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Standard Guide to Testing Solvent-Borne Architectural Coatings[1]

This standard is issued under the fixed designation D5146; 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 solvent-borne coatings to be used on exterior, interior or both types of surfaces (see Note 1). The properties that can be examined or, in some cases, the relevant test procedures are listed in Table 1 and Table 2.

NOTE 1—The term "architectural coating" as used here combines the definition in Terminology D16 with that in the FSCT Paint/Coatings Dictionary, as follows: "Organic coatings intended for on-site application to interior or exterior surfaces of residential, commercial, institutional, or industrial buildings, in contrast to industrial coatings. They are protective and decorative finishes applied at ambient temperatures. Often called Trade Sales Coatings."

NOTE 2—Architectural coatings that are designed to give better performance than most conventional coatings because they are tougher and more stain- and abrasion-resistant are covered by Guide D3730.

1.2 The types of organic coatings covered by this guide are as follows:

(1) Type 1 Interior Low-Gloss Wall Finish,

(2) Type 2 Interior Gloss and Semigloss Wall and Trim Enamels,

(3) Type 3 Exterior House and Trim Coatings, and

(4) Type 4 Floor Enamel, Exterior and/or Interior.

1.2.1 Each is intended for application by brushing, rolling, spraying, or other means to the materials appropriate for its type, which may include wood, plaster, wallboard, masonry, steel, previously painted surfaces, and other architectural substrates.

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

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

2. Referenced Documents

2.1 *ASTM Standards:*[2]

D16 Terminology for Paint, Related Coatings, Materials, and Applications

D56 Test Method for Flash Point by Tag Closed Cup Tester

D93 Test Methods for Flash Point by Pensky-Martens Closed Cup Tester

D154 Guide for Testing Varnishes

D185 Test Methods for Coarse Particles in Pigments

D215 Practice for the Chemical Analysis of White Linseed Oil Paints (Withdrawn 2005)[3]

D344 Test Method for Relative Hiding Power of Paints by the Visual Evaluation of Brushouts

D358 Specification for Wood to Be Used as Panels in Weathering Tests of Coatings

D522 Test Methods for Mandrel Bend Test of Attached Organic Coatings

D523 Test Method for Specular Gloss

D562 Test Method for Consistency of Paints Measuring Krebs Unit (KU) Viscosity Using a Stormer-Type Viscometer

D660 Test Method for Evaluating Degree of Checking of Exterior Paints

D661 Test Method for Evaluating Degree of Cracking of Exterior Paints

D662 Test Method for Evaluating Degree of Erosion of Exterior Paints

D772 Test Method for Evaluating Degree of Flaking (Scaling) of Exterior Paints

D869 Test Method for Evaluating Degree of Settling of Paint

D968 Test Methods for Abrasion Resistance of Organic Coatings by Falling Abrasive

D1006 Practice for Conducting Exterior Exposure Tests of Paints on Wood

D1014 Practice for Conducting Exterior Exposure Tests of Paints and Coatings on Metal Substrates

D1038 Terminology Relating to Veneer and Plywood

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

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

[3] The last approved version of this historical standard is referenced on www.astm.org.

TABLE 1 List of Standards in Sectional Order

Property (or related test)	Section	ASTM Standard	Federal Test Method Standard 141D
Sampling	6.2	D3925	
Liquid Paint Properties			
Skinning	7.1	D154	3021
Condition in container	7.2		3011
Coarse particles and foreign matter	7.3	D185	
Density or Weight per gallon	7.4	D1475	
Fineness of dispersion	7.5	D1210	
Flash point	7.6	D56, D93, D3278	
Odor	7.7	D1296	
Absorption	7.8		4421
Colorant acceptance	7.9		
Dilution stability	7.10		4203
Package stability	7.11		
Heat stability	7.11.1	D1849	
Settling	7.11.2	D869	
Coating Application and Film Formation			
Application properties	8.1		4541
Brush application	8.1.1	D5068	
Brush drag	8.1.1.1	D4958	
Roller application	8.1.2	D5069	
Roller spatter	8.1.2.1	D4707	
Spray application	8.1.3		2131
Touch-up uniformity	8.2	D3928, D7489	
Rhelological properties	8.3		
Consistency (Low-shear viscosity)	8.3.1	D562	
Rheological properties of non-Newtonian liquids	8.3.2	D2196, D4287	
Sag resistance	8.3.3	D4400	4494
Levelling properties	8.3.4	D4062	
Drying properties	8.4	D1640	4061
Appearance of Dry Film			
Color difference	9.1		
Color appearance	9.1.1		
Color differences by visual comparison	9.1.2	D1729	
Color differences using instrumental measurements	9.1.3	D2244	
Directional reflectance	9.2	E1347	
Gloss	9.3		
Gloss, 60°	9.3.1	D523	
Sheen (85° gloss)	9.3.2	D523	
Hiding power	9.4	D344, D2805	
Yellowness index	9.5	E313	6131
Properties of Dry Film			
Interior and Exterior Coatings	10.1		
Abrasion resistance	10.1.1	D968, D4060	6192
Adhesion	10.1.2	D2197, D3359, D5179	
Flexibility	10.1.4	D522, D2370	6221[A]
Resistance to household chemicals	10.1.5	D1308	
Interior Coatings	10.2		
Color change of white enamels	10.2.1		6132
Ink Stainblocking	10.2.5	D7514	
Washability and cleansability	10.2.2		
Washability	10.2.2.1	D2486, D4213	
Cleansability	10.2.2.2	D3450, D4828	6141[B]
Exterior Coatings	10.3		
Blister resistance	10.3.1	D4585	
Exposure resistance	10.3.2	D1006, D1014	
Chalking	10.3.2.2	D4214	
Checking	10.3.2.3	D660	
Cracking	10.3.2.4	D661	
Erosion	10.3.2.5	D662	
Flaking	10.3.2.6	D772	
Mildew resistance	10.3.3	D3456	[C]
Fume resistance	10.3.4		
Tannin Stain Resistance	10.3.6	D6686	
Coating Analysis			
Chemical analysis	11.1	D215	
Volatile content	11.2	D2369	
Nonvolatile volume content	11.3	D2697, D6093	
Water content	11.4	D3792, D4017	
Pigment content	11.5	D2371	4021
Pigment analysis	11.6	D215	7261
Nonvolatile vehicle content	11.7	D215	
Vehicle separation	11.8	D2372	
Nonvolatile vehicle identification	11.9	D2621, D2245	

