not permit discrimination. It is not possible by simple methods to differentiate between a solvent-borne (cutback) and water-borne (emulsion) bituminous coating.

7. Test for Polyester Coatings

7.1 This test identifies polyester-based coatings from the group of chemically cured coatings that are not affected by the solubility test.

7.2 *Apparatus:*

7.2.1 *Test Tube.*

7.2.2 *Medicine Droppers.*

7.3 *Reagents:*

7.3.1 *Potassium Hydroxide in Methanol.*

7.3.2 *Hydroxylamine Hydrochloride Solution in Methanol*, 10 %.

7.3.3 *Ferric Chloride Solution*, saturated in distilled water.

7.3.4 *Hydrochloric Acid*, 3 %.

7.3.5 *Warm Water*, 125°F (50°C).

7.4 *Procedure*—Place a small quantity of the film sample in a test tube. Add 10 drops of potassium hydroxide solution and 6 drops of hydroxylamine hydrochloride solution. Place the test tube in a container of warm water for 2 min. Add 10 drops of hydrochloric acid and one drop of ferric chloride solution.

7.5 *Interpretation of Results:*

Observation	Identification
Muddy violet color	dibasic polyester is present
Absence of color or light yellow color	dibasic polyester is not present

8. Test for Epoxy Coatings

8.1 All common epoxy coatings give positive results in this test. Epoxy ester coatings may also give positive results.

8.2 *Apparatus:*

8.2.1 *Ashless or Low-Ash Filter Paper*, 90 to 110-mm diameter.

8.2.2 *Medicine Droppers.*

8.3 *Reagent:*

8.3.1 *Sulfuric Acid*, concentrated.

8.4 *Procedure*—Support the filter paper off surfaces that may be damaged or could cause interference in the test. A watch glass can be used to support the paper. Place a specimen of coating in the filter paper. Place 2 or 3 drops of sulfuric acid directly on the coating. Place 1 or 2 drops of acid elsewhere on the filter paper not in contact with the coating. Let stand for 1 to 2 min. Carefully hold and tilt the filter paper toward the vertical until the acid runs down the paper away from the specimen. Wait 10 to 30 s or until there is development of color in the acid itself, not on the coating.

8.5 *Interpretation of Results*

Observation	Identification
Development of red to violet color in the acid	presence of epoxy
Absence of color in the acid	coating is not epoxy

8.5.1 If red to violet color develops in the drop of acid not in contact with the specimen, then the paper is contaminated or was placed on an epoxy or epoxy-coated surface. Discard and repeat the test. A very slight pink color may develop in the acid. This is not a positive result. Bitumen-filled epoxies may discolor the acid enough to mask color development. If the acid stream is discolored brown to black, carefully rinse the filter paper briefly in water or under running water if available. Color from a positive test will remain in the filter paper after the discoloration is washed off. The filter paper itself will be charred brown by the acid and eventually dissolve. The color of a positive test should occur early enough to be seen before the paper chars.

9. Test for Pigments that Contain Lead and Hexavalent Chromium

9.1 *Summary of Test Method:*

9.1.1 Knowledge of the presence of pigments that contian lead and hexavalent chromium in an existing coating system may be important in a decision on whether the coating system is to be retained and recoated or on the method of removal and disposal of the coating system residue.

9.1.2 Pigments that contain lead or hexavalent chromium, or both, may be used both in primers as rust-inhibitive pigments and in topcoats as weather-resistant colored pigments. Depending on the ease with which a coating system can be separated, topcoats and primer coats may be individually tested for lead or hexavalent chromium, or both.

9.1.3 The presence of lead and hexavalent chromium containing pigments can be qualitatively determined in the field with the following two tests. Both tests can be done directly on the coated surface or on chips or dust of the coating placed in the well of a spot plate.

9.2 *Apparatus*—Glass beakers, jars or bottles, porcelain spot plates, sandpaper, razor blade or knife.

9.3 *Reagents:*

9.3.1 *Sodium Sulfide Powder or Crystals.*

9.3.2 *Hydrochloric Acid*, concentrated.

9.3.3 *Diphenylcarbohydrazide Powder.*

9.3.4 *Phosphoric Acid*, concentrated (85 %).

9.3.5 *Acetone.*

9.3.6 *Denatured Ethanol.*

9.3.7 *Distilled or Deionized Water.*

9.4 *Preparation of Test Solutions:*

9.4.1 A solution of sodium sulfide in water is used to test for presence of lead. Prepare the solution by dissolving 1.5 g of sodium sulfide in 20 mL of distilled water and adding hydrochloric acid dropwise while swirling the solution until a white precipitate forms and remains with continued swirling (pH should be about 8). A proportionally smaller or larger amount of solution can be made up. The solution loses strength with age. Test the solution by placing a drop on a strip of lead acetate paper and observing the paper for the development of the black color of lead sulfide. If color development does not occur, discard the solution and make a fresh one.

9.4.2 A solution of 1,5-diphenylcarbohydrazide is used to test for the presence of hexavalent chromium. Prepare the solution using the following or proportionally smaller amounts of ingredients. Dissolve 0.5 g of 1,5-diphenylcarbohydrazide in a mixture of 20 mL acetone and 20 mL ethanol in a beaker, warming the beaker in warm water if necessary to facilitate solution. Carefully add 20 mL of phosphoric acid to 20 mL of cold distilled water in a separate container. Slowly add the acetone-ethanol mixture to the dilute acid solution and mix thoroughly by swirling. The 1,5-diphenylcarbohydrazide solution is not stable. It may be stored for short periods of time in an opaque glass bottle but is best prepared just prior to use. The solution can be tested by placing a drop on a material known to contain a hexavalent chromium pigment. If a blue to violet color does not rapidly develop in the drop of solution, discard the solution and prepare a fresh solution.

9.5 *Procedure:*

9.5.1 Abrade two separate spots on the coating film with sandpaper or knife if the tests are to be done on the coating surface. Alternatively, abrade one spot of the coating and collect the dust and flakes in two wells of a spot plate. Abrasion of the film is required to expose pigments in an aged, weathered film.

9.5.2 On one abraded spot or on the specimen in one well of the spot plate, place 1 or 2 drops of sodium sulfide solution. Development of a black or dark grey color on the film or flakes indicates the presence of lead. Lack of color development indicates less than 0.1 % by weight lead (approximate practical limit of sensitivity of this test procedure).

9.5.3 Metals other than lead give a positive sulfide test but may not be common to coatings or usually do not interfere in this test in the form present. If there is doubt, laboratory testing beyond the scope of this test method is required to confirm the presence of lead.

9.5.4 On one abraded spot or to the second well of the spot plate place 1 or 2 drops of 1,5 diphenylcarbohydrazide solution. Rapid development of blue to violet color in the solution droplets indicates the presence of hexavalent chromium.

9.6 *Interpretation of Results*—The combination of results from the two tests, together with consideration of the color of the coating, may be used to establish more definitely the pigments that are present, as shown in the following scheme, which is not all inclusive:

Observation	Identification
Positive for lead, negative for chromium	pigment is red lead, white lead, or lead suboxide (white)
Negative for lead, positive for chromium	pigment is zinc or strontium chromate (yellow)
Positive for lead, positive for chromium	chrome yellow, chrome green, chrome orange, or molybdate orange (all color pigments containing lead chromate) or basic lead silichromate (orange-red inhibitive pigment)

10. Precision and Bias

10.1 Precision cannot be determined for these test methods because the variability of coatings on a surface does not permit the collection of reliably uniform samples and because few specimens will be tested from one particular coating.

10.2 Bias cannot be established for these test methods because accepted reference standards are not available.

11. Keywords

11.1 coatings; field; generic resin; identification

Designation: D 5063 – 90

Standard Guide for Use of Certification of Coating Conformance Form[1]

This standard is issued under the fixed designation D 5063; 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 certification of coating conformance form provides procurement information concerning products being furnished in accordance with a specific coating specification and additional requirements contained in the purchase order (see Fig. 1).

1.2 The completed form can be utilized to help evaluate the acceptability of the paint being furnished.

2. Referenced Documents

2.1 *ASTM Standards:*

D 16 Terminology Relating to Paint, Varnish, Lacquer, and Related Products[2]

3. Instructions for Completing Certification Form

3.1 Use only known and industry accepted descriptions. Standard definitions of terms relating to paint, varnish, lacquer, and related materials are provided in Terminology D 16 (see Fig. 2).

3.2 The sections are self-explanatory. Applicable information in Section II should be provided by the buyer. Applicable information in Section III should be provided by the seller.

3.3 For two-component coatings, separate forms should be provided for each component, if appropriate.

4. Keywords

4.1 certification form; conformance form

[1] This guide is under the jurisdiction of ASTM Committee D-1 on Paint and Related Coatings and Materials and is the direct responsibility of Subcommittee D01.45 on Marine Coatings.

Current edition approved May 25, 1990. Published July 1990.

[2] *Annual Book of ASTM Standards*, Vol 06.01.

