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Standard Guide for Testing Industrial Protective Coatings[1]

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1. Scope

1.1 This guide covers the selection and use of test methods and procedures for testing industrial protective coatings. Selection of the standards to be followed must be governed by experience and the requirements in each individual case, together with agreement between the supplier and the user.

1.2 This guide covers the testing of liquid coatings as applied on substrate by brushing, rolling, spraying, or other means appropriate to the coating and circumstance.

NOTE 1—The term "industrial protective coating" as used in this guide is described in the scope of Subcommittee D01.46[1] as "paints applied to substrates on-site of structures and buildings, especially where subject to corrosive environments, as industrial, urban, and marine environments."

NOTE 2—Guides for testing other coating types, such as Guides D 4712, D 5146, D 5324 or for surface preparation, coating application, such as Guide D 3276, are available and should be used when it is applicable.

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

2. Referenced Documents

2.1 *ASTM Standards:*

B 117 Practice for Operating Salt Spray (Fog) Apparatus[2]
C 868 Test Method for Chemical Resistance of Protective Linings[3]
D 16 Terminology for Paint and Related Coatings, Materials, and Applications[4]
D 56 Test Method for Flash Point by Tag Closed Tester[5]
D 93 Test Methods for Flash-Point by Pensky-Martens Closed Cup 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 Methods 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[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 Exposure Apparatus[4]
D 823 Practices 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 Practice for Conducting Exterior Exposure Tests of Paints on Steel[4]

[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 D01.46 on Protective Coatings.

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[2] *Annual Book of ASTM Standards*, Vol 03.02.
[3] *Annual Book of ASTM Standards*, Vol 04.05.
[4] *Annual Book of ASTM Standards*, Vol 06.01.
[5] *Annual Book of ASTM Standards*, Vol 05.01.
[6] *Annual Book of ASTM Standards*, Vol 06.03.
[7] *Annual Book of ASTM Standards*, Vol 06.02.
[8] Discontinued; see *1995 Annual Book of ASTM Standards*, Vol 06.01.

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 by Hegman-Type Gage[4]
D 1212 Test Methods for Measurement of Wet Film Thickness of Organic Coatings[4]
D 1296 Test Method for Odor of Volatile Solvents and Diluents[9]
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 Nonconductive 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 Liquid Coatings, Inks, and Related Products[4]
D 1535 Practice for Specifying Color by the Munsell System[4]
D 1640 Test Methods for Drying, Curing, or Film Formation of Organic Coatings at Room Temperature[4]
D 1653 Test Methods for Water Vapor Transmission of Organic Coating Films[4]
D 1654 Test Method for Evaluation of Painted or Coated Specimens Subjected to Corrosive Environments[4]
D 1729 Practice for Visual Appraisal of Colors and Color Differences of Diffusely-Illuminated Opaque Materials[4]
D 1730 Practices for Preparation of Aluminum and Aluminum-Alloy Surfaces for Painting[10]
D 1731 Practices for Preparation of Hot-Dip Aluminum Surfaces for Painting[10]
D 1732 Practices for Preparation of Magnesium Alloy Surfaces for Painting[10]
D 1735 Practice for Testing Water Resistance of Coatings Using Water Fog Apparatus[4]
D 1849 Test Method for Package Stability of Paint[7]
D 2092 Guide for Treatment 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 Practice for Preparation of Zinc-Coated and Zinc-Alloy-Coated Steel Panels for Testing Paint and Related Coating Products[4]
D 2243 Test Method for Freeze-Thaw Resistance of Waterborne Coatings[7]
D 2244 Test Method for Calculation of Color Differences from Instrumentally Measured Color Coordinates[4]
D 2247 Practice for Testing Water Resistance of Coatings in 100 % Relative Humidity[4]
D 2354 Test Method for Minimum Film Formation Temperature (MFFT) of Emulsion Vehicles[6]
D 2369 Test Method for Volatile Content of Coatings[4]
D 2371 Test Method for Pigment Content of Solvent-Reducible Paints[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 2621 Test Method for Infrared Identification of Vehicle Solids from Solvent-Reducible Paints[4]
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 Guide for Testing Filiform Corrosion Resistance of Organic Coatings on Metal[4]
D 2805 Test Method for Hiding Power of Paints by Reflectometry[4]
D 2832 Guide for Determining Volatile and Nonvolatile Content of Paint and Related Coatings[4]
D 3134 Practice for Establishing Color and Gloss Tolerances[4]
D 3168 Practice for Qualitative Identification of Polymers in Emulsion Paints[4]
D 3170 Test Method for Chipping Resistance of Coatings[7]
D 3276 Guide for Painting Inspectors (Metal Substrates)[7]
D 3278 Test Methods for Flash Point of Liquids by Small-Scale Closed-Cup Apparatus[4]
D 3281 Test Method for Formability of Attached Organic Coatings with Impact-Wedge Bend Apparatus[11]
D 3359 Test Methods for Measuring Adhesion by Tape Test[4]
D 3363 Test Method for Film Hardness by Pencil Test[4]
D 3792 Test Method for Water Content of Water-Reducible Paints by Direct Injection into a Gas Chromatograph[4]
D 3793 Test Method for Low-Temperature Coalescence of Latex Paint Films[7]
D 3912 Test Method for Chemical Resistance of Coatings Used in Light-Water Nuclear Power Plants[7]
D 3924 Specification for Standard Environment for Conditioning and Testing Paint, Varnish, Lacquers, 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 3960 Practice for Determining Volatile Organic Compound (VOC) Content of Paints and Related Coatings[4]
D 4017 Test Method for Water in Paints and Paint Materials by Karl Fischer Method[4]
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 4138 Test Methods for Measurement of Dry Film Thickness of Protective Coating Systems by Destructive Means[7]