[A] Equivalent only to Method B of Test Methods D522.
[B] Except for scrub medium.
[C] 6271 is not equivalent.

TABLE 2 Alphabetical List of Properties

Property (or related test)	Section	ASTM Standard	Federal Test Method Standard 141D
Abrasion Resistance	10.1.1	D968, D4060, D6037	6192
Absorption	7.8		4421
Adhesion	10.1.2	D2197, D3359	
Analysis, chemical	11.1	D215	
Application properties	8.1		4541
Blister resistance	10.3.1	D4585	
Brush application	8.1.1	D5068	
Brush drag	8.1.1.1	D4958	
Chalking	10.3.2.2	D4214	
Checking	10.3.2.3	D660	
Cleansability	10.2.2.2	D3450, D4828	6141[A]
Coarse particles and foreign matter	7.3	D185	
Colorant acceptance	7.9		
Color appearance	9.1.1	...	
Color change	10.2.1	...	6132
Color differences by visual comparison	9.1.2	D1729	
Color differences using instrumental measurements	9.1.3	D2244	
Condition in container	7.2		3021
Consistency	8.3.1	D562	
Cracking	10.3.2.4	D661	
Density or weight per gal	7.4	D1475	
Dilution stability	7.10		4203
Drying properties	8.4	D1640, D5895	
Erosion	10.3.2.5	D662	
Exposure resistance	10.3.2	D1006, D1014	
Fineness of Dispersion	7.5	D1210	
Flaking	10.3.2.6	D772	
Flash point	7.6	D56, D93, D3278	
Flexibility	10.1.4	D522, D2370	6221[B]
Fume resistance	10.3.4		
Gloss	9.3		
Gloss, 60°	9.3.1	D523	
Heat stability	7.11.1	D1849	
Hiding power	9.4	D344, D2805	
Ink Stainblocking	10.2.5	D7514	
Levelling properties	8.3.4	D4062	
Mildew resistance	10.3.3	D3456	[C]
Nonvolatile vehicle content	11.7	D215	4053
Nonvolatile vehicle identification	11.9	D2621, D2245	
Nonvolatile volume content	11.3	D2697, D6093	
Odor	7.7	D1296	
Package stability	7.11	D1849	
Pigment analysis	11.6	D215	7261
Pigment content	11.5	D2371	4021
Reflectance, directional	9.2	E1347	
Resistance to household chemicals	10.1.5	D1308	
Rheological properties of non-Newtonian liquids	8.3.2	D2196, D4287	
Roller application	8.1.2		2112
Roller spatter	8.1.2.1	D4707	
Sag resistance	8.3.3	D4400	4494
Sampling	6.2	D3925	
Settling	7.11.2	D869	
Sheen (85° gloss)	9.3.2	D523	
Skinning	7.1	D154	3021
Spray application	8.1.3		2131
Tannin Stain Resistance	10.3.6	D6686	
Touch-up uniformity	8.2	D3928, D7489	
Vehicle separation	11.8	D2372	
Volatile content	11.2	D2369	
Washability	10.2.2.1	D2486, D4213	
Water content	11.4	D1208, D3792, D4017	4081
Yellowness index	9.5	E313	6131

[A] Except for scrub medium.
[B] Equivalent only to Method B of D522.
[C] 6271 is not equivalent.

D1208 Test Methods for Common Properties of Certain Pigments
D1210 Test Method for Fineness of Dispersion of Pigment-Vehicle Systems by Hegman-Type Gage
D1296 Test Method for Odor of Volatile Solvents and Diluents
D1308 Test Method for Effect of Household Chemicals on Clear and Pigmented Organic Finishes

