Designation: D 6763 – 02

Standard Guide for Testing Exterior Wood Stains[1]

1. Scope

1.1 This guide covers the selection and use of procedures for testing exterior wood stains. This includes both water borne and solvent borne semitransparent and opaque stains. The properties that can be examined or, in some cases, the relevant test procedures are listed in 2.1 and 2.2.

NOTE 1—The term "opaque stain" is defined as a pigmented composition intended for use on wooden surfaces to produce a uniform finish that obscures the grain and color of the wood, but not its surface texture; also called solid color or solid hide.

NOTE 2—The term "semitransparent" is defined as a pigmented composition intended for use on wooden surfaces to produce a uniform finish that does not fully obscure the grain or the texture of the wood.

1.1.1 *Discussion*—When applied to woods that differ in color, there is a color difference between stained substrates.

1.2 *This standard may involve hazardous materials, operations, and equipment. This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory requirements prior to use.*

2. Referenced Documents

2.1 *ASTM Standards:*

D 16 Terminology for Paint, Related Coatings, Materials, and Applications[2]
D 56 Test Method for Flash Point by Tag Closed Cup Tester[3]
D 93 Test Methods for Flash-Point by Pensky-Martens Closed Cup Tester[3]
D 154 Guide for Testing Varnishes[4]
D 185 Test Methods for Coarse Particles in Pigments, Pastes, and Paints[4]
D 215 Practice for the Chemical Analysis of White Linseed Oil Paints[2]
D 344 Test Method for Relative Hiding Power of Paints by the Visual Evaluation of Brushouts[2]
D 358 Specification for Wood To Be Used As Panels in Weathering Tests of Coatings[5]
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 Measuring Krebs Unit (KU) Viscosity Using a Stormer-Type Viscometer[2]
D 660 Test Method for Evaluating Degree of Checking of Exterior Paints[2]
D 661 Test Method for Evaluating Degree of Cracking of Exterior Paints[2]
D 662 Test Method for Evaluating Degree of Erosion of Exterior Paints[2]
D 714 Test Method for Evaluating Degree of Blistering of Paints[2]
D 772 Test Method for Evaluating Degree of Flaking (Scaling) of Exterior Paints[2]
D 869 Test Method for Evaluating Degree of Settling of Paint[5]
D 968 Test Methods for Abrasion Resistance of Organic Coatings by Falling Abrasive[2]
D 1006 Practice for Conducting Exterior Exposure Tests of Paints on Wood[2]
D 1038 Terminology Relating to Veneer and Plywood[6]
D 1210 Test Method for Fineness of Dispersion of Pigment-Vehicle Systems by Hegman-Type Gage[2]
D 1296 Test Method for Odor of Volatile Solvents and Diluents[7]
D 1310 Test Method for Flash Point and Fire Point of Liquids by Tag Open Cup Apparatus[2]
D 1475 Test Method for Density of Liquid Coatings, Inks, and Related Products[2]
D 1554 Terminology Relating to Wood-Base Fiber and Particle Panel Materials[6]
D 1640 Test Methods for Drying, Curing or Film Formation of Organic Coatings at Room Temperature[4]
D 1729 Practice for Visual Appraisal of Colors and Color Differences of Diffusely-Illuminated Opaque Materials[2]
D 1849 Test Method for Package Stability of Paint[5]

[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.

Current edition approved Feb. 10, 2002. Published April 2002.

[2] *Annual Book of ASTM Standards*, Vol 06.01.
[3] *Annual Book of ASTM Standards*, Vol 05.01.
[4] *Annual Book of ASTM Standards*, Vol 06.03.
[5] *Annual Book of ASTM Standards*, Vol 06.02.
[6] *Annual Book of ASTM Standards*, Vol 04.10.
[7] *Annual Book of ASTM Standards*, Vol 06.04.