[9] *Annual Book of ASTM Standards*, Vol 06.04.
[10] *Annual Book of ASTM Standards*, Vol 02.05.
[11] Discontinued; see *1994 Annual Book of ASTM Standards*, Vol 06.01.

D 4141 Practice for Conducting Accelerated Outdoor Exposure Tests of Coatings[4]
D 4212 Test Method for Viscosity by Dip-Type Viscosity Cups[4]
D 4214 Test Methods for Evaluating Degree of Chalking of Exterior Paint Films[4]
D 4287 Test Method for High-Shear Viscosity Using the ICI Cone/Plate Viscometer[4]
D 4366 Test Methods for Hardness of Organic Coatings by Pendulum Damping Tests[4]
D 4400 Test Methods for Sag Resistance of Paints Using a Multinotch Applicator[7]
D 4457 Test Method for Determination of Dichloromethane and 1,1,1-Trichloroethane in Paints and Coatings by Direct Injection into a Gas Chromatograph[4]
D 4541 Test Method for Pull-Off Strength of Coatings Using Portable Adhesion Testers[7]
D 4585 Practice for Testing the Water Resistance of Coatings Using Controlled Condensation[4]
D 4587 Practice for Conducting Tests on Paint and Related Coatings and Materials Using a Fluorescent UV-Condensation Light- and Water-Exposure Apparatus[4]
D 4712 Guide for Testing Industrial Water-Reducible Coatings[7]
D 4752 Test Method for Measuring MEK Resistance of Ethyl Silicate (Inorganic) Zinc-Rich Primers by Solvent Rub[7]
D 4958 Test Method for Comparison of the Brush Drag of Latex Paints[7]
D 5009 Test Method for Evaluating and Comparing Transfer Efficiency Under Laboratory Conditions[7]
D 5031 Practice for Conducting Tests on Paints and Related Coatings and Materials Using Enclosed Carbon-Arc Exposure Apparatus[4]
D 5064 Practice for Conducting a Patch Test to Assess Coating Compatibility[7]
D 5065 Guide for Assessing the Condition of Aged Coatings on Steel Surfaces[7]
D 5146 Guide to Testing Solvent-Borne Architectural Coatings[7]
D 5162 Practice for Discontinuity (Holiday) Testing of Nonconductive Protective Coatings on Metallic Substrates[7]
D 5201 Practice for Calculating Formulation Physical Constants of Paints and Coatings[4]
D 5235 Test Method for Microscopical Measurement of Dry Film Thickness of Coatings on Wood Products[7]
D 5286 Test Methods for Determination of Transfer Efficiency Under General Production Conditions for Spray Application of Paints[7]
D 5324 Guide for Testing Water-Borne Architectural Coatings[7]
D 5327 Practice for Evaluating and Comparing Transfer Efficiency Under General Laboratory Conditions[7]
D 5402 Practice for Assessing the Solvent Resistance of Organic Coatings Using Solvent Rubs[7]
D 5894 Practice for Cyclic Salt Fog/UV Exposure of Painted Metal, (Alternating Exposures in a Fog/Dry Cabinet and a UV/Condensation Cabinet)[4]
D 6093 Test Method for Percent Volume Nonvolatile Matter in Clear or Pigmented Coatings Using a Helium Gas Pycnometer[4]
D 6132 Test Method for Nondestructive Measurement of Dry Film Thickness of Applied Organic Coatings Over Concrete Using an Ultrasonic Gage[4]