D1475 Test Method For Density of Liquid Coatings, Inks, and Related Products
D1554 Terminology Relating to Wood-Base Fiber and Particle Panel Materials
D1640 Test Methods for Drying, Curing, or Film Formation of Organic Coatings at Room Temperature
D1729 Practice for Visual Appraisal of Colors and Color Differences of Diffusely-Illuminated Opaque Materials
D1849 Test Method for Package Stability of Paint
D2196 Test Methods for Rheological Properties of Non-Newtonian Materials by Rotational (Brookfield type) Viscometer
D2197 Test Method for Adhesion of Organic Coatings by Scrape Adhesion
D2244 Practice for Calculation of Color Tolerances and Color Differences from Instrumentally Measured Color Coordinates
D2245 Test Method for Identification of Oils and Oil Acids in Solvent-Reducible Paints
D2369 Test Method for Volatile Content of Coatings
D2370 Test Method for Tensile Properties of Organic Coatings
D2371 Test Method for Pigment Content of Solvent-Reducible Paints
D2372 Practice for Separation of Vehicle From Solvent-Reducible Paints
D2486 Test Methods for Scrub Resistance of Wall Paints
D2621 Test Method for Infrared Identification of Vehicle Solids From Solvent-Reducible Paints
D2697 Test Method for Volume Nonvolatile Matter in Clear or Pigmented Coatings
D2805 Test Method for Hiding Power of Paints by Reflectometry
D3273 Test Method for Resistance to Growth of Mold on the Surface of Interior Coatings in an Environmental Chamber
D3278 Test Methods for Flash Point of Liquids by Small Scale Closed-Cup Apparatus
D3359 Test Methods for Measuring Adhesion by Tape Test
D3450 Test Method for Washability Properties of Interior Architectural Coatings
D3456 Practice for Determining by Exterior Exposure Tests the Susceptibility of Paint Films to Microbiological Attack
D3730 Guide for Testing High-Performance Interior Architectural Wall Coatings
D3792 Test Method for Water Content of Coatings by Direct Injection Into a Gas Chromatograph
D3925 Practice for Sampling Liquid Paints and Related Pigmented Coatings
D3928 Test Method for Evaluation of Gloss or Sheen Uniformity
D3960 Practice for Determining Volatile Organic Compound (VOC) Content of Paints and Related Coatings
D4017 Test Method for Water in Paints and Paint Materials by Karl Fischer Method
D4060 Test Method for Abrasion Resistance of Organic Coatings by the Taber Abraser
D4062 Test Method for Leveling of Paints by Draw-Down Method
D4213 Test Method for Scrub Resistance of Paints by Abrasion Weight Loss
D4214 Test Methods for Evaluating the Degree of Chalking of Exterior Paint Films
D4287 Test Method for High-Shear Viscosity Using a Cone/Plate Viscometer
D4400 Test Method for Sag Resistance of Paints Using a Multinotch Applicator
D4585 Practice for Testing Water Resistance of Coatings Using Controlled Condensation
D4707 Test Method for Measuring Paint Spatter Resistance During Roller Application
D4828 Test Methods for Practical Washability of Organic Coatings
D4946 Test Method for Blocking Resistance of Architectural Paints
D4958 Test Method for Comparison of the Brush Drag of Latex Paints
D5068 Practice for Preparation of Paint Brushes for Evaluation
D5069 Practice for Preparation of Paint-Roller Covers for Evaluation of Architectural Coatings
D5179 Test Method for Measuring Adhesion of Organic Coatings to Plastic Substrates by Direct Tensile Testing
D5895 Test Methods for Evaluating Drying or Curing During Film Formation of Organic Coatings Using Mechanical Recorders
D6037 Test Methods for Dry Abrasion Mar Resistance of High Gloss Coatings
D6093 Test Method for Percent Volume Nonvolatile Matter in Clear or Pigmented Coatings Using a Helium Gas Pycnometer
D6686 Test Method for Evaluation of Tannin Stain Resistance of Coatings
D7489 Practice for Evaluating Touch-Up Properties of Architectural Coatings under Various Environmental Conditions
D7514 Test Method for Evaluating Ink Stainblocking of Architectural Paint Systems by Visual Assessment
E105 Practice for Probability Sampling of Materials
E313 Practice for Calculating Yellowness and Whiteness Indices from Instrumentally Measured Color Coordinates
E1347 Test Method for Color and Color-Difference Measurement by Tristimulus Colorimetry

2.2 *U.S. Federal Standard:*
Federal Test Method Standard No. 141D[4]
2131 Application of Sprayed Films
3011 Condition in Container
4203 Reducibility and Dilution Stability
4421 Absorption Test
4541 Working Properties and Appearance of Dried Film
6132 Accelerated Yellowness

[4] Available from Standardization Documents Order Desk, DODSSP, Bldg. 4, Section D, 700 Robbins Ave., Philadelphia, PA 19111-5098, http://dodssp.daps.dla.mil.

2.3 *Other Document:*
Paint/Coatings Dictionary of the Federation of Societies for Coatings Technology[5]

3. Terminology

3.1 For definitions of terms in this guide refer to Terminology D16, D1038, and D1554 and to the FSCT Paint/Coatings Dictionary.

4. Conditions Affecting Solvent-Reducible Coatings

4.1 *Interior and Exterior Coatings:*

4.1.1 *Substrate Type*—The substrate to be painted can affect not only the application properties of a coating, such as gloss and uniformity, but is also a factor in determining the type of coating to use. For instance, low-gloss wall finishes do not have the abrasion resistance required on floors, whereas finishes intended only for interior service probably do not have adequate resistance to weather factors. Other factors are the type and quality of metal, wood or wood composite (plywood, particle board or hardboard), the type, quality and alkalinity of concrete, plaster and joint cement systems, and the type and condition of any previous coatings.

4.1.2 *Substrate Conditions*—Conditions such as porosity, hardness or, in the case of unpainted concrete, alkalinity determine the kind of coating that can be applied. The condition of previously painted substrates, such as degree of chalk, presence of grease, dirt, and mold, film adhesion and porosity, all influence the performance of coatings. Smoothness of the substrate affects the spreading rate, final appearance, and texture.

4.1.3 Preparation of previously painted substrates including detergent cleaning, solvent cleaning, and sanding.

4.1.4 Type and quality of primer or undercoat and time of drying before topcoating.

4.1.5 Environmental conditions such as temperature and humidity at the time of coating application and during drying.

4.2 *Exterior Finishes:*

4.2.1 *Substrate Weathering*—Weathering of wood before painting will probably adversely affect the performance of exterior coatings. Some weathering of masonry surfaces may have beneficial effects on the performance.

4.2.2 *Substrate Aspects of the Building*—If construction defects or defects due to age are such that excessive moisture from the inside or the outside makes its way through the substrate or if the substrate is in direct contact with damp ground, blistering, flaking or peeling may result.

4.2.3 Environmental conditions after application, both general for the area and specific, such as under eaves, behind shrubbery, northside and southside exposure.