CERTIFICATION OF COATING CONFORMANCE FORM Number:
Date:

I. GENERAL TYPE AND DESCRIPTION:

Generic Type:
Manufacturer's Designation:
Specification Number:
Formula Number:
Number of Components:
Component Identification (if applicable):
Color:

II. BUYER INFORMATION:

Name and Address:

Purchase Order Number:
Release Number (if applicable):
Part Number (if applicable):
Item Number (if applicable):
Stock Number (if applicable):

III. SELLER INFORMATION:

Name and Address:

Seller's Representative:
(Include Telephone Number)
Batch Number:
Lot No.:
Date of Manufacture:
Date of Expiration of Certification:

IV. CERTIFICATION:

This is to certify that the above material being furnished has been manufactured in accordance with the specification and meets all specification requirements contained in the above purchase order.

NAME AND TITLE _____ SIGNATURE _____ DATE

FIG. 1 Certification Form

CERTIFICATION OF CONFORMANCE FORM Number: A001
Date: 6/26/88

I. GENERAL TYPE AND DESCRIPTION:

Generic Type: Polyamide Epoxy
Manufacturer's Designation: Perfect Paint 1234
Specification Number: MIL-P-24441
Formula Number: Formula 150
Number of Components: Two
Component Identification: Component A
Color: Green

II. BUYER INFORMATION:

Name and Address: American Shipbuilders
1234 Easy St.
Anytown, USA

Purchase Order Number: 0001-0002
Release Number (if applicable): #1
Part Number (if applicable): 11B
Item Number (if applicable): #3
Stock Number (if applicable): 4321

III. SELLER INFORMATION:

Name and Address: Perfect Paint Co.
11 Profit St.
Paint City, USA

Seller's Representative: I.B. Responsive
(Include Telephone Number) 703/123-4567
Batch Number: 88-F-01
Lot Number: 0001
Date of Manufacture: 6/20/88
Date of Expiration of Certification: 6/19/89

IV. CERTIFICATION:

This is to certify that the above material being furnished has been manufactured in accordance with the specification and meets all specification requirements contained in the above purchase order.

I.M. Xpert, Tech Director _____ 6/26/88
NAME AND TITLE SIGNATURE DATE

FIG. 2 Example of Completed Form

Designation: D 5064 – 90

Standard Practice for Conducting a Patch Test to Assess Coating Compatibility[1]

This standard is issued under the fixed designation D 5064; 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 procedures for testing coating compatibility when maintenance of an in-place coating system is being contemplated. It does not cover procedures for assessing the integrity of the existing coating to determine if it can be repainted, nor does it establish the compatibility of the maintenance coating system with the substrate or corrosion products. The practice is intended for use in the field.

NOTE 1—Pass-Fail Criteria (for example, adhesion requirements) are not established by this practice. These should be established by the user or specifier with input from the supplier.

1.2 *This standard does not purport to address the safety problems 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 1186 Test Methods for Nondestructive Measurement of Dry Film Thickness of Nonmagnetic Coatings Applied to a Ferrous Base[2]

D 1400 Test Method for Nondestructive Measurement of Dry Film Thickness of Nonconductive Coatings Applied to a Nonferrous Metal Base[2]

D 3359 Test Methods for Measuring Adhesion by Tape Test[2]

D 4138 Test Method for Measurement of Dry Film Thickness of Protective Coating Systems by Destructive Means[3]

D 4414 Practice for Measurement of Wet Film Thickness by Notch Gages[2]

3. Terminology

3.1 *Definitions*—For definitions of terms used in this practice, refer to the Federation of Societies for Coatings Technology (FSCT) *Paint/Coatings Dictionary*.[4]

4. Summary of Test Method

4.1 The materials under test are applied to the previously painted surface after proper surface preparation. After the appropriate time has elapsed, the test patch is examined for visual defects and adhesion is determined.

5. Significance and Use

5.1 In performing maintenance of a coating system, the new coating being applied must be compatible with the existing coating. While general guides exist which indicate compatibility of different generic types of coatings, differences in manufacturer's formulation and the condition of the in-place coating will affect compatibility.

6. Procedure

6.1 Select test locations for evaluation that properly characterize differences in configuration of the structure and exposure, that is, vertical versus horizontal surfaces and bold versus sheltered exposure. A minimum of three test locations with one test patch in each is recommended.

6.2 The size of each test patch will be determined by the size and configuration of the test locations. Each test patch shall be as large as possible, with a minimum size of 10 ft^2 (0.93 m^2) recommended.

6.3 Clean the surface of the test areas using the methods specified for the maintenance painting procedure (Note 2). Alternative methods of preparation may also be evaluated in separate, adjacent tests.

NOTE 2—This test method assesses compatibility with the existing coating only and does not apply to areas where the substrate is exposed by the methods of preparation.

6.4 Measure the existing coating thickness in accordance with Test Methods D 1186, D 1400, or D 4138, as appropriate for the substrate.

6.5 Measure the ambient conditions and surface temperature and assure the conditions are within the limits specified by the coatings manufacturer for the product being tested.

6.6 Apply the test coating to the thickness recommended for the particular job. Use the application technique as intended for use on the full-scale job. If agreed upon between the purchaser and the seller, the method of coating application may be different from that used on the job, that is, brush application of the test patch even though spray application will be used on the job. However, this can cause some error and is not generally recommended.

6.7 Immediately after application, measure the wet-film thickness in accordance with Practice D 4414. Make corrections to the application, if necessary, by either applying more material if the expected dry-film thickness is low or applying another test patch if the expected dry-film thickness is above the recommended maximum. Inspect each patch for application defects such as runs, sags, and holidays. If such defects cannot be corrected as a part of the initial application process, prepare a new test patch.

6.8 After the coating has dried, measure the dry-film

---

[1] This practice is under the jurisdiction of ASTM Committee D-1 on Paint and Related Coatings and Materials and is the direct responsibility of Subcommittee D01.46 on Industrial Protective Coatings.

Current edition approved May 25, 1990. Published July 1990.

[2] *Annual Book of ASTM Standards*, Vol 06.01.

[3] *Annual Book of ASTM Standards*, Vol 06.02.

[4] *Paint/Coatings Dictionary*, Federation of Societies for Coatings Technology, Philadelphia, PA, 1978.

thickness in accordance with Test Method D 1186, D 1400, or D 4138.

NOTE 3—When using Test Methods D 1186 or D 1400, the dry film thickness is the difference in average thickness of the coating system less the average thickness of the in-place coating.

6.9 Allow the coating to cure or weather prior to testing. Cure durations are defined as long term and short term. Long-term curing provides the most reliable assessment of compatibility. Short-term curing provides for more rapid evaluation of results.

6.9.1 *Long-Term Curing*—Curing for as long a time as possible, with a minimum of six months preferred. Curing should span seasonal weather changes.

6.9.2 *Short-Term Curing*—Curing at the following minimum times based on average daily (24 h) temperatures:

50°F (10°C)	70°F (21°C)	90°F (32°C)
14 days	10 days	7 days

6.10 After curing, examine the total surface of each test patch for wrinkling, blistering, mudcracking, checking, cracking, peeling, lifting, and disbonding. Measure or rate the adhesion in a minimum of five locations per test patch in accordance with Test Methods D 3359.

6.11 Examine the test patches for the defects noted in 6.10 on a regular schedule, discounting rust caused by previous tests such as adhesion measurements and destructive film thickness measurements.

7. Report

7.1 Report the following information:

7.1.1 The identity of the structure tested, the location and size of the test patches, the identity of the test coating, the method and grade of surface preparation, and the method of coating application.

7.1.2 For each test patch, the dry film thickness measurements and average of the in-place coating, the dry film thickness measurements and average of the test coating, the elapsed time for each evaluation, the visual defects noticed, and the results of adhesion tests.

8. Keywords

8.1 coating; coating compatibility; coating test patch; paint; paint compatibility; test patch

Designation: D 5065 – 90

Standard Guide for Assessing the Condition of Aged Coatings on Steel Surfaces[1]

This standard is issued under the fixed designation D 5065; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

1. Scope

1.1 This guide provides general guidelines for a detailed assessment of the condition of aged coatings on steel structures and the extent of rust breakthrough of the coated surface. Additional assessment may be required to support coating failure analyses or other job specific needs.

1.2 This guide does not address the problem of determining the structural condition of a steel substrate. It provides procedures to determine the percent of the surface rusted, but not the severity, condition, or cause of such rusting.

NOTE 1—A more comprehensive condition assessment procedure, Practice F 1133, based upon two sets of visual standards, one for level and one for extent of deterioration, has been developed for determining the condition of coatings on ship hulls.

1.3 *This standard does not purport to address the safety problems 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 610 Test Methods for Evaluating Degree of Rusting on Painted Steel Surfaces[2]

D 660 Test Method for Evaluating Degree of Checking of Exterior Paints[3]

D 714 Test Method for Evaluating Degree of Blistering of Paints[3]

D 1186 Test Methods for Nondestructive Measurement of Dry Film Thickness of Nonmagnetic Coatings Applied to a Ferrous Base[3]

D 3359 Test Method for Measuring Adhesion by Tape Test[3]

D 4214 Test Methods for Evaluating Degree of Chalking of Exterior Paint Films[3]

D 4541 Test Method for Pull-Off Strength of Coatings Using Portable Adhesion Testers[2]

D 5043 Test Methods for Field Identification of Coatings[2]

F 1133 Practice for Inspecting the Coating System of a Ship's Underwater Hull and Boottop During Drydocking[4]

2.2 *Steel Structures Painting Council Standard:*[5]

SSPC-PA-2 Measurement of Dry Paint Thickness with Magnetic Gages

3. Summary of Practice

3.1 This practice for assessing the condition of coatings consists of identifying general types of components of a structure and assessing each separately for commonly occurring modes of coating deterioration and rust breakthrough of the coating using visual standards and simple evaluation tools. A form for recording the results of the assessment procedure (Fig. 1) is provided.