E 84 Test Method for Surface Burning Characteristics of Building Materials[12]
F 1249 Test Method for Water Vapor Transmission Rate Through Plastic Film and Sheeting Using a Modulated Infrared Sensor[13]
G 7 Practice for Atmospheric Environmental Exposure Testing of Nonmetallic Materials[14]
G 8 Test Methods for Cathodic Disbonding of Pipeline Coatings[7]
G 14 Test Method for Impact Resistance of Pipeline Coatings (Falling Weight Test)[7]
G 19 Test Method for Disbonding Characteristics of Pipeline Coatings by Direct Soil Burial[7]
G 20 Test Method for Chemical Resistance of Pipeline Coatings[7]
G 23 Practice for Operating Light-Exposure Apparatus (Carbon-Arc Type) With and Without Water for Exposure of Nonmetallic Materials[14]
G 26 Practice for Operating Light-Exposure Apparatus (Xenon-Arc Type) With and Without Water for Exposure of Nonmetallic Materials[14]
G 42 Test Method for Cathodic Disbonding of Pipeline Coatings Subjected to Elevated Temperatures[7]
G 50 Practice for Conducting Atmospheric Corrosion Tests on Metals[2]
G 53 Practice for Operating Light-and Water-Exposure Apparatus (Fluorescent UV-Condensation Type) for Exposure of Nonmetallic Materials[14]
G 80 Test Method for Specific Cathodic Disbonding of Pipeline Coatings[7]
G 85 Practice for Modified Salt Spray (Fog) Testing[2]
G 90 Practice for Performing Accelerated Outdoor Weathering of Nonmetallic Materials Using Concentrated Natural Sunlight[14]
G 95 Test Method for Cathodic Disbondment Test of Pipeline Coatings (Attached Cell Method)[7]
G 113 Terminology Relating to Natural and Artificial Weathering Tests of Nonmetallic Materials[14]
G 141 Guide for Addressing Variability in Exposure Testing on Nonmetallic Materials[14]
G 147 Practice for Conditioning and Handling of Nonmetallic Materials for Natural and Artificial Weathering Tests[14]

[12] *Annual Book of ASTM Standards*, Vol 04.07.
[13] *Annual Book of ASTM Standards*, Vol 15.09.
[14] *Annual Book of ASTM Standards*, Vol 14.04.

G 151 Practice for Exposing Nonmetallic Materials in Accelerated Test Devices That Use Laboratory Light Sources[14]
G 152 Practice for Operating Open Flame Carbon Arc Light Apparatus for Exposure of Nonmetallic Materials[14]
G 153 Practice for Operating Enclosed Carbon Arc Light Apparatus for Exposure of Nonmetallic Materials[14]
G 154 Practice for Operating Fluorescent Light Apparatus for UV Exposure of Nonmetallic Materials[14]
G 155 Practice for Operating Xenon Arc Light Apparatus for Exposure of Nonmetallic Materials[14]

2.2 *Federal Standards:*

2.3 *U.S. Federal Test Method Standard No. 141C:*[15]
1022 Sampling for Inspection and Testing
2112 Application by Roller
2131 Application of Sprayed Films
2141 Application of Brushed Films
2161 Application of Film with Film Applicator (Magnetic Chuck)
2162 Application of Film with Film Applicator Using Suction Panel Holder
3011 Condition in Container
4061 Drying Time
4321 Brushing Properties
4331 Spraying Properties
4335 Roller Coating Properties
4401 Odor Test