5. Selection of Tests

5.1 Because the conditions to which a coating is subjected vary with (*a*) the surface type: wall, floor, ceiling, and (*b*) the service environment: exterior or interior, specialized types of solvent-borne coatings have been developed for the different locations. The recommended test methods presented in Table 1 and Table 2 cover practically all the properties of solvent-reducible coatings but all of them are not required with each type. Coatings intended for exterior use only or both exterior and interior use require certain properties not relevant to those for interior use only. Selection of the methods to be followed must be governed by experience and the requirements in each individual case, together with agreement between the purchaser and the seller.

5.2 The purchaser should first determine the properties a coating should have and then select only those test methods that measure or evaluate those properties. After selecting the desired tests, the purchaser should then decide which properties are the most important and establish the requirements or specifications accordingly. Since coating properties frequently tend to oppose each other, such as low sheen versus good cleansability, some properties may need to be less emphasized if others are to be accentuated. This balance of properties must be considered when selecting the tests and establishing the requirements. The significance of the tests and the normal range of values are presented in the different sections, in most cases.

5.3 This guide does not indicate relative importance of the various tests nor does it recommend specific test values because properties very important to one purchaser may be less so to another.

6. Sampling

6.1 Prior to sampling, the condition of the container should be checked since damage to it may cause evaporation, skinning, or other undesirable effects on the coating.

6.2 Sample in accordance with Practice D3925. Determine the density in pounds per kilograms/litre (gallon) in accordance with Test Method D1475. Continue sampling and determining density until successive results agree within 45 g (0.1 lb) or as agreed upon between the purchaser and seller. Then take samples for testing.

6.3 Specify the amount required for a representative sample, the package sizes, and an identification code. A 4-L (or 1-U.S. gal) sample is usually sufficient for the recommended tests, but for guidance in selecting a sampling plan consult Practice E105.

7. Liquid Coating Properties

7.1 *Skinning*—Coatings that contain a binder that dries by oxidation may be subject to skin formation in a partially-filled can. Since skins are insoluble in the material, they must be removed before use. The referenced test in a partially-filled container indicates the tendency of the material to skin. A typical minimum time for skinning in accordance with this method is 48 h. Examine the original sample for skins, both on and below the surface. Using a well-mixed skin-free portion of the sample, perform a skinning test in accordance with Guide D154.

7.2 *Condition in Container*—Thickening, pigment settling, and separation are undesirable and objectionable if material that has been stored cannot be readily reconditioned and made

[5] Available from Federation of Societies for Coatings Technology (FSCT), 492 Norristown Rd., Blue Bell, PA 19422-2350, http://www.coatingstech.org.

suitable for application with a reasonable amount of stirring. The referenced method covers procedures for determining changes in properties after storage and lists characteristics that are undesirable and objectionable in a stored paint. Determine condition in the container in accordance with Method 3011 of Federal Test Method Standard No. 141D. (See also 7.11, Package Stability.)

7.3 *Coarse Particles and Foreign Matter*—Liquid coatings must be free of coarse particles and foreign matter to be able to form uniform films of good appearance, a typical maximum being 0.5 weight % of the total material. The referenced method with a 325-mesh (45-µm) screen gives the percent of these particles. Determine content of coarse particles and foreign matter in accordance with Test Methods D185.

7.4 *Density or Weight per Gallon*—The density measured in pounds per kilograms per litre = g/mL (gallon) is used to ensure product uniformity from batch to batch, provides a check against the theoretical weight calculated from the formula, and is useful for determining the similarity of two samples. The referenced method gives a procedure for measuring the density of the coating at a specified temperature. Most interior paints have densities of about 1.2 to 1.4 kg/L (10 to 12 lb/gal). Determine density in accordance with Test Method D1475, using a calibrated weight per gallon cup.

7.5 *Fineness of Dispersion*—Generally, the more finely a pigment is dispersed, the more efficiently it is being utilized. One method for measuring the degree of dispersion (commonly referred to as "fineness of grind.") is to draw the liquid coating down a calibrated tapered groove varying in depth from 100 to 0 µm (0–8 Hegman units) (4 to 0 mils) . The depth at which continuous groupings of particles or agglomerates, or both, protrude through the surface of the wet film is taken as the fineness of dispersion value. Higher readings in Hegman units or lower readings in mils or micrometres indicate finer dispersion. Low sheen finishes may have a dispersion value of 50 µm or 4 Hegman (2 mils) while gloss enamels might be near zero (8 Hegman) indicating that the pigment agglomerates are too small to be detected by the referenced method. Determine fineness of dispersion in accordance with Test Method D1210.

7.6 *Flash Point*—Organic solvents used in these coatings have characteristic temperatures at which they support combustion. This temperature is known as the flash point and is often used for danger classification in shipping by common carrier. It is also used to determine conditions of storage to meet fire regulations and the safety requirements of the U.S. Occupational Safety and Health Act (OSHA). Determine flash point in accordance with Test Methods D56, D93, Part B, or D3278.

7.7 *Odor*—Some solvent combinations produce obnoxious odors, particularly when painting indoors with inadequate ventilation and at elevated temperatures. Interior solvent-borne coatings usually contain low-odor or odorless mineral spirits. Nevertheless, they should be evaluated to ensure that they are acceptable. Although not specifically designed for liquid coatings Test Method D1296 may be used with the solvent-reducible type.

7.8 *Absorption*—On porous surfaces, binder penetration can result in pigment volume concentration changes as the film dries. This may cause appearance to vary. The referenced method provides a rough measure of the wetting and penetrating properties of the binder on a porous surface. Determine the absorption in accordance with Method 4421 of Federal Test Method Standard No.141D.

7.9 *Colorant Acceptance*—Tintability of white bases with colorants of standardized tinting strength is a trade requirement. If tinting colors are not adequately compatible with tint bases, lighter, darker, or nonuniform shades of colors are produced. There is no accepted ASTM test method at present. Test methods may be agreed upon between the purchaser and seller.