D 2196 Test Methods for Rheological Properties of Non-Newtonian Materials by Rotational (Brookfield type) Viscometer[2]
D 2197 Test Method for Adhesion of Organic Coatings by Scrape Adhesion[2]
D 2243 Test Method for Freeze-Thaw Resistance of Water-Borne Coatings[5]
D 2244 Test Method for Calculation of Color Differences from Instrumentally Measured Color Coordinates[2]
D 2245 Test Method for Identification of Oils and Oil Acids in Solvent-Reducible Paints[2]
D 2369 Test Method for Volatile Content of Coatings[2]
D 2370 Test Method for Tensile Properties of Organic Coatings[2]
D 2371 Test Method for Pigment Content of Solvent-Reducible Paints[2]
D 2372 Practice for Separation of Vehicle from Solvent-Reducible Paints[2]
D 2486 Test Method for Scrub Resistance of Wall Paints[5]
D 2574 Test Method for Resistance of Emulsion Paints in the Container to Attack by Microorganisms [2]
D 2621 Test Method for Infrared Identification of Vehicle Solids From Solvent-Reducible Paints[2]
D 2697 Test Method for Volume Nonvolatile Matter in Clear or Pigmented Coatings[2]
D 2805 Test Method for Hiding Power of Paints by Reflectometry[2]
D 3168 Practice for Qualitative Identification of Polymers in Emulsion Paints[2]
D 3274 Test Method for Evaluating Degree of Surface Disfigurement of Paint Films by Microbial (Fungal or Algal) Growth or Soil and Dirt Accumulation[2]
D 3278 Test Methods for Flash Point of Liquids by Small Scale Closed-Cup Apparatus[2]
D 3359 Test Methods for Measuring Adhesion by Tape Test[2]
D 3456 Practice for Determining by Exterior Exposure Tests the Susceptibility of Paint Films to Microbiological Attack[2]
D 3719 Test Method for Quantifying Dirt Collection on Coated Exterior Panels[5]
D 3723 Test Method for Pigment Content of Water-Emulsion Paints by Low-Temperature Ashing[2]
D 3793 Test Method for Low-Temperature Coalescence of Latex Paint Films[5]
D 3925 Practice for Sampling Liquid Paints and Related Pigmented Coatings[2]
D 3928 Test Method for Evaluation of Gloss or Sheen Uniformity[5]
D 3960 Practice for Determining Volatile Organic Compound (VOC) Content of Paints and Related Coatings[2]
D 4017 Test Method for Water in Paints and Paint Materials by Karl Fischer Method[2]
D 4060 Test Method for Abrasion Resistance of Organic Coatings by the Taber Abraser[2]
D 4062 Test Method for Leveling of Paints by Draw-Down Method[5]
D 4212 Test Method for Viscosity by Dip-Type Viscosity Cups[2]
D 4214 Test Methods for Evaluating the Degree of Chalking of Exterior Paint Films[2]
D 4287 Test Method for High-Shear Viscosity Using a Cone/Plate Viscometer[2]
D 4400 Test Method for Sag Resistance of Paints Using a Multinotch Applicator[5]
D 4446 Test Method for Anti-Swelling Effectiveness of Water-Repellent Formulations and Differential Swelling of Untreated Wood When Exposed to Liquid Water Environments[6]
D 4585 Practice for Testing Water Resistance of Coatings Using Controlled Condensation[2]
D 4958 Test Method for Comparison of the Brush Drag of Latex Paints[5]
D 5326 Test Method for Color Development in Tinted Latex Paints[5]
D 5401 Test Method for Evaluating Clear Water Repellent Coatings on Wood[5]
E 70 Test Method of pH of Aqueous Solutions with the Glass Electrode[8]
E 105 Practice for Probability Sampling of Materials[9]
E 313 Practice for Calculating Yellowness and Whiteness of Indices from Instrumentally Measured Color Coordinates[2]
E 1347 Test Method for Color and Color- Difference Measurement by Tristimulus (Filter) Colorimetry[2]