2.4 *U.S. Environmental Protection Agency Standard:*[16]
EPA Federal Reference Method 24 – Determination of Volatile Matter Content, Density, Volume Solids, and Weight Solids of Surface Coatings

2.5 *NACE Standard:*[17]
TM-01-74 Laboratory Methods for the Evaluation of Protective Coatings and Lining Materials in Immersion Service

2.6 *ANSI Standard:*[18]
N512 Protective Coatings (Paints) for the Nuclear Industry

3. Terminology

3.1 *Definitions*:

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

3.1.2 The definitions given in Terminology G 113 relating to natural and artificial weathering tests are applicable to this guide.

4. Significance and Use

4.1 This guide is intended to provide assistance in selecting appropriate tests for evaluating the general performance level to be expected of a coating or coating system on a given substrate exposed to a given type of environment.

4.2 Surface preparation or cleanliness prior to application of the coating can be critical to the proper performance of the coating.

4.3 Results obtained in the tests cited in this guide may not be adequate for predicting coating service life of a specific coating system in a specific environmental exposure. A suitable control coating system of known performance in the service environment should be included in the testing for comparison.

5. Conditions Affecting Performance

5.1 Practical requirements and performance of industrial coatings may vary with the following:

5.1.1 *Substrate Type*—Ferrous, nonferrous, previously coated surfaces, masonry, and other materials.

5.1.2 *Substrate Conditions and Surface Profile*—Cleanliness, porosity, smoothness, and weathering of the substrates.

5.1.3 *Substrate Aspects of Structure*—Construction defects or defects due to age such that excessive moisture makes its way through a porous substrate or is trapped in components; design defects that cause galvanic corrosion; environmental exposure to deteriorating materials such as deicing salts, improperly prepared welds, or other site-specific detrimental conditions.

5.1.4 Type, quality, and suitability of the surface treatment or primer used and time of drying before coating application.

5.1.5 Application methods and techniques.

5.1.6 *Application and Cure Conditions*—Environmental conditions, such as temperature and relative humidity, during application and drying.

5.1.7 *Service Conditions*—Environmental conditions such as temperature, humidity, and chemical and mechanical stress.

6. Sampling and Test Conditions

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 D 3925 or Method 1022 of Federal Test Method Standard No. 141C. Prepare coating films of uniform thickness on test panels in accordance with Practices D 823.

6.3 Tests and observations shall be at standard laboratory conditions in accordance with Specification D 3924 unless otherwise specified or agreed upon between the supplier and the user.

7. Liquid Coatings Properties

7.1 *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 test method, Method 3011.1 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.

7.2 *Coarse Particles and Foreign Matter*—Liquid coatings must be free of coarse particles and foreign matter to be able to

[15] Available from Standardization Documents Order Desk, Bldg. 4 Section D, 700 Robbins Ave., Philadelphia, PA 19111-5094, Attn: NPODS.
[16] Available from Superintendent of Documents, U.S. Government Printing Office, Washington, DC 20402.
[17] Available from the National Association of Corrosion Engineers, P.O. Box 218340, Houston, TX 77218.
[18] Available from American National Standards Institute, 11 W. 42 St., 13th Floor, New York, NY 10036.

form uniform films of good appearance. A typical maximum value is 0.5 weight % of the total material. Determine the content of coarse particles and foreign matter in accordance with Test Methods D 185. This referenced method uses material retained in a 325-mesh (45-μm) screen as a measure of coarse particle and foreign matter.

7.3 *Density or Weight per Gallon*—The density as measured by weight per gallon is used to help ensure product uniformity from batch to batch. Test Method D 1475. gives a procedure for measuring the density of the coating at specified temperature. A calibrated weight-per-gallon cup is used. Determine the density in accordance with Test Method D 1475.