7.10 *Dilution Stability*—Dilution with a specified thinner shows whether the materials are compatible and whether the reduced coating is stable. Consequently the suggested diluent should be readily incorporated into the coating without excessive stirring or shaking. The referenced method evaluates the stability of the material that has been reduced by a given amount or to a specified viscosity. Determine dilution stability in accordance with Method 4203 of Federal Test Method Standard No. 141D.

7.11 *Package Stability*—Since coatings are normally not used immediately after manufacture, they must remain stable in the can for some time. At normal temperatures most solvent-borne coatings can be stored for over a year with little change in properties. However, exposure in uninsulated warehouses, or during shipping to high temperatures in the summer, may cause unacceptable changes in these products. Another unsatisfactory condition that may occur during storage is excessive settling.

7.11.1 *Heat Stability*— Exposure to high temperatures can be used to test for the stability of a packaged coating that frequently encounters such conditions in service, or as an accelerated test to predict stability at normal temperatures. Although indications of long term package stability can usually be obtained in several days or weeks at an elevated temperature such as 50°C (125°F) or 60°C (140°F), occasionally the results of the accelerated test do not agree with those at prolonged normal storage conditions. In the referenced method the changes in consistency and certain other properties of the accelerated aged material are compared to those occurring in a control kept at normal temperatures for a longer period. When testing for heat stability, as such, changes in viscosity, flow, gloss, foam resistance, color uniformity, and wet adhesion are usually checked. Determine heat stability in accordance with Test Method D1849.

7.11.2 *Settling*—Modern coatings are generally resistant to hard settling, but do at times show separation and soft settling. The referenced method covers the degree of pigment suspension in and ease of remixing of a shelf-aged specimen to a homogeneous condition suitable for the intended use. Determine settling in accordance with Test Method D869.

8. Coating Application and Film Formation

8.1 *Application Properties*—Application or working properties of a paint are generally compared to a standard or

described by requirements in the product specification. Determine working properties in accordance with Method 4541 of Federal Test Method Standard No. 141D.

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. Brush drag should not be excessive although some degree of drag may be desirable for adequate film thickness application. Wall finishes are tested on vertical surfaces and floor coatings on horizontal surfaces, although evaluation of the latter on vertical surfaces may be necessary to determine performance on stair risers, railings, posts, etc. Practice D5068 covers a means for the determination of the brushing properties of a coating.

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 durability. Conversely, increasing brush drag too much can cause difficulties in spreading the material easily and uniformly, leading to excessive sagging and prolonged drying time. 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 viscosity's obtained instrumentally using Test Method D4287 (see 8.3.2), provided the paints differ in viscosity by at least 0.3 poise (0.03 Pa.s). Determine brush drag ratings in accordance with Test Method D4958."

8.1.2 *Roller Application*—Both wall and floor coatings are frequently applied by roller. This type of application tends to produce some stipple pattern. Practice D5069 covers the evaluation of a material's characteristics when applied by roller.

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 D4707.

8.1.3 *Spray Application*—Architectural coatings are sometimes applied by spray. Both air and airless spray are used on commercial work. Determine the spray application properties in accordance with Method 2131 of Federal Test Method Standard No. 141D. Manual application is very subjective and should be performed only by an individual skilled in the art of using spray equipment.

8.2 *Touch-Up Uniformity*—Coatings applied to large, flat surfaces may exhibit localized areas of noticeably different appearance due to variation in film thickness, different methods of application or localized damage in service. With a coating of suitable touch-up properties, additional material of the same batch or lot can be applied only to those localized areas to provide uniformity of color, gloss, and levelling over the entire surface. Determine touch-up properties in accordance with Test Method D3928. Variations in drying conditions effect architectural coatings in field application and are also known to impact touch-up uniformity. Determining touch-up uniformity under a variety of laboratory-controlled temperature and humidity scenarios may be accomplished by following Practice D7489.

8.3 *Rheological Properties:*

8.3.1 *Consistency (Low-Shear Viscosity)*—Consistency is important, relating to application and flow, and should fall within a stated range for satisfactory reproduction of a specific formula. While consistency is an important property it does not determine the quality of a coating 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. The load value is frequently converted to Krebs units (KU) and the Stormer Consistency reported on that basis. Although the consistency of most solvent-borne house and trim coatings is about 150 to 300 g/100 revolutions (72 to 95 KU), a much wider range is possible because of the great variation that may occur in the rheological properties of these paints. Enamels for professional painters are usually formulated at a higher consistency range than consumer enamels. Typical ranges are 75 to 90 KU for consumer enamels and 90 to 100 for professional painter enamels. Two paints of the same consistency may have quite different rheological properties during application. Determine the consistency in accordance with Test Method D562.

8.3.2 *Rheological Properties of Non-Newtonian Materials*—Rheological properties are related to application and flow characteristics of the liquid coating. The referenced methods cover the determination of rheological properties and are particularly suited for coatings that display thixotropic characteristics. However, they measure viscosity under different shear rates. In Test Method D4287 the rate is similar to that occurring during brush application so that the measured viscosity is related to brush drag, spreading rate and film build. Determine rheological properties in accordance with Test Methods D2196 or D4287, or both.

8.3.3 *Sag Resistance*—Some coatings sag and form curtains before the film sets. Resistance to this type of flow is an important property particularly for semigloss and gloss enamels because of the unsightly film appearance. Measure sag resistance in accordance with Test Methods D4400.

8.3.4 *Levelling Properties*—Levelling is an important property when smooth, uniform surfaces are to be produced, as it affects hiding and appearance. The referenced method covers the relative levelling characteristics of liquid coatings. Determine levelling in accordance with Test Method D4062.