2.2 *U.S. Federal Standards:*
U.S. Federal Test Method Standard No. 141 C
2131 Application of Sprayed Films
2141 Application of Brushed Films
3011 Condition in Container
4203 Reducibility and Dilution Stability
4401 Odor
4421 Absorption Test
4541 Working Properties and Appearance of Dried Film
6301 Wet Adhesion (Tape Test)

2.3 *Other Documents:*
Paint/Coatings Dictionary of the Federation of Societies for Coatings Technology[10]
Paint and Coatings Testing Manual

3. Terminology

3.1 For definitions of terms in this guide refer to Terminology D 16, D 1038, and D 1554 and to the FSCT Stain/Coatings Dictionary.

4. Conditions Affecting Coatings

4.1 *Moisture*—Wood is porous and will absorb moisture, causing it to swell. As it dries, it will shrink. It is this cycle of shrinking and swelling that causes warping and cracking in the wood substrate. This dimensional instability stresses a coating, affecting its durability. Many semitransparent and opaque, or

[8] *Annual Book of ASTM Standards*, Vol 15.05.
[9] *Annual Book of ASTM Standards*, Vol 14.02.
[10] Available from the Federation of Societies for Coatings Technology, 492 Norristown Rd., Blue Bell, PA 19422.

solid color, exterior stains are formulated to repel water to protect wood from ingress of moisture, thereby reducing the tendency of the wood to warp and crack.

4.2 *Substrate Type*—The substrate to be coated 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, a primer may be required for previously coated wood that will receive opaque stain; or a primer-sealer on previously uncoated wood. Other factors include the type and quality of wood or wood composite (plywood, particle board or hardboard).

4.3 *Substrate Conditions*—Conditions such as species of wood, porosity, degree of weathering, and previous coatings determine the kind of coating that can be applied. The performance of coatings on uncoated new wood can be influenced by the presence of mill glaze and wood grain orientation. The condition of previously stained substrates such as degree of chalk, presence of dirt, mold, and water-soluble or oily contaminants, extractives, film adhesion, and porosity also influence the performance of coatings. Smoothness of the substrate affects the spreading rate, final appearance, and texture.

4.4 Preparation of previously coated or weathered substrates including cleaning, sanitizing, and sanding.

4.5 The application properties are affected by temperature and humidity at the time of application and during drying.

4.5.1 *For Water Reducible*—As these materials contain water, surfaces do not have to be completely dry before application. However, application and surface temperatures lower than 50°F may cause poor film formation.

4.5.2 *For Solvent Reducible*—Surface dampness may adversely effect film uniformity, wetting, and adhesion. Humidity and low temperature have relatively little effect except for slowing the drying.

4.6 *Substrate Weathering*—Weathering of wood before staining will adversely affect the performance of exterior coatings.

4.6.1 *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 it way through the substrate or if the substrate is in direct contact with damp ground, blistering flaking or peeling may result.

4.6.2 Environmental conditions after application, both general for the area and specific, such as under eaves, behind shrubbery, northside and southside exposure are significant weathering factors.

5. Selection of Tests

5.1 Because the conditions to which a coating is subjected vary with (*1*) the surface type: deck, siding, species of wood and (*2*) the service environment; sheltered, exposed, and horizontal, specialized types of solvent-borne and water-borne coatings have been developed for the different locations. Selection of the referenced 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 which properties are the most important. After establishing the requirements or specifications, select the test methods that measure or evaluate those properties. The balance of properties must be considered when establishing the requirements and selecting the tests. The significance of the tests and the normal range of values are presented in the different sections, in most cases.

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 coatings.

6.2 Sample in accordance with Practice D 3925. Determine the density in pounds per gallon (kilograms/litre) in accordance with Test Method D 1475. Continue sampling and determining density until successive results agree within 0.1 lb (45 g) 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 1-US gal (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 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 D 154.