4. Significance and Use

4.1 Assessment of the condition of aged coated surfaces strengthens decisions on when coating maintenance is required, aids in the selection of effective coating maintenance procedures, and provides a means to characterize performance of coating systems.

5. Procedure

5.1 Survey the structure to (*1*) determine the general types of unique components (for example, for fuel tanks the components may be shell, roof, ladders, and piping) and the service exposure environment for each, (*2*) visually identify areas having a typical level of coating deterioration and rust breakthrough for each component and (*3*) identify areas having a much greater visual level of deterioration than typical and unique environmental conditions that may correspond to these areas (for example, bridge expansion joints). Record a description of the components and their general environment on an inspection form and describe areas having greater deterioration, as well as any unique associated environments in the remarks column. A suggested general format for data collection is shown in Fig. 1. Modification of the form (for example, adding or deleting specific items) will be required for each specific application.

5.2 Based upon the knowledge of what constitutes typical deterioration for each component as determined in the initial survey, examine the condition of the coating on a representative sample of each component. Rate the condition of the coatings using the appropriate ASTM visual standard for rust breakthrough (Test Methods D 610), blistering (Test Method D 714), peeling (use Test Methods D 610 to report amount), chalking (Test Methods D 4214), and cracking/checking (Test Method D 660) of the coating film. Record the rating in the appropriate column of the report form for each

[1] This guide is under the jurisdiction of ASTM Committee D-1 on Paint and Related Coatings and Materials and is the direct responsibility of Subcommittee D01.46 on Industrial Protective Coatings.

Current edition approved May 25, 1990. Published July 1990.

[2] *Annual Book of ASTM Standards*, Vol 06.02.

[3] *Annual Book of ASTM Standards*, Vol 06.01.

[4] *Annual Book of ASTM Standards*, Vol 01.07.

[5] Available from Steel Structures Painting Council, 4400 Fifth Ave., Pittsburgh, PA 15213.

Condition Assessment

Structure _____ Date _____ Inspector _____ Overall Environment _____

Original Coating System	1st Maintenance Coating System	2nd Maintenance Coating System
Surface Preparation _____	Surface Preparation _____	Surface Preparation _____
Year Applied _____	Year Applied _____	Year Applied _____
Primer _____	Primer _____	Primer _____
Midcoat _____	Midcoat _____	Midcoat _____
Midcoat _____	Midcoat _____	Midcoat _____
Topcoat _____	Topcoat _____	Topcoat _____

Structure	Description	Ratings						Measurements		
Component	Local Environment	Rust[A]	Under film Condition[A]	Peeling	Blistering	Cracking	Chalking	Thickness	Adhesion	Remarks

[A] Rusting corresponds to Test Methods D 610, that is, that observed upon visual inspection of the coated surface while underfilm condition corresponds to substrate condition under an intact coating as described in Section 4.

FIG. 1 Example 1 Report Form

component. Determine and record the type of peeling, for example, intercoat delamination. Rate the condition in enough areas to ensure that for each component the coating evaluation is representative of the condition over the entire structure. If additional areas of greater deterioration are detected during this assessment, make note of them in the remarks column.

NOTE 2—For the purpose of an initial general assessment, cracking and checking can be assessed as one type of failure, using the pictorial standards in Test Method D 660 to define type and extent.

5.3 When rusting beneath an intact coating film is suspected, examine the condition of the underlying substrate. Remove apparently intact coatings using chemical strippers or closely spaced parallel knife cuts. For structural steel, determine the type of previous surface preparation from the presence of millscale or profile. Identify evidence of corrosion from the presence of pits, black anodic spots or corrosion scale, or from results of a test for ferrous ion using potassium ferriferrocyanide paper. Record the results of the examination on the report form.

5.4 Using one of the procedures described in Test Methods D 1186, determine the coating thickness in enough areas of each component to ensure a representative measure. Record the measured thicknesses.

5.5 Using one of the procedures described in Test Methods D 3359 or D 4541, determine coating adhesion in enough areas of each component to ensure a representative measure. Record the adhesion reading and the type of procedure and equipment used.

NOTE 3—The number of areas in which coating thickness and adhesion is measured will depend upon the desired precision of the measurement. More measurements would be made on structures in which precise knowledge of the thickness and adhesion of the coating is required. SSPC-PA-2 states the required number of thickness measurements as a function of coating area for conformance of thickness to a specification.

5.6 If required for a maintenance decision, identify the generic type(s) of the existing coating film component from records or using the procedure in Test Method D 5043. To the extent possible, each layer of the film should be characterized.

6. Report

6.1 Prepare an inspection report. Figure 1 provides an example of the types of information to be included.

7. Keywords

7.1 assessment; coatings; condition; field; paint; weathered

Designation: D 5066 – 91

Standard Test Method for Determination of the Transfer Efficiency Under Production Conditions for Spray Application of Automotive Paints—Weight Basis[1]

This standard is issued under the fixed designation D 5066; 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 provides procedures for determination of the transfer efficiency (using a weight method) under production conditions for in-plant spray application of automotive paints.

1.2 The transfer efficiency is calculated from the weight of the paint solids sprayed and that deposited on the painted part. The recommended approach involves painting the part directly. Also described is an alternative approach for painting parts covered with aluminum foil.

1.3 *This standard does not purport to address all of the safety problems, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.* Specific hazard statements are given in 10.9.

2. Referenced Documents

2.1 *ASTM Standards:*

D 1475 Test Method for Density of Paint, Varnish, Lacquer, and Related Products[2]

D 2369 Test Methods for Volatile Content of Coatings[2]

2.2 *USEPA/MVMA (Motor Vehicle Manufacturers Association) Standards:*

EPA 450/3-88-018, U.S. Environmental Protection Agency Protocol for Determining the Daily Volatile Organic Compound Emission Rate of Automobile and Light Duty Truck Topcoat Operations,[3]

EPA Federal Reference Method 24—Determination of Volatile Matter Content, Water Content, Density, Volume Solids, and Weight Solids, of Surface Coatings[4]

3. Terminology

3.1 *Descriptions of Terms Specific to This Standard:*

3.1.1 *paint*—the liquid material that is applied onto the part to cover or coat the surfaces.

3.1.2 *transfer efficiency*—the ratio of the weight of paint solids deposited to the total weight of paint solids used during the application process, expressed as a percent.

3.1.3 *paint weight solids content*—the weight of the nonvolatile materials in the liquid paint material divided by the total weight of the paint, times 100, determined by Test Method D 2369.

3.1.4 *paint density*—the mass of a unit volume of the liquid paint material at any given temperature, determined by Test Method D 1475.

3.1.5 *satellite paint supply system*—a smaller, paint-circulating system separate from the main production paint-circulating supply system capable of supplying paint under the same conditions.

4. Summary of Test Method

4.1 The weight of the part to be painted is determined before and after the paint application process. The weight of liquid paint used per part is determined from material usage and part processing records. The determined weight solids content of the paint material is determined and used to calculate the paint solids sprayed per part. The transfer efficiency of the process is calculated by dividing the weight of paint solids deposited by the weight of the paint solids sprayed.

5. Significance and Use

5.1 This test method is specifically directed at the spray painting of automobile car and light duty truck bodies. The general principles are applicable to the painting of other automotive parts.

5.2 This test method may also be used to measure transfer efficiency in full-sized painting facilities simulating production conditions and operations.

6. Interferences

6.1 Limitations include the ability of the weighing device to determine accurately the weight of the paint solids deposited on the part and the capability of accurate measurement of the amount of paint sprayed (see Section 7).

6.2 It may be difficult to cover the surface of complex shaped parts with aluminum foil (see 11.6.11).

7. Apparatus

7.1 *Tension Load Cells*, with upper/lower transition pieces.

7.1.1 1500-lb (682 kg) capacity with 0.05-lb (0.02 kg) precision for weighing automobile body and support frame.

---

[1] This test method is under the jurisdiction of ASTM Committee D-1 on Paint and Related Coatings and Materials and is the direct responsibility of Subcommittee D01.55 on Factory Applied Coatings on Preformed Products.

Current edition approved May 15, 1991. Published July 1991. Originally published as D 5066 – 90. Last previous edition D 5066 – 90.

[2] *Annual Book of ASTM Standards*, Vol 06.01.

[3] Available from Superintendent of Documents, U.S. Government Printing Office, Washington, DC 20402. Refer to EPA 450/3-88-018 dated December 1988. This protocol makes reference to the determination of production spray transfer efficiency.