8.4 *Drying Properties*—The drying time of a coating is important in determining when a freshly painted room, floor or stair may be put back in use. Slow drying may result in dirt or insect pickup resulting in a poor appearance or, if on an exterior surface, rain or dew may cause a nonuniform appearance. The drying time of a coating is determined by its composition and by atmospheric conditions during drying. Typical drying times for enamels are ½ to 2 h set-to-touch and

18 h dry hard under normal temperature and humidity conditions. Some coatings lose drying speed during storage in the container. Any of the several methods for determining the various stages of film formation in the drying or curing of organic coatings may be used. For example, if two coats are specified the determination of "dry-to-recoat" time is important. Determine appropriate drying time(s) in accordance with Test Methods D1640 or Test Method D5895.

9. Appearance of Dry Film

9.1 *Color Difference:*

9.1.1 The appearance of color is greatly influenced by several factors. A color next to a yellow wall looks different than the same color next to a blue wall. The visual appearance of a colored object illuminated by incandescent light, fluorescent light, and natural light differs because the spectral compositions of the incident lights vary. Gloss also affects color appearance, Low and high gloss coatings frequently look different in color even though instrumentally their colors may be identical.

9.1.2 *Color Differences by Visual Comparison*—Visual comparison of colors 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, sizes of specimens, and general procedures to be used in the visual evaluation of color differences of opaque materials relative to their standards. Determine color difference in accordance with Practice D1729.

9.1.3 *Color Differences Using Instrumental Measurements*—The difference in color between a product and its standard can be measured by instrument. Generally the tolerance is agreed upon by the purchaser and seller and may also be required if a product specification is involved. Color measuring instruments provide numerical values that can be compared to subsequent measurements. The referenced method covers the calculation of instrumental determinations of small color differences observable in daylight illumination between nonfluorescent, nonmetameric, opaque surfaces such as coated specimens. If metamerism is suspected, visual evaluation (9.1) should be used to verify the results. Calculate in accordance with Practice D2244 the color differences that have been measured instrumentally.

9.2 *Directional Reflectance*—This property is a measure of the appearance of lightness of a coating. It is usually assigned a value in specifications for white and pastel shades, a typical range being 76 to 92 % for white finishes. In the referenced method the directions of illumination and viewing are specified so as to eliminate the effect of gloss. Determine daylight directional reflectance in accordance with Test Method E1347.

9.3 *Gloss*—This property is a measure of the capability of a coating surface to reflect light in a mirror-like (specular) manner, that is, light strikes the surface and is reflected at the equal but opposite angle. In the referenced method the numerical gloss units are the ratio of light reflected by a specimen to that reflected by the primary standard black glass that is assigned a gloss value of 100. The gloss of some coatings varies greatly with the angle of incidence so that a complete description of their gloss would require measurements over a wide range of angle. In practice, the gloss of architectural finishes is adequately characterized by measurements at 60° or 85°, or both, from a line perpendicular (normal) to the surface. The 85° angle is a very low ("grazing") angle (5°) of illuminating and viewing the surface and the gloss at this angle is called "sheen." Attempts to standardize the levels of gloss associated with the several descriptive terms have not been very successful since the gloss scale is continuous with no distinct boundaries. Hence, there is some overlap at the ends of some gloss classifications in common usage.

9.3.1 *Gloss, 60°*—Semigloss enamels are particularly sensitive to enamel hold-out of primers and undercoats. Low or uneven gloss reading are indicative of this defect. Oil house paints are typically in a 60° gloss range from 30 to 70 while trim enamels are from 70 to 90. Floor enamels generally have a high (90 +) gloss reading when first applied but this decreases with time and traffic. Interior semigloss enamels after drying 48 h are typically in the range from 40 to 70 but measurements taken shortly after drying should be repeated after one week because the gloss can drop considerably in the first few days of drying. Determine the 60° gloss in accordance with Test Method D523.

9.3.2 *Sheen (85° Gloss)*—Although low-gloss paints with good uniformity of appearance at low angles of viewing often have little sheen while those with good cleansability usually have moderate sheen, this is not always the case so that sheen should not be used as a measure of other paint properties. The referenced method, using the 85° geometry, is useful in characterizing the low-angle appearance of low-gloss coatings. Nominally, flat wall paints have a sheen of 1 to 10 whereas velvets or eggshells range from 15 to 35. Determine the sheen (85° gloss) in accordance with Test Method D523.

9.4 *Hiding Power*—Hiding power is a measure of the ability of a coating to obscure the substrate and is usually expressed as the spreading rate for a specified level of opacity. It is, however, dependent on uniformity of film thickness, which in practical applications is influenced by flow, levelling and application properties of the coating. Test Method D2805 is precise and gives an absolute rather than a comparative result. Paint is applied with an applicator bar to minimize the effects of flow and levelling, film thickness is rigorously measured, and film opacity is determined instrumentally. Test Method D344 is a practical test in which paint is applied with a brush, wet-film thickness is approximately controlled by spreading rate, and hiding power is evaluated visually by comparison with a standard paint, but results are affected by flow and levelling of the materials. Determine hiding power in accordance with Test Methods D344 or D2805.

9.5 *Yellowness Index*—The referenced method is used for white or near white specimens to determine color departure from white toward yellow when first applied. Determine the yellowness index in accordance with Practice E313. (See also 10.2.1.)

10. Properties of the Dry Film

10.1 *Interior and Exterior Coatings:*

10.1.1 *Abrasion Resistance*—Abrasion resistance is a measure of the ability of a dried film to withstand wear from foot traffic and marring from objects rolled or pulled across the surface. In the referenced methods, dry abrasive is applied to a coated panel using the force of gravity or a jet blast for free-flowing abrasive or a weighted wheel for abrasive embedded in a resilient rubber matrix. Determine dry abrasion resistance in accordance with Test Methods D968 or D4060, or D6037. (See 10.2.2.1 for wet abrasion resistance.)