7.2 *Condition in Container*—Thickening, settling, and separation are undesirable and objectionable if material that has been stored cannot be readily reconditioned and made 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 stain. Determine condition in the container in accordance with Method 3011 of Federal Test Method Standard No. 141. (See also 7.12, 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 D 185.

7.4 *Density or Weight per Gallon*—The density measured in pounds per gallon (kilograms per litre = g/mL) 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 reference method gives a procedure for measuring the density of the coating at a specified temperature. Most stains have densities of about 8 to 11 lb/gal (1.2 to 1.4 kg/L). Determine density in accordance with Test Method D 1475, 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 4 to 0 mils (100 to 0 µm) (0-8 Hegman units). 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 micrometers indicate finer dispersion. Low sheen finishes may have a dispersion value of 2 mils (50 µm or 4 Hegman). Determine fineness of dispersion and cleanliness in accordance with Test Method D 1210.

7.5.1 The referenced method was designed primarily for coatings with good fineness of dispersion, such as high gloss finishes. Some exterior stains, which are typically flat finishes, may contain pigments so coarse that it is impractical to measure the fineness with a grind gage because the agglomerates are carried along by the scraper. The best stains for appearance do not have Hegman readings below 2.

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 US Occupational Safety and Health Act (OSHA). Suitable methods include Test Methods D 56, D 93, Part B, or D 3278.

7.7 *Odor*—Some solvent combinations produce obnoxious odors. Test for odor in accordance with Method 4401 of Federal Test Method Standard No. 141. Although not specifically designed for liquid coatings Test Method D 1296 may be used with the solvent-reducible type. One of the advantages of latex coatings are that they contain little if any organic solvent. Thus latex stains do not have odors characteristic of solvent-borne coatings. However, other ingredients that may be used, such as ammonia, might also be objectionable. Although there is no specific ASTM test method for evaluating odor of water-borne coatings, the industry does attempt to measure this property. Determine whether the stain has an unpleasant or irritating odor as agreed upon between the purchaser and seller, taking adequate precautions to ensure the safety of the operator.

7.8 *Penetration*—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. 141. Stains are formulated to penetrate into the wood substrate in order to help protect the wood. Test methods for penetration are not yet available.

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. Test Method D 5326 may be used. Test methods may be agreed upon between the purchaser and seller.

7.10 *pH*—Latex stains with low (acidic) pH may corrode metal containers. To avoid this problem, the pH is normally stabilized within the range from about 5 to 10, depending upon the type of latex used and the general formulation. The pH does not necessarily determine the quality of a latex stain and should be used primarily to ensure product uniformity. The pH of a stain can also effect package stability and in-can corrosion. Change in pH during storage may indicate poor stability and an unacceptable change in the properties of a latex stain. Determine pH in accordance with Test Method E 70.

7.11 *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. 141.

7.12 *Package Stability*—Since stains cannot normally be used immediately after manufacture, they must remain stable in the can for some time. At normal temperatures most stains 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 125°F (50°C) or 140°F (60°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 of packaged stain when stored at temperatures above freezing. Determine package stability in accordance with Test Method D 1849.

7.13 *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 when stored at temperatures above freezing. Although an indication of long term package stability can usually be obtained in several days or weeks at an elevated temperature, such as 125°F (50°C) for 1 month or 140°F (60°C) for 2 weeks. 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, pH, foam resistance, color uniformity, and wet adhesion are usually checked. Determine heat stability in accordance with Test Method D 1849.

7.14 *Freeze-Thaw Stability*—Water-borne coatings may be subjected to freezing conditions during shipping and storage. Suitably stabilized products can resist three to five cycles of freezing and thawing without showing deleterious changes such as coagulation, graininess (seeding), or excessive viscosity increase. Many latex stains that increase in viscosity can still be considered usable, 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.

7.15 *Settling*—Latex stains 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. Thin-bodied solvent based stains often settle. The degree of settling and the ease of mixing the settled materials back into a homogeneous stain should be evaluated. Determine settling in accordance with Test Method D 869.