[4] Available from Superintendent of Documents, U.S. Government Printing Office, Washington, DC 20402. Refer to CFR 40, Part 60, Appendix A.

7.1.2 500 to 800-lb (227 to 364-kg) capacity with 0.05-lb (0.02 kg) precision for weighing mix tanks or automobile components.

7.1.3 A safety cable is required for upper to lower transition.

7.2 *Electronic Digitizer/Readout*, readability of 0.05 lb (0.02 kg) and special filtering.

7.2.1 The electronic digitizer/readout shall meet OIML (International Organization of Legalized Metrology) specifications.[5]

7.3 *Voltage Regulator.*

7.4 *Swivel Devices*, as required.

7.5 *Rule and Calipers* for measuring diameter of paint supply tank shaft, etc.

7.6 *Sample Containers*, clean and airtight for paint material.

7.7 *Lifting Device and Support Frame Apparatus* to lift body.

7.7.1 Total weight must not exceed capacity of load cell or scale.

7.8 *Standard Calibration Weight*, approximately 2 lb (0.9 kg).

7.9 *Measure Stick*, Starret precision spring tempered, satin chrome finish, 36 in. (91.4 cm), with 4R graduations, or equivalent.

8. Paint Usage Measurement Procedures

8.1 Transfer efficiency measurement requires that accurate measurements be made of the quantity of paint material used in the application process during the time period associated with the coating of specific vehicles or parts. Two general procedures are applicable for accurately measuring paint usage.

8.1.1 The preferred procedure is to determine the weight of paint used during the application study period. Under typical production conditions, such weighing may be difficult, due to the large number of applicators requiring paint supply from a common tank. If a separate, isolated paint supply tank is used in the test; it is important to control paint viscosity, temperature, and flow rate consistent with the regular production system (see 9.1).

8.1.2 Where direct paint usage measurement by weight is not practical, an alternative procedure for determining paint usage by volume is suggested. This procedure involves measuring the drop in paint level in the paint supply tank during the test. To provide sufficient accuracy, it may be necessary to paint a "block" (isolated group) of similar vehicles or parts from the paint supply system while usage measurements are taken.- Typically, this may require painting approximately 30 vehicles (see 9.2).

9. Paint Usage Determination by Weight Procedure

9.1 This procedure for determining paint usage during the test is preferred when a satellite paint supply system is available for the process to be tested. With this procedure, it is usually easier to isolate paint usage for measurement purposes, and accurate results can be obtained with a smaller number of vehicles or parts (see 9.1.1).

9.1.1 At least 5.0 lb (2.27 kg) of paint material must be used during the test with the specified weighing equipment.

9.2 Before a satellite paint supply system can be used, it must be demonstrated that the system is capable of supplying the paint at sufficient volume and pressure to maintain normal process conditions (fluid deliveries of the spray devices) and that the paint can be maintained at a representative temperature and viscosity for the duration of the test period. These requirements can best be assured by mounting the satellite tank on a load cell or scale and directly piping it into the production supply system of the spraybooth. For this procedure the requirements are as follows:

9.2.1 Level and calibrate a weighing device (see Section 7) for weighing the satellite supply tank.

9.2.2 If an electronic weighing device is used, it must be turned on long enough to achieve stability, following the manufacturer's directions. All weighing devices must be situated to minimize disturbance from vibration or air movement.

9.2.3 Introduce the paint material, reduced to spraying viscosity, into the tank to be weighed. Before the test is conducted, be certain that fluid flows are properly set, that all supply and return lines are filled with the paint, and that no leaks are present in the piping system.

9.2.4 Shut off the agitator to minimize vibration during the weighing of the system.

9.2.5 Calibrate the weighing device in accordance with manufacturer's instructions. Weigh and tare a lifting frame, if used to support the satellite paint supply tank.

9.2.6 Weigh the satellite paint supply tank before the test vehicles or parts are run. Flexible connections are required to minimize strain. Carefully note the configuration of the tank so that the same configuration is used for both initial and the final weighing (that is, hose connections, height, etc.). Weigh the tank until 2 consecutive measurements are obtained within the measurement error of the weighing system ±0.05 lb (0.02 kg). Average the two readings. The satellite tank may be left on the weighing device during the painting operation to monitor painting usage on a continuous basis.

9.2.7 After painting the test vehicles or parts, reweigh the satellite paint supply tank in accordance with 9.2.5 and 9.2.6.

9.2.8 Obtain representative paint samples immediately after completion of the test for solids and density analysis.

10. Paint Usage Determination by Tank Level Measurement (Volume Procedure)

10.1 This procedure for determining the paint usage requires that the drop in the liquid level in the system supply tank be measured accurately. This procedure is applicable with either a satellite system or a main-mix room supply system. A sufficient number of parts must be processed in the test block to provide at least a 3-in. (7.6-cm) drop in the liquid level in the paint supply tank. Careful measurement is critical to the overall accuracy of the transfer efficiency test. This procedure consists of the following:

10.1.1 Accurately measure the inside diameter of the paint supply tank(s) to be used for the various test materials. If the agitator shafts, fill pipes, or any other objects are located in the measurement zone, the occupied volume of

[5] Electronic digitizer, Model 5322, available from Sterling Scale Co., 20950 Boening, Southfield, MI 48075, has been found suitable for this purpose.

these items must be determined and subtracted from the total volume. Careful selection of the section of the tank for the test measurement will minimize the difficulty of this task. The measurements are used to develop a conversion factor between level drop and volume of paint.

10.1.2 Most main paint supply systems consist of two tanks connected together to maintain the material supply. During the test, the paint supply tank must be isolated. Check to ensure that there is no leakage or overflow between the two tanks and that the directional valves for paint return function properly. Make sure that these checks are made just prior to and after the test, and are done by measuring the volume in both tanks.

10.1.3 Place the test paint, which has been reduced to spraying viscosity, into the paint supply tank to be measured. No material additions or reductions may be made to the tank during the test. Before the test is conducted, make certain that valving is set so that paint is being drawn from the test tank and returned to the test tank, and that all air has been removed from the delivery system.

10.1.4 With satellite paint supply tank systems, special care must be taken to ensure that all fluid lines are completely filled.

10.1.5 Prior to taking the volume measurement, turn off any agitation within the tank that will interfere with the measuring process and then turn it back on after the measurement.

10.1.6 Record the tank levels before and after the test. Take the initial reading just prior to the first test vehicle or part of the block that enters the first application station in the tested process. Take the final reading just after the last vehicle or part has left the last application area in the tested process.

10.1.7 With clearcoat (or other paint materials that cannot be isolated to a specific block of cars due to other connected operations such as repair), take the initial reading as the first vehicle or part in the test block enters the first station applying clearcoat. Take the final reading when the vehicle after the last job in the test block enters the first station, applying clearcoat (the same point at which the initial reading was taken). If this is not done, the block size for clearcoat will be different from the block size for basecoat (this is acceptable but must be accurately reflected in the calculations).

10.1.8 The measurements are to be taken to the nearest 1/16 in. with a measuring stick with 1/16-in. (1.6-mm) or less graduations. Measurements are made from the top of the tank to the top of the liquid level at least 3 to 4 in. (7.6 to 10.2 cm) from the sides of the tank. The top of the tank is to be determined by laying a straight edge across the top of the tank in the same position for each measurement.

NOTE—**Caution**—Any measuring instruments used in this procedure must be effectively grounded before contacting the coating tank or coating liquid surface. Review all measuring instruments for suitability and resistance to the paint solvents prior to the test.

10.1.9 It may be necessary to provide two-way radio communication between the mix-room monitor and the tested process operation to coordinate the measurement process and timing.

10.1.10 Obtain representative paint samples immediately after completion of the test for density and solids determinations.

11. Paint Solids Deposited Measurement Procedure

11.1 To determine the transfer efficiency, it is necessary to determine both the weight of paint solids sprayed per vehicle or part and the weight of paint solids actually deposited onto the object in the tested process. These are obtained by weighing vehicles or parts incorporated in the same sample (block) used to obtain the paint usage measurement.

11.2 *Vehicle or Part Weighing Procedure*—The weight of paint solids deposited during the application process is determined by weighing the vehicle(s) or part(s) prior to and after the paint is applied and baked. At least two vehicles or parts are required to be tested. A control part is also run and weighed before and after the application process. No paint is applied to the control part in the process. The control is required to determine weight loss from miscellaneous materials (primarily sealants and plastics applied prior to the tested process) that may occur in the drying oven. The difference in the weight of the measurement vehicles adjusted for the weight loss in the control vehicle or part, is the weight of paint solids applied in the tested process.

11.3 Weighing of the parts requires the use of a precision weighing device and digitizer as described in 7.1 and 7.2. A lifting frame and hoist are required to support the test vehicle. The measurement site(s) must be selected to avoid disturbance caused by air movement or production activities and to allow convenient removal of the test vehicles or parts from the production line and their subsequent replacement to the production line. Fork trucks or other mechanical handling aids along with sufficient manpower to move the vehicle bodies into and out of the weighing frame will be required.