NOTE 3—Because of the poor reproducibility of abrasion test methods, testing should be restricted to only one laboratory when numerical abrasion resistance values are to be used. Interlaboratory agreement is improved significantly when rankings are used in place of numerical values.

10.1.2 *Adhesion*—Adhesion, the ability of a film to resist, removal from the substrate, is an important property of a coating. Determine adhesion in accordance with Test Methods D2197, D3359, or D5179.

10.1.3 *Wet Adhesion*—It is essential that a finish adhere tightly to a given substrate or primer under wet conditions of washing or scrubbing. There is no adequate test method published by ASTM. Determine the wet adhesion of paints by a method acceptable to the purchaser and the seller.

10.1.4 *Flexibility*—Elongation is a measure of the flexibility of a coating film. Generally, gloss house paints and trim enamels have no problems in passing a mandrel bend test at 3.2 mm (⅛ in.). However, interior flat and eggshell finishes may pass only a 6.4-mm (¼-in.) bend. For exterior coatings Test Method D2370 is a much more discriminating method.[6] Determine flexibility in accordance with Test Methods D522 or elongation with Test Method D2370.

10.1.5 *Resistance to Household Chemicals*—An important property of interior coatings is the ability to resist spotting, softening or removal when subjected to household chemicals or strong cleaners. Determine resistance to these chemicals in accordance with Test Method D1308.

10.2 *Interior Finishes:*

10.2.1 *Color Change of White Architectural Enamels*—Color permanence is an important characteristic for interior white enamels. Lack of permanence is usually caused by after-yellowing. Determine resistance to color change in accordance with Method 6132 of Federal Test Method Standard No. 141D.

10.2.2 *Washability and Cleansability*—The capability of satisfactorily removing marks without damaging the film is essential for good performance of interior finishes. A coating may be washable, that is, unaffected by the detergent solution, but may not have good cleansability. Frequently the difference between the two terms "cleansability" and "washability," is not clearly understood so that there is confusion as to what is really being tested; for example, the title of Test Method D3450. Cleansability is evaluated by applying one or more stains and soils and determining how readily they are removed. Washability is evaluated by determining the resistance of the film to wet erosion either by visual assessment or measured film loss. In general, the precision of both types of test is poor because several properties, such as hardness, water and detergent resistance, cohesion and adhesion, are involved and the end point, except for the wet abrasion method, is rather indefinite.

10.2.2.1 *Washability (Also referred to as Scrubbing or Wet Abrasion Resistance)*—The scrubbing method, Test Methods D2486, developed for interior latex flat wall paints can be applied to coatings of almost any type. In it the coating is applied to a black plastic panel that, during scrubbing with a nylon brush and abrasive cleaning agent, is raised by a narrow shim to concentrate the test area. The number of back-and-forth strokes (cycles) required to remove the film over the shim is determined. Interior flat wall paints can vary in scrub resistance from less than 100 to more than 1000 cycles. The wet-abrasion method, Test Method D4213, is similar except that a sponge is used in place of the bristle brush while the shim is not used. This method also provides for the use of a nonabrasive medium with paints having very low abrasion resistance. The weight or volume loss per 100 cycles to erode the film almost to exposure of the black substrate is the measure of scrub resistance. Evaluate washability, as described just, in accordance with Test Methods D2486 or D4213.

10.2.2.2 *Cleansability*—The older referenced method, Test Method D3450, is similar to the wet-abrasion method, Test Method D4213, except that the sponge is used with either the nonabrasive or abrasive cleaning agent to remove a carbon black-oil stain. The ability to remove the stain is expressed as the ratio (in percent relative) of the reflectance of the cleaned area to that of the area before application of the stain. In Test Method D4828, referred to as a "practical" test, numerous staining and soiling agents found in service and commercial abrasive or nonabrasive cleaners as well as the standardized cleaning agents can be used. The films may be cleansed manually or mechanical but only the latter is suitable for interlaboratory testing. Evaluate ease of removability in accordance with Test Methods D3450 or D4828.

10.2.3 *Mildew Resistance*—Many paints are subject to microbiological discoloration on the surface with time. This is especially true in warm, moist climates. Determine mildew resistance in accordance with Test Method D3273.

10.2.4 *Blocking Resistance*—Blocking or sticking of paints caused by slower drying gloss coatings can be evaluated in accordance with Test Method D4946, which describes an accelerated procedure for evaluating the face-to-face resistance of trade sale coatings.

10.2.5 *Ink Stainblocking*—Many architectural coatings systems are designed to have functionality to both cover stains found on interior household surfaces and block them from penetrating to the surface of subsequent topcoats. This is especially true for architectural primer coatings. Determine the ability of a coating system to block stains from a variety of inks or other household staining materials in accordance with Test Method D7514.

10.3 *Exterior Coatings:*

10.3.1 *Blister Resistance*—Blister resistance is the ability of a dry film on wood to resist the formation of blisters caused by water from the wood substrate. In practice water can come

[6] Ashton, H. E., "Flexibility and its Retention in Clear Coatings Exposed to Weathering," *Journal of Coatings Technology*, Vol 511, No. 653, June 1979, p. 41.

from either the interior of a home or from structural defects that permit entry of exterior water behind the wood. Moisture blister resistance can be qualitatively evaluated in a laboratory test. Determine resistance to moisture blistering in accordance with Practice D4585.

10.3.2 *Exposure Resistance*—If the coating is intended for exterior use, evaluation of the resistance to weathering may be required. In conducting exterior exposures follow Practice D1006 for wood substrates or Practice D1014 for steel.