7.4 *Fineness of Dispersion*—Pigmented paints involve the dispersion of colored pigments and filler pigments into the liquid vehicle. Generally, the more finely a pigment is dispersed, the more efficiently it is being utilized. The fineness of dispersion (or fineness of "grind") provides a means to measure and report the degree to which pigment agglomerates have been broken down in the dispersion process. The degree of dispersion can affect paint properties such as color, gloss, and pigment settling. Determine fineness of dispersion in accordance with Test Method D 1210.

7.5 *Settling*—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. Pigments and fillers dispersed in paints are subject to settling as generally described in Stokes Law. Determine the degree of settling in accordance with Test Method D 869.

7.6 *Viscosity*—Viscosity refers to the flow resistance of a fluid. Viscosity values are often related to application properties such as flow, leveling, and sag resistance and should fall within an agreed-upon range.

7.6.1 *Viscosity of Newtonian or Near Newtonian Fluids*—(constant viscosity regardless of shear rate), may be measured in accordance with Test Methods D 1200 and D 4212. This viscosity measurement is used to determine package viscosity and application viscosity. Viscosity of non-Newtonian materials should be measured in accordance with Test Methods D 2196 since it measures resistance to flow at different shear rates. The ratio of viscosity values at different shear rates is also a way of measuring thixotropy often related to film build or sag resistance. Determine viscosity in accordance with Test Methods D 1200 or D 2196.

7.6.2 *Consistency (Low-Shear Viscosity)*—Consistency is used mainly to ensure product uniformity. Consistency is defined in Test Method D 562. as the load in grams required to produce a specific rate of rotation in a specimen using the Stomer viscometer. This is a one-speed test method. Two paints of the same consistency may have quite different rheological properties during application. Determine consistency in accordance with Test Method D 562.

7.6.3 *High-Shear Viscosity*—The viscosity of a paint under high shear is related to its behavior when brushed, rolled, or sprayed applied. In Test Methods D 4287 and D 4958, the shear rate is similar to that occurring during brush application so that the measured viscosity is related to brush drag, spreading rate, and film build. High-shear viscosity is more likely used in the development and quality control of paints than a requirement in a paint specification. Determine high-shear viscosity in accordance with Test Method D 4287.

7.7 *Flash Point*—Flash point refers to the lowest temperature at which a vapor will ignite if presented with an ignition source such as a flame or spark. The flash point for a paint is needed to conform with many government regulations concerning transportation, labeling, packaging, and storage procedures. Determine flash point in accordance with Test Methods D 56, D 93, or D 3278.

7.8 *Freeze-Thaw Stability*—Waterborne coatings may be subjected to freezing conditions during shipping and storage. Suitably stabilized products can resist several cycles of freezing and thawing without showing deleterious changes such as coagulation, graininess (seeding), or excessive viscosity increase. Test Method D 2243 covers the determination of the extent to which waterborne 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.

7.9 *Odor*—Odor is often associated with the volatile components: organic solvents or ammonia in waterborne coatings. No specific ASTM test method is available for evaluating odor. Method 4401 of Federal Test Method Standard No. 141C does address" characteristic" or expected odor. Test Method D 1296 may also be suitable as the basis for a test even though it is not specifically designed for liquid coatings.

7.10 *Microorganism Resistance*—Microorganisms in waterborne paints can cause gassing, putrefaction, or fermentation and their corresponding odors, and loss in viscosity and film build capability. Determine if the liquid coating contains living bacteria and if it is resistant to attack by bacteria in accordance with Test Method D 2574.

7.11 *Package Stability*—Since liquid coatings cannot normally be used immediately after manufacture, they must remain stable in the package for some time. Test Method D 1849 covers the change in consistency and in certain related properties that may take place in packaged coatings when stored at a temperature above room temperature. Determine package stability in accordance with Test Method D 1849.

7.12 *Volatile Content of Coatings*—Test Method D 2369 is used to determine the weight percent volatile content of coatings. Test Method D 2369 is also used in the determination of the volatile organic compound (VOC) content of coatings (Practice D 3960 and EPA Method 24). Test Method D 2369 can also be used to set acceptance limits in qualification testing or purchase specifications. Guide D 2832 provides a guideline in selecting standards for determining volatile and nonvolatile content of paint.