11.3.1 Passenger car bodies generally will weigh 800 to 900 lb (364 to 409 kg). Since the maximum capacity of the specified load cell is 1500 lb (682 kg), the weight of the lifting frame and rigging must be kept to less than 600 lb (273 kg) or a higher capacity load cell with the specified accuracy must be utilized.

11.4 It is critical that the vehicles or parts be allowed to cool completely to room temperature prior to weighing. Closely monitor heavy metal sections (usually around the door frames) as these areas will cool more slowly than exterior body surfaces. If during the weighing process there is any doubt that the vehicle or part is fully cooled, weigh the test part and allow it to stand 15 to 20 min and weigh again. If a weight increase of more than 0.05 lb (0.02 kg) is noted, allow the body to cool an additional 15 to 20 min and repeat the weighing procedure. Repeat this process until consistent weights are obtained.

11.5 Check that all accessories and miscellaneous materials (hangers, spacers, etc.) remain in the same position (either on or off) for both the initial and final weighings.

11.6 *Weighing Procedure:*

11.6.1 Turn on the weighing device and digitizer and allow them to warm up in accordance with the manufacturer's instructions.

11.6.2 Zero the instrument in accordance with manufacturer's instructions.

11.6.3 Attach the lifting frame to the load cell. Lift and

weigh the frame until two consecutive readings within 0.05 lb (0.02 kg) are obtained. Record this tare weight, W_t.

11.6.4 Mount a completely cooled vehicle or part into the lifting frame. Lift the test unit until it is completely clear of the carrier and fully suspended by the load cell. If the test unit does not hang level, adjust the suspension point on the lifting frame and recheck for proper tare weight. If necessary, the calibration weights may be used to help level the test unit, but be certain to include this weight in the initial weight.

11.6.5 Allow the suspended vehicle or part to completely stabilize (usually 2 to 3 min). Be certain that nothing is touching the test unit or suspension frame and record the weight.

11.6.6 Add a standard calibration weight to the suspended vehicle or part and check for instrument accuracy. Recalibrate the system if a discrepancy is noted.

11.6.6.1 Select the calibration weight to represent the estimated increase in weight of the vehicle or part in the painting process.

11.6.7 Lower the vehicle or part back onto the carrier to remove the weight from the load cell. Relift the vehicle or part and weigh as just indicated until two consecutive weights within 0.05 lb (0.02 kg) are obtained. Record the average of two consecutive initial weights, that is W_i for part (1) and $W_{c,i}$ for the control.

11.6.8 Remove the first body and repeat 11.6.5 through 11.6.7 for the other vehicles and the weight loss control vehicle (if included in this test run). Between test measurements and after the last unit is weighed, resuspend the empty lifting frame and verify the tare weight, W_t.

11.6.9 Apply the paint to the specified vehicles or parts, allowing the control unit to proceed through the spraybooth and oven uncoated.

11.6.9.1 Considerable care must be taken in handling the weighed units to eliminate any weight gain or loss due to handling, parts addition, parts removal, or miscellaneous debris.

11.6.10 After the vehicles or parts have been painted and cured in the oven, allow them to cool to room temperature prior to reweighing. Repeat the weighing procedure in 11.6.1. through 11.6.8 and record the weights, $W_{l,f}$ for the coated part (1) and $W_{c,f}$ for the control.

11.6.11 *Foiled Part Procedure*—The procedure is identical to that described in 11.2 except that aluminum foil is preapplied to the vehicle or part. All the surfaces to be painted are covered with foil as smoothly and tightly as possible to ensure that the covered surface is representative of the area painted in the normal production environment.

12. Measurement of Other Paint Usage

12.1 When the measurement of paint used cannot be completely isolated to the application process under test because of the process and facilities arrangement, it may be necessary to obtain an estimate of paint solids deposited from the same paint supply system in the nonisolated operations (such as repair, etc.). With this estimated value, the total paint solids deposited in the main process can be directly correlated to the amount of paint used in calculating the resultant transfer efficiency. Such a correlation can be established by either making a separate estimate or measurement of the paint used or the paint solids deposited outside the tested process. The amount of material involved should be small (less than 5 %) relative to the total paint used or deposited.

12.2 While an estimate of paint used is generally preferred, in practice it is usually easier to obtain an estimate of the amount of paint solids deposited onto the test unit. For repair type operations, an estimate of paint solids applied may be obtained by counting the number of panels repaired while the test block is being processed and multiplying by the square feet per panel and the average film build applied (determined from measurements or historical data). This technique works well since almost all repairs involve complete body panels for which data can readily be obtained.

13. Analysis of Paint Samples

13.1 Make the following analytical determinations for each paint sample obtained:

13.1.1 *Weight Fraction Solids*, in accordance with Test Method D 2369 per EPA Federal Reference Method 24.

13.1.2 *Paint Density*, in accordance with Test Method D 1475.

13.2 These determinations are required to calculate transfer efficiency. Obtain separate determinations for each paint material used in each test.

14. Calculations and Report Submission

14.1 Upon completion of the test and receipt of the paint analytical results, the transfer efficiency calculations can be made in accordance with the following procedure:

14.2 Calculate the average weight gain of the vehicle or part, corrected for the weight gain or loss of the control unit.

$$G_{avg} = \frac{\text{Sum}[W_f - W_i]}{n} - [W_{c,f} - W_{c,i}] \quad (1)$$

where:

G_{avg} = average weight gain, lb (kg),
W = weight, lb (kg),
W_f = final weight, lb (kg),
W_i = initial weight, lb (kg),
n = number of test units coated,
c = control,
$W_{c,p}$ = final weight of control vehicle or part, lb (kg), and
$W_{c,i}$ = initial weight of control vehicle or parts, lb (kg).

14.3 Calculate the average amount of paint used during the test period by either the weight procedure or the volume procedure.

14.3.1 *Weight Procedure* (see Section 9):

$$P_{avg} = [P_i - P_f]/m \quad (2)$$

where:

P_{avg} = average weight of paint used during the test, lb (kg),
P_i = initial weight, lb (kg),
P_f = final weight, lb (kg), and
m = number of units measured.

14.3.2 *Volume Procedure* (see Section 10):

$$P_{avg} = (V \times P)/m \quad (3)$$

where:

V = volume of paint used during the test,
D = paint density in accordance with Test Method D 1475, and
m = number of units measured.

14.4 Calculate the average paint solids used during the test period.

$$S_{avg} = P_{avg} \times F \quad (4)$$

where:

S_{avg} = average weight of paint solids used during the test, lb (kg), and

F = weight fraction solids in the paint material from Test Method D 2369.

14.5 Calculate the transfer efficiency T result.

$$T = G_{avg}/S_{avg} \times 100 \quad (5)$$

15. Precision and Bias

15.1 *Precision*—Engineering estimates based on error assumptions indicate an accuracy of ±5 % can be expected for typical automotive painting operations.

15.2 *Bias*—Since there is no accepted reference procedure suitable for determining the bias for this test method, no statement on bias is being made.

16. Keywords

16.1 automotive painting; production method; spray-applied; transfer efficiency

Designation: D 5067 – 90[ε1]

Standard Specification for Artists' Watercolor Paints[1]

This standard is issued under the fixed designation D 5067; 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.

[ε1] NOTE—Table X1.1 was editorially corrected in March 1991.

1. Scope

1.1 This specification establishes requirements for composition, physical properties, performance, and labeling of artists' watercolor paints.

1.2 This specification covers pigments, vehicles, and additives. Requirements are included for pigment identification, lightfastness, and consistency.

1.3 Table 1 lists some pigments meeting the lightfastness requirements in this specification. In order to identify other pigments that meet these requirements, instructions are given for test specimen preparation. Test methods for determining relative lightfastness are referenced.

2. Referenced Documents

2.1 *ASTM Standards:*

D 185 Test Methods for Coarse Particles in Pigments, Pastes, and Paints[2]

D 1210 Test Method for Fineness of Dispersion of Pigment-Vehicle Systems[3]

D 4236 Practice for Labeling Art Materials for Chronic Health Hazards[4]

D 4303 Test Methods for Lightfastness of Pigments Used in Artists' Paints[4]

E 284 Terminology of Appearance[3]

3. Terminology

3.1 *Definitions:*

3.1.1 *Colour Index Name*—consists of the category (type of dye or pigment), general hue, and an assigned number given to a colorant in the Colour Index[5] as an international identification system.

3.1.1.1 *Discussion*—For example, the Colour Index Name of one phthalocyanine blue pigment is Pigment Blue 15 (PB 15).

3.1.2 *Colour Index Number*—a five-digit number given in the Colour Index that describes the chemical constitution of a colorant.

3.1.2.1 *Discussion*—For example, the Colour Index Number of one phthalocyanine blue pigment is 74160.

3.1.3 Appearance terms used in this standard are defined in Terminology E 284.

3.2 *Descriptions of Terms Specific to this Standard:*

3.2.1 *watercolor paint*—a pigment dispersion in a water soluble gum/resin vehicle that dries water soluble and is intended primarily for transparent applications.

4. Significance and Use

4.1 This specification establishes quality requirements and provides a basis for common understanding among producers, distributors, and users.

4.2 It is not intended that all paints meeting the requirements be identical nor of uniform excellence in all respects. Variations in manufacture, not covered by this specification, may cause some artists to prefer one brand over another, either of which may be acceptable under this specification.