10.3.2.1 In establishing exterior performance on wood, use the panels described in Specification D358.

10.3.2.2 *Degree of Chalking*—Determine the rating using Test Methods D4214.

10.3.2.3 *Degree of Checking*—Determine the rating using Test Method D660.

10.3.2.4 *Degree of Cracking*—Determine the rating using Test Method D661.

10.3.2.5 *Degree of Erosion*—Determine the rating using Test Method D662.

10.3.2.6 *Degree of Flaking*—Determine the rating using Test Method D772.

10.3.3 *Mildew Resistance*—Many paints are subject to microbiological discoloration on the surface with time. This is especially true in warm, moist climates. Determine mildew resistance in accordance with Practice D3456.

10.3.4 *Fume Resistance*—Some paints exhibit a change in appearance (usually color) when exposed to air containing certain sulfur compounds, notably hydrogen sulfide and sulfur dioxide. This type of atmosphere may be present near industrial or other polluted areas and can cause paint to yellow or darken in as little time as overnight. There are no ASTM or Federal test methods for evaluating this color change, but one procedure used by the industry is as follows:

10.3.4.1 Apply a sufficient number of coats of the paint to two glass plates to hide the surface completely, allow to dry for 6 h and expose one in a moist atmosphere of hydrogen sulfide for 18 h. Compare the color with the unexposed plate. The color difference should not exceed that between plates that have been coated with a paint made with titanium dioxide pigment, lead-free zinc oxide, raw or refined linseed oil, and sufficient cobalt added for drying, and similarly treated.

10.3.5 *Color Fading*—Exterior coatings usually have good color retention because of their good chalking resistance. However, the use of improper binder, pigment volume concentration, or pigments can lead to fading. There are no ASTM nor Federal Test Methods specifically designed for evaluation of fade resistance, but change in color on exposure can be measured in accordance with Practice D2244 (see 9.1.3).

10.3.6 *Tannin Stain Resistance*—Architectural coatings that are applied directly to raw wood surfaces are often expected to have the ability to prevent tannins and extractives found within the wood from penetrating into a topcoat. This is especially important for painting wood boards that are more heavily concentrated in tannins, such as cedar or redwood, in humid environments. Determine the ability of a coating to resist tannin staining in accordance with Test Method D6686.

11. Coating Analysis

11.1 *Chemical Analysis*—If a specification requires certain raw materials or certain components in a given amount then analysis is needed to determine whether the specified components are present and in what amounts. Analysis is primarily a measure of uniformity and does not necessarily establish quality that can also be greatly affected by manufacturing techniques. No single schematic analysis is comprehensive enough to cover the wide variety of paint compositions. Select test procedures from Practice D215 and other ASTM methods that are pertinent to the components of solvent-borne coatings.

11.2 *Volatile Content*—The percent of volatile matter is a measure of the amount of a film lost as it dries. This quantity is not necessarily indicative of the quality of the coating. It is useful, however, for determining the similarity of two batches. The referenced method covers the determination of the volatile content of solvent- and water-reducible coatings. The quantity determined subtracted from 100 % gives the nonvolatile content of the coating. Determine the volatile content in accordance with Test Method D2369.

11.3 *Nonvolatile Content (Volume Percent)*—The nonvolatile content by volume is a useful figure in calculating coverage or spreading capacity per gallon (or litre) at a specified dry-film thickness. Determine nonvolatile content volume percent in accordance with Test Methods D2697 or D6093.

11.4 *Water Content*—If too much water is incorporated in a solvent-reducible coating it may retard the drying at high relative humidities. The amount of water in a coating may be required in the calculation of the volatile organic content (VOC) of coatings. One referenced method covers the determination of water in paint and related materials by distilling with a volatile solvent. The newer method utilizes the Karl Fischer reaction. Determine the water content in accordance with Test Methods D3792 or D4017.

11.5 *Pigment Content*—Pigment provides the hiding and color and influences many other properties of a coating. The referenced method describes the procedure for the quantitative separation of the vehicle from the pigment in solvent-reducible coatings. It is used to measure the weight percent pigment in the paint. Determine the percent pigment content in accordance with Test Method D2371.

11.6 *Pigment Analysis*—The analysis of pigment may be required if the product is covered by a specification or upon agreement between the purchaser and seller. Analyze the pigment in accordance with selected test procedures from Practice D215 and other appropriate ASTM methods.

11.7 *Nonvolatile Vehicle Content*—The nonvolatile vehicle is the film-forming portion of a coating excluding the pigment. Water, volatile thinner, and pigment are determined and their sum subtracted from 100 % to give the binder content in accordance with Practice D215. The vehicle may be separated for further analysis.

11.8 *Separation of Vehicle*—The recommended procedure describes this separation for certain solvent-borne coatings. If desired or required, separate the vehicle in accordance with Practice D2372.

11.9 *Identification of Nonvolatile Vehicle*—The type of binder used in a coating has a great influence on its properties. The referenced method covers the qualitative characterization or identification by infra-red spectroscopy of separated nonvolatile vehicle. It is useful in detecting uniformity, batch to batch, and the presence of adulterants. Identify the nonvolatile vehicle in accordance with Test Method D2621. The composition of this vehicle can be further broken down into the types of oils present. If desired determine the identity of oils in accordance with Test Method D2245.

11.10 *Volatile Organic Content*—The volatile organic compound (VOC) content of solvent and waterborne coatings and related materials is determined from the quantity of material released from the sample under specific bake conditions and subtracting exempt volatile compounds and water present as described by Practice D3960. Contact your local air pollution control agency for regulations.

12. Keywords

12.1 architectural coatings; coatings tests; solvent-borne coatings; water-borne coatings