7.13 *Volume Solids Content*—The volume of solid materials from a can of paint is related to the spread rate at recommended dry film thickness and 100 % transfer efficiency. The volume of solid materials can be used to calculate the number of square feet a gallon of paint will cover at recommended film thickness and actual transfer efficiency. The volume solids value then can be used to estimate the amount of paint needed for a job or allow a common basis for the economic comparison of competitive paints whose volume solids and recommended film thickness may differ. The measured value of volume solids

may not equal volume solids based on calculation (Practice D 5201). Determine volume solids in accordance with Test Methods D 2697 and D 6093.

7.14 *Volatile Organic Compound Content*—The U.S. EPA Federal Reference Method 24 is the regulatory method of VOC content determination. Practice D 3960 is used to determine the VOC content of the paint, based on volatile content, Test Method D 2369, density, Test Method D 1475, water content, Test Method D 3792 (GC analysis) or Test Method D 4017 (Karl Fischer titration), and exempt solvent, Test Method D 4457 (GC analysis for 1,1,1-trichloroethane).

7.15 *Chemical Analysis*—Chemical analysis determines the presence of specified components and their quantities. Test Method D 2621 and Practice D 3168 address the use of infrared spectroscopy to identify paint vehicle solids. Test Method D 2371 describes the procedure for quantitative separation of the vehicle from the pigment in coatings to determine the weight percent pigment in the paint. More complete series of test methods by which paint or its component materials may be analyzed, are governed by Subcommittee D01.21.

7.16 *Transfer Efficiency*—The transfer efficiency of paint is defined as the ratio of paint solids deposited to the total paint solids used during the application process, expressed as a percent. Transfer efficiency is important in qualifying application test methods in certain regulated regions of the country. Transfer efficiency is a function of the application test method, application equipment, and operator skill. Determine transfer efficiency of a coating application test method or equipment in accordance with Test Methods D 5009 and D 5286 and Practice D 5327.

8. Application and Film Formation

8.1 *Panel Preparation*—Select a substrate as agreed upon between the supplier and the user. Prepare panels in accordance with appropriate Practices D 609, D 1730, D 1731, D 1732, or D 2201 or Guide D 2092.

8.2 *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 kinetic viscosity, non-Newtonian rheology, surface tension, shear sensitivity, micelle stability, electrical resistivity, erosion abrasiveness, conductivity, heat capacity, and corrosiveness. Determine the application properties in accordance with Method 2112, 2131, 2141, 2161, 2162, 4321, 4331, or 4335 of Federal Test Method Standard No. 141C.

8.3 *Drying Properties*—The drying time of the 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 Methods D 1640, Method 4061 of the Federal Test Method Standard No. 141C, or as agreed upon between the purchaser and the seller.

8.4 *Leveling Properties*—Leveling is an important factor when uniform surfaces are to be produced, as it affects hiding and appearance. The referenced test method covers the laboratory determination of the relative leveling characteristics of liquid coatings. Determine the leveling characteristics in accordance with Test Method D 4062.

8.5 *Wet Film Thickness*—The measurement of wet film thickness provides opportunity to check the coating and its application process. It is important that wet film measurements are made as soon as the coating is applied to avoid error due to solvent loss during the curing process. Determine the wet film thickness in accordance with Test Methods D 1212.

8.6 *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 continuous 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.

8.7 *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 its appearance is significantly different than the appearance of 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.

8.8 *Sag Resistance*—Sagging is driven by gravitational shear stress. The sagging shear stress magnitude depends entirely on the wet film thickness and density. Test the sag resistance in accordance with Test Methods D 4400.

8.9 *Pot Life*—Pot life is the length of time in which the application and performance properties of catalyzed paints will not change within an acceptable range. Pot life of the coating can be determined by monitoring the change in coating application and performance properties over time using various viscosity, sag resistance, application, and performance tests.

9. Appearance of Dry Film

9.1 *Color*—The color of the 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 film may be prepared by making one or more applications of 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.

9.1.1 *Color Differences by Visual Evaluation*—Visual comparison of color is fast, and often acceptable, although numerical values are not obtained. Practice D 1729 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.

9.1.2 *Color Differences of Opaque Material by Instrumental Evaluation*—Instruments can measure color difference between a product and the standard. Generally, the tolerance is