5. Labeling Requirements

5.1 *Pigment(s) Identification:*

5.1.1 Every label shall include for each pigment contained in the paint (*1*) the information underlined in Table 1 (which includes the Common Name, Colour Index Name, and any additional terms necessary to identify the form of the pigment) and (*2*) the appropriate Lightfastness Category.

5.1.2 The complete pigment identification given in Table 1, which also includes the Colour Index Number and a simple chemical description, shall be given in an appropriate producer publication. Manufacturers are encouraged to put this complete identification on the container label when label size permits.

5.1.3 The Common Name shall be placed on the front of the label and shall be the name of the paint except as described in 5.1.5 and 5.1.6. Other identification may be placed elsewhere on the container.

5.1.4 The Colour Index Name may be spelled out in full or abbreviated depending on the size of the label. Example: Pigment Blue 15, or Pig. Blue 15 or PB 15.

5.1.5 *Substituted Pigments*—In the case of substituted pigments, the word "Hue" in equal size letters shall follow in the title, on the front of the tube, immediately after the name of the pigment that has been simulated. Directly below the title, the Common Name of the significant pigment used shall be given in letters no less than the next type size smaller than the title. For example:

COBALT BLUE HUE
(ULTRAMARINE BLUE).

5.1.6 Proprietary names or optional names may be used

[1] This specification is under the jurisdiction of ASTM Committee D-1 on Paint and Related Coatings and Materials and is the direct responsibility of Subcommittee D01.57 on Artist Paints and Related Materials.

Current edition approved May 25, 1990. Published September 1990.

[2] *Annual Book of ASTM Standards*, Vol 06.03.

[3] *Annual Book of ASTM Standards*, Vol 06.01.

[4] *Annual Book of ASTM Standards*, Vol 06.02.

[5] *Colour Index*, 3rd ed., The Society of Dyers and Colourists, London, 1971–75, five vols and revisions. Available from the American Association of Textile Chemists and Colorists, PO Box 12215, Research Triangle Park, NC 27709.

TABLE 1 Suitable Pigments List

NOTE—Underlined information and the lightfastness category in the table shall be included on every label.

Key:

Lightfastness Category:

Lightfastness I Excellent Lightfastness
Lightfastness II Very Good Lightfastness

Abbreviations Used for Colour Index Names:

NR Natural Red
PB Pigment Blue
PBk Pigment Black
PBr Pigment Brown
PG Pigment Green
PO Pigment Orange
PR Pigment Red
PV Pigment Violet
PW Pigment White
PY Pigment Yellow

Pigment Notations:

(CC) Concentrated cadmium pigments may contain up to 15 % barium sulfate for color control. Cadmium-barium pigments contain a much higher amount of barium sulfate.
(NA) Colour Index name or number not assigned.
(SM) Sensitive to moisture in direct sunlight.

Colour Index Name	Lightfastness Category Watercolors	Common Name and Chemical Class	Colour Index Number
		YELLOWS	
PY 3	II	Arylide Yellow 10G, with option of adding the name Hansa Yellow Light, arylide yellow	11710
PY 31	I	Barium Chromate Lemon, barium chromate	77103
PY 34	I	Chrome Yellow Lemon, lead chromate and lead sulfate	77600
PY 35	I	Cadmium Yellow Light, concentrated cadmium zinc sulfide (CC) (SM)	77205
PY 35:1	I	Cadmium-Barium Yellow Light, cadmium zinc sulfide coprecipitated with barium sulfate (SM)	77205:1
PY 37	I	Cadmium Yellow Medium or Deep, concentrated cadmium sulfide (CC) (SM)	77199
PY 37:1	...	Cadmium-Barium Yellow Medium or Deep, cadmium sulfide coprecipitated with barium sulfate (SM)	77199:1
PY 40	II	Aureolin, with option of adding the name Cobalt Yellow, potassium cobaltinitrite	77357
PY 42	I	Mars Yellow, with option of adding the name Yellow Iron Oxide, synthetic hydrated iron oxide	77492
PY 42	I	Mars Orange, synthetic hydrated iron oxide	77492
PY 43	I	Yellow Ochre, natural hydrated iron oxide	77492
PY 97	II[A]	Arylide Yellow FGL, arylide yellow	11767
		ORANGES	
PO 20	I	Cadmium Orange, concentrated cadmium sulfo-selenide (CC)	77202
PO 20:1	I	Cadmium-Barium Orange, cadmium sulfo-selenide coprecipitated with barium sulfate	77202:1
PO 62	I	Benzimidazolone Orange H5G, monoacetolone	NA
		REDS	
PR 101	I	Indian Red, synthetic red iron oxide (bluish hue)	77491
PR 101	I	Light or English Red Oxide, synthetic red iron oxide (yellowish hue)	
PR 101	I	Mars Red, with option of adding the name Red Iron Oxide, synthetic red iron oxide	77491
PR 101	I	Mars Violet, with option of adding the name Violet Iron Oxide, synthetic iron oxide (violet hue)	77015
PR 101	I	Venetian Red, synthetic iron oxide (yellowish hue)	77491
PR 104	I	Chrome Orange, lead chromate and lead molybdate	77605
PR 108	I	Cadmium Red Light, Medium, or Deep, concentrated cadmium-seleno sulfide (CC)	77202:1
PR 108:1	I	Cadmium-Barium Red Light, Medium, or Deep, cadmium seleno-sulfide coprecipitated with barium sulfate	77202:1
		PURPLES	
PV 14	I	Cobalt Violet, cobalt phosphate, cobalt ammonium phosphate	77360 77362
PV 15	I	Ultramarine Red, complex silicate of sodium and aluminum with sulfur	77007
PV 15	I	Ultramarine Violet, complex silicate of sodium and aluminum with sulfur	77007
PV 16	I	Manganese Violet, manganese ammonium pyrophosphate	77742
PV 19	II[A]	Quinacridone Violet, quinacridone violet b	73900
		BLUES	
PB 15	II[A]	Phthalocyanine Blue, copper phthalocyanine	74160
PB 27	I	Prussian Blue, with the option of adding the name Milori Blue, ferriammonium ferrocyanide	77510
PB 28	I	Cobalt Blue, oxides of cobalt and aluminum	77346
PB 29	I	Ultramarine Blue, complex silicate of sodium and aluminum with sulfur	77007
PB 33	I	Manganese Blue, barium manganate with barium sulfate	77112
PB 35	I	Cerulean Blue, oxides of cobalt and tin	77368
PB 36	I	Cerulean Blue, Chromium, oxides of cobalt and chromium	77343
		GREENS	
PG 7	I	Phthalocyanine Green, chlorinated copper phthalocyanine	74260
PG 17	I	Chromium Oxide Green, anhydrous chromium sesquioxide	77288
PG 18	I	Viridian, hydrous chromium sesquioxide	77289
PG 19	I	Cobalt Green, oxides of cobalt and zinc	77335

TABLE 1 *Continued*

Colour Index Name	Lightness Category Watercolors	Common Name and Chemicald Class	Colour Index Number
		BROWNS	
PBr 7	I	Burnt Sienna, calcined natural iron oxide	77492
PBr 7	I	Burnt Umber, calcined natural iron oxide containing manganese	77492
PBr 7	I	Raw Sienna, natural iron oxide	77492
PBr 7	I	Raw Umber, natural iron oxide containing manganese	77492
		BLACKS	
PBk 6	I	Lamp Black, nearly pure amorphous carbon	77266
PBk 7	I	Carbon Black, nearly pure amorphous carbon	77266
PBk 8			
PBk 9	I	Ivory Black, amorphous carbon produced by charring animal bones	77267
PBk 19	I	Gray Hydrated Aluminum Silicate, hydrated aluminum silicate	77017
		WHITES	
PW 4	I	Zinc White, zinc oxide with option of adding the name Chinese White	77947

[A] These pigments were put into the lightfastness II category pending results of retesting.

provided the Common Name(s) given in Table 1 appears on the front of the label directly under the proprietary or optional name in letters no less than the next type size smaller than the proprietary or optional name.

5.1.7 *Mixed Pigments*—Artists' paints containing more than one colorant comply with this specification if all colored pigments used are on the suitable pigment list (Table 1) and provided the mixture itself has passed all other test requirements in this specification. The lightfastness category shall be that of the least lightfast pigment. This lightfastness category may be changed if these paints are tested for lightfastness in accordance with Test Methods D 4303 and results indicating a different category are submitted to ASTM Subcommittee D01.57 for evaluation.

5.2 Provide on the label the identification of the gum/resin used.

5.3 *Lightfastness*—The label shall contain the word "Lightfastness" followed by the appropriate rating, I or II, as given for each pigment in Table 1.

5.3.1 Lightfastness I pigments, when made into paint specimens as described in Section 7 and exposed, tested, and rated in accordance with Test Methods D 4303, shall have a color difference (ΔE^*_{ab}) of 4 or less CIELAB units between the specimens measured before and after exposure.

5.3.2 Lightfastness II pigments, when made into paint specimens as described in Section 7 and exposed, tested, and rated in accordance with Test Methods D 4303, shall have a color difference (ΔE^*_{ab}) of more than 4.0 but not more than 8.0 CIELAB units between the specimens measured before and after exposure.

5.3.3 Pigments were placed in a lightfastness category on the basis of either known historical performance in art works or the ratings from four lightfastness tests conducted as described in Test Methods D 4303. Results from further tests on these, or other pigments, are solicited by Subcommittee D01.57.

5.3.3.1 The lightfastness category of a pigment shall be changed if results from several further tests conducted in accordance with Test Methods D 4303 and approved by ASTM Subcommittee D01.57, establish a different lightfastness category than the one given in Table 1.

5.3.3.2 Additional pigments shall be placed in Table 1 after they have been tested for lightfastness in accordance with Test Methods D 4303 and the test results submitted to ASTM Subcommittee D01.57 for evaluation, provided the results demonstrate that the pigments have the lightfastness ratings required for Lightfastness I or Lightfastness II, as described above.

5.3.4 For information and to establish nomenclature, pigments in Lightfastness III category are given in Table X1.1 in Appendix X1, but are not to be used in paint conforming to this specification. These pigments have a color difference before and after exposure of more than 8.0 but not more than 16.0 CIELAB units.

5.4 *Toxicity*—All products and labeling must conform to the Federal Hazardous Substances Act and to Practice D 4236.

5.5 *Statement of Conformance*—"Conforms to ASTM Specification D 5067," or "Conforms to ASTM D 5067," or "Conforms to the quality requirements of ASTM D 5067." This statement may be combined with other conformance statements, such as, "Conforms to the quality and health requirements of ASTM Specification D 5067 and Practice D 4236."

5.6 *Address*—Include on the label (*1*) the name and address of the manufacturer or importer and (*2*) the country of manufacture.

6. Quality Assurance for Artists' Watercolor Paints

6.1 *Conditions not Covered in This Specification That Affect Artists' Watercolor Paints:*

6.1.1 *Substrate*—The effective pH of the paper used will affect the long-term color of the applied watercolor.

6.1.2 *Environmental Conditions*—Factors such as temperature, humidity, airflow, and light conditions affect application properties, drying time, and adhesion.

6.1.3 *Storage*—With aging and elevated temperatures there may be a change in consistency and a discernible separation of vehicle.

6.2 *Vehicles*—Only water soluble gums/resins shall be used.

6.3 *Pigments*—Pigments used in watercolors shall be limited to those in Table 1. Their lightfastness rating shall be the numeral given in the same row.

6.4 *Additives*—Thickeners, preservatives, surfactants, and humectants may be used to achieve consistency, prevent

microbe deterioration, and control application results.

6.5 *Inerts*—Inerts shall only be used to produce desirable working qualities.

6.6 *Preparation of Sample*—For paste and fluid paints, empty the contents of the previously unopened container onto a glass slab and mix thoroughly with a spatula to a homogeneous sample. For cake paints, take a piece of the cake on a glass slab and add water and mix until a homogeneous paint is formed.

6.7 *Coarse Particles*—Paints shall be free of oversize particles and shall form a uniform film. The maximum content of coarse particles shall be 1 weight % as determined by Test Methods D 185.

6.8 *Fineness of Dispersion*—Determine the fineness of dispersion by Test Method D 1210. For paste paint, on a glass plate, using a spatula, mix the paint with an equal volume of water until homogeneous. The maximum allowable grind reading is 1.5 mils (40 μm).

6.9 *Consistency*—Paints shall be smooth and easily solubilized with water to a homogeneous color.

6.10 *Freeze-Thaw Stability*—Using a freezer that has a temperature of 20°F (−7°C) or lower, subject the paint to five freeze-thaw cycles. A freeze-thaw cycle shall consist of freezing the paint to a solid state (minimum of 18 h) and then thawing the paint to room temperature (minimum of 5 h). The paint shall then meet the requirements of 6.7, 6.8, and 6.9.

7. Lightfastness Determination

7.1 If a pigment is not listed in Table 1, test specimens of a watercolor containing the pigment shall be prepared. These test specimens shall be tested in accordance with the requirements for exposure and evaluation given in Test Methods D 4303.

NOTE—A report of the results of these tests may be submitted to Subcommittee D01.57 for inclusion of the pigments in Table 1. The report shall include information on test conditions and instruments used and shall be accompanied by the test specimens (which will be returned).

7.2 *Materials:*

7.2.1 *Filter Paper*, 15.0-cm diameter, ashless.[6]

7.2.2 *Drawdown Bar* with 3-mil (75-μm) aperture.

7.2.3 *Posterboard*, lightweight, approximately 20 mils (0.5 mm) thick, having a glossy finish on one side.

7.2.4 *Distilled Water.*

7.2.5 *Acrylic Latex Adhesive.*

7.3 *Preparation of Test Paints:*

7.3.1 The pigment to be tested may be milled in a soft paste consistency. If a prepared artists' paint of known composition is available it may be used for this test instead of preparing a standard.

7.3.2 Dilute the watercolors with water and drawdown on paper until the spectrophotometric measurement of the dry paint shows from 35 to 45 % reflectance at the wavelength of maximum absorption for that pigment. The wavelength of maximum absorption is located at the point of lowest reflectance on the spectral curve between 420 and 620 nm. If using a tristimulus filter colorimeter, the lowest of the three filter readings is the region of maximum absorption and the dilution should be adjusted so that a reading of 35 to 45 % reflectance is obtained with this filter. The diffuse white reference standard for all measurements should have an absolute reflectance between 97 and 100 %.

7.3.3 Use an applicator with a 3-mil (75-μm) aperture to make a drawdown on the filter paper. Tape the filter paper to a smooth surface such as a piece of glass. Place the drawdown bar just above the upper edge of the paper so it is ready to use. Pour a small amount of the diluted paint, which is thoroughly mixed, onto the top of the filter paper. Using the drawdown bar, draw the paint down, running the excess off the edge of the filter paper at the bottom. Quickly untape the filter paper and hang it to dry at room temperature. There will be a dark puddle area where the paint was originally applied, but the remaining part of the paper will be uniform in color for use in obtaining spectrophotometric measurements.

7.3.3.1 Prepare four specimen panels for each pigment under test. Two are used in the first lightfastness tests and two are retained in subdued light, one for visual comparisons with the exposed panels and one in case a third test is needed to supplement results from the first two tests, as described in Test Methods D 4303.

7.3.3.2 Apply the test paints to the filter paper as described in 7.3.3. The panels should be air dried for 2 h and then put in an oven at 50°C for overnight drying.

7.3.3.3 Cut the uniform color section of the filter paper drawdown panel into 1½-in. (38-mm) square panels. Adhere the panels to the light posterboard (see 7.2.3) using a thin coat of an acrylic-latex adhesive. The size of the posterboard shall conform to the dimensions of the exposure equipment test racks.

8. Exposure

8.1 Conduct exposure tests, calculate mean color difference, and assign pigments to lightfastness categories as described in Test Methods D 4303.

9. Keywords

9.1 lightfastness; quality requirements; specimen preparation; watercolors

[6] Whatman No. 42 Filter Paper, available from Fisher Scientific, 711 Forbes Ave., Pittsburg, PA 15219, has been found satisfactory for this purpose.

APPENDIX

(Nonmandatory Information)

X1. LIGHTFASTNESS III

X1.1 The pigments in Table X1.1 are not sufficiently lightfast to be used in paints that conform to this specification. These pigments are listed here solely to establish common terminology. They may be satisfactory when used full strength (without dilution) or with extra protection from exposure to light.

TABLE X1.1 Lightfastness III

NOTE—Underlined information and the lightfastness category in the table shall be included on every label.

Key:

Pigment Notations:

(LF) Lightfast type

(NA) Colour Index name or number not assigned

Colour Index Name	Lightfastness Category	Common Name and Chemical Class	Colour Index Number
PY 1:1	III	Arylide Yellow G, with option of adding the name Hansa Yellow Medium, arylide yellow	11680
PY 74 (LF)†	III	Arylide Yellow 5GX, with option of adding Hansa Yellow 5GX, arylide yellow	11741
PY 110	III	Isoindolinone Yellow R, tetrachloroisoindolinone	NA
PR 106	III	Vermilion, mercuric sulfide	77766
PR 112	III	Naphthol AS-D, naphthol AS-D	12370
PR 122	III	Quinacridone Magenta, quinacridone	73915

† Editorially corrected.

Designation: D 5068 - 92

Standard Practice for Preparation of Paint Brushes for Evaluation[1]

This standard is issued under the fixed designation D 5068; 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 describes the preparation of paint brushes for evaluation.

1.2 This practice is applicable to paint brushes 2 to 4 in. (50 to 100 mm) in width.

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

2. Referenced Document

2.1 *ASTM Standard:*

D 3924 Specification for Standard Environment for Conditioning and Testing Paint, Varnish, Lacquer, and Related Materials[2]

3. Summary of Practice

3.1 Using a paint chosen for the evaluation, the brush to be tested is repeatedly loaded with this paint and brushed out over a specified area in a specified application time.

4. Significance and Use

4.1 Until a paint brush is fully wetted with paint, only part of the paint loaded onto the brush can be transferred to the surface being painted. By properly preparing the brush before using, the amount of paint delivered to the surface can be made more uniform and reflect real use.

5. Apparatus

5.1 *Container*, to hold paint, for example, a quart can.

5.2 *Test Brush*, 2 to 4 in. (50 to 100 mm) in width.

6. Materials

6.1 *Test Paint.*

6.2 *Brush-Out Panels*, or other typical panels to be used.[3]

6.3 *Masking Tape*, to secure the panel to a flat surface.

7. Procedure

7.1 All tests are to be conducted in an atmosphere having a temperature of 73.5 ± 3.5°F (23 ± 2°C) and a relative humidity of 50 ± 5 % (see Specification D 3924).

7.2 Secure the brush-out panel with masking tape to a flat, smooth, horizontal surface.

7.3 Dip the test brush into the specified paint to the depth shown below:

Brush Width, in. (mm)	Depth, in. (mm)
2 and 2½ (50 and 62.5)	1½ (38)
3 and 3½ (75 and 87.5)	1¾ (45)
4 (100)	2 (50)

7.4 Hold the brush at the specified depth in the paint for 10 s. Remove and hold the brush vertically for 30 s allowing any excess paint to drain.

7.5 After the drain period, immediately apply paint to the specified initial area on the brush-out panel as indicated below:

Brush Width, in. (mm)	Initial Area, cm²
2 and 2½ (50 and 62.5)	250
3 to 4 (75 to 100)	500

7.6 Application time shall be 15 s for 2 and 2½-in. (50 and 62.5-mm) brushes and 20 s for 3 to 4-in. (75 to 100-mm) brushes.

7.7 Repeat this procedure three times.

7.8 Maintain the level of paint in the container. Keep the angle of the handle and displacement of the filaments of the test brush uniform throughout the entire series. When applying paint, always displace the test brush filament about one third to one half of the filament length and maintain the handle perpendicular to the paint-out surface.

7.9 When applying paint, always start in the middle of the area to be painted with each loading. This leaves the excess paint in the middle where it is easiest to spread to the area being covered and will result in a more uniform coverage (see Fig. 1).

8. Keyword

8.1 brush preparation

---

[1] This practice is under the jurisdiction of ASTM Committee D-1 on Paint and Related Coatings, Materials, and Applications and is the direct responsibility of Subcommittee D01.61 on Paint Application Tools.

Current edition approved March 15, 1992. Published May 1992. Originally published as D 5068 - 90. Last previous edition D 5068 - 90.

[2] *Annual Book of ASTM Standards*, Vol 06.01.

[3] Any smooth type panel, for example, upson boards, can be used. A Leneta 8H-BW Chart, available from The Leneta Co., P. O. Box 86, Ho-Ho-Kus, NJ 07427, has been found satisfactory for this purpose.

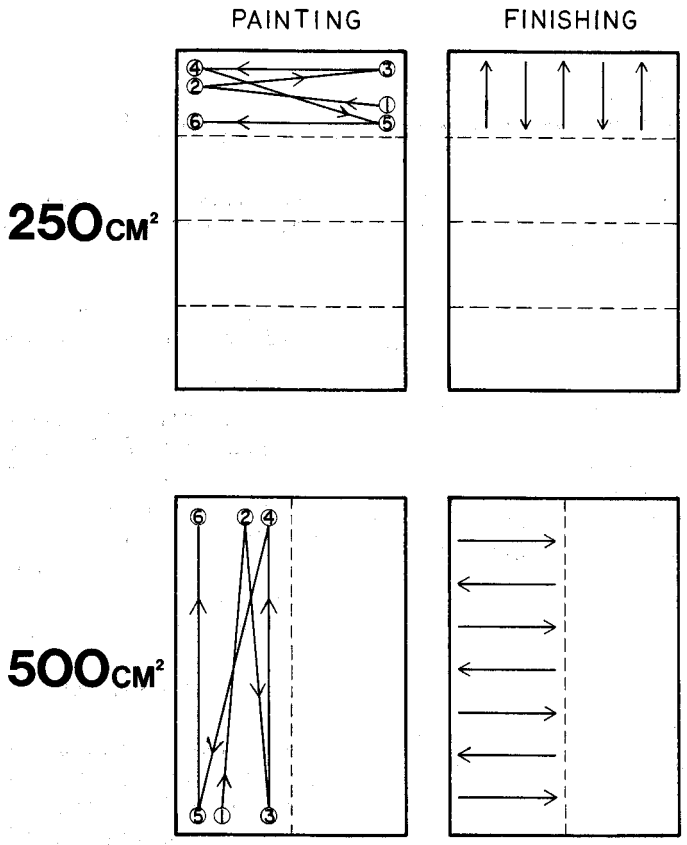


FIG. 1 Paint Application

Designation: D 5069 – 92

Standard Practice for Preparation of Paint-Roller Covers for Evaluation[1]

This standard is issued under the fixed designation D 5069; 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 describes the preparation or breaking-in of paint-roller covers for evaluation.

1.2 This practice is applicable to paint-roller covers having nap lengths up to ½ in. (13 mm).

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

2. Referenced Document

2.1 *ASTM Standard:*

D 3924 Specification for Standard Environment for Conditioning and Testing Paint, Varnish, Lacquer, and Related Materials[2]

3. Summary of Practice

3.1 Using the paint chosen for the evaluation, the paint-roller cover to be tested is repeatedly and generously loaded with paint and painted out over the same area of approximately 4 to 6 ft^2 (0.4 to 0.6 m^2) until it is saturated with paint, that is, the paint-roller cover cannot pick up any more paint, nor apply any more paint to the area being used for break-in.

4. Significance and Use

4.1 Until a paint-roller cover is saturated with paint, only part of the paint loaded onto the paint-roller cover can be transferred to a surface being painted. The remainder of the paint is absorbed into the fabric of the paint-roller cover. The amount of paint absorbed by a paint-roller cover is inversely proportional to the amount already present within the paint-roller cover. By saturation of the paint-roller cover before testing, quantitative inaccuracies of the amount of paint delivered to a surface are eliminated.

4.1.1 Using a saturated paint-roller cover enables the user to apply paint at controllable spreading rates.

4.1.2 Using a saturated paint-roller cover affords reproducibility when repeating a test.

5. Apparatus

5.1 *Paint Tray.*

5.2 *Paint Roller Frame*, of the same size as the paint-roller cover being prepared.

6. Materials

6.1 *Paint*, to be used in test.

6.2 *Primed or Painted Surface*, to be used for the roller-cover break-in.

7. Procedure

7.1 All tests are to be conducted in an atmosphere having a temperature of 73.5 ± 3.5°F (23 ± 2°C) and a relative humidity of 50 ± 5 % (see Specification D 3924).

7.2 Place the paint-roller cover on the frame.

7.3 Load the paint-roller cover with the paint from the tray by rolling the paint-roller cover over the surface of the paint so that just the nap is submersed. See Fig. 1.

7.4 Roll out the roller cover on the surface being used for break-in in an upward and downward motion in no larger an area than 2 ft. (0.6 m) high by the width of the roller cover.

7.5 Reload the paint-roller cover with paint and roll out in the same manner over the same area. Do not increase the area except as necessary to control excess dripping of paint.

7.6 Repeat the above procedure as necessary until the following conditions are met:

7.6.1 Reloading the paint-roller cover does not result in increased paint pickup.

7.6.2 There is so much paint on the surface being used that the fully loaded paint-roller cover cannot transfer any more paint to the surface.

7.6.3 When the above conditions are met, there will be so much paint on the roller cover that constant movement (turning over) is necessary to prevent dripping, and the panel will show profuse sagging of the paint. About six roller-cover

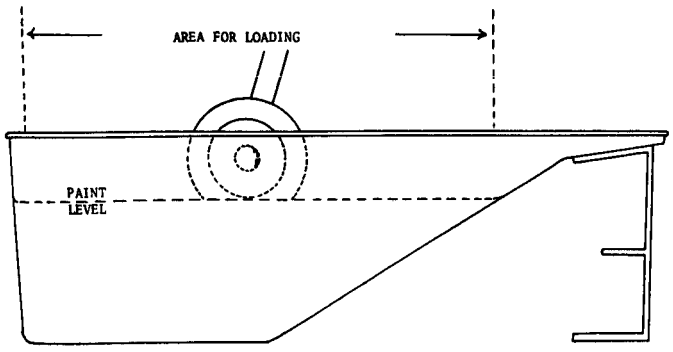


FIG. 1 Loading the Paint Roller

[1] This practice is under the jurisdiction of ASTM Committee D-1 on Paint and Related Coatings, Materials, and Applications and is the direct responsibility of Subcommittee D01.61 on Paint Application Tools.

Current edition approved March 15, 1992. Published May 1992. Originally published as D 5069 – 90. Last previous edition D 5069 – 90.

[2] *Annual Book of ASTM Standards*, Vol 06.01.

loadings are usually necessary to achieve this.

7.7 The roller cover is now prepared for immediate testing.

8. Keywords

8.1 break-in; paint roller; paint–roller cover; test preparation, roller