7.16 *Microorganism Resistance*—Microorganisms in a water-borne coating can cause gassing, putrefactive or fermentative odors, and loss of viscosity. Determine if the stain contains living bacteria and if it is resistant to attack by bacteria in accordance with Test Method D 2574.

8. Coating Application and Film Formation

8.1 *Application Properties*—Application or working properties of a stain 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. 141.

8.1.1 *Brush Application*—Stains are primarily brush applied. Even when sprayed, it is recommended to back brush to increase penetration into the wood substrate and to improve color uniformity. 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 applications. Siding finishes are tested on vertical surfaces and floor or deck coatings on horizontal surfaces, although evaluation of the later on vertical surfaces may be included when appropriate. The referenced method covers a means for the determination of the brushing properties of a coating. Even though the test is subjective, someone experienced in the art can produce quite consistent results, particularly in the evaluation of drag qualities. Determine the brushing properties in accordance with Method 2141 of Federal Test Method Standard No. 141. Brush drag for latex paints Test Method D 4958 can be performed.

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

8.2.1 *Lap Sheen Uniformity*—On large surfaces where a coating must be applied in sections, an area of application may extend over an adjacent area, where coating was applied previously. Sheen and color variations may exist in these areas due to a heavier application of the coating. Similar to touch-up uniformity, these areas should be uniform in gloss and leveling so as not to adversely affect the overall appearance of the surface. Determine lap sheen uniformity in accordance with Test Method D 3928. Variations in color, opacity, and sheen can be observed at intervals agreed upon. Customary intervals for lap uniformity observations include 10, 15, and 20 min.

8.3 *Low-Temperature Coalescence*—If a latex stain is applied at too low a temperature it will not form a coherent film. The referenced test method determines how well the latex particles fuse together or coalesce to form a continuous film at low temperatures. Determine low-temperature coalescence of a series of coatings or reformulations in accordance with Test Method D 3793.

8.4 *Rheological Properties*—Rheology is measured to predict the properties of a coating when it is subjected to various external forces, such as brushing, rolling, or spraying. Measurements are made with various instruments, such as Shell or Ford cups, Brookfield or Stormer viscometers. The data taken are used to infer properties such as resistance to sag, flow, leveling, or brush drag.

8.4.1 *Consistency (Low-Shear Viscosity)*—Consistency is important, relating to application and flow, sag, and leveling and should fall within a stated range for satisfactory reproduction of a specific formula. Semitransparent stains are typically thinner and not measurable on a Stormer viscometer. Typically they are measured using efflux cups such as Shell or Ford. Opaque stains are often measured by Stormer or Brookfield viscometers. 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. Two stains of the same consistency may have quite different rheological properties during application. Determine the consistency in accordance with Test Method D 562 or D 4212.

8.4.2 *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. They actually measure viscosity under different shear rates. In Test Method D 4287 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 D 2196 or D 4287, or both.

8.4.3 *Sag Resistance*—Some coatings sag and form curtains before the film sets. Measure sag resistance in accordance with Test Method D 4400. This test is valid for non-penetrating opaque stains. Stains that penetrate the wood can not be measured by this method.

8.4.4 *Leveling Properties*—Leveling is an important property when smooth, uniform surfaces are to be produced, as it affects hiding and appearance. The referenced method covers the relative leveling characteristics of liquid coatings. Determine leveling in accordance with Test Method D 4062. This test is valid for non-penetrating opaque stains. Stains that penetrate the wood can not be measured by this method.

8.5 *Drying Properties*—The drying time of a coating is important in determining when a freshly stained surface may be put back in use or re-coated. Slow drying may result in dirt or insect pickup resulting in a poor appearance or, 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. Also, some coating formulations dry more slowly with aging. Any of several methods may be used to determine the various stages of film formation or curing. Determine appropriate drying time(s) in accordance with Test Methods D 1640.

9. Appearance of Dry Film

9.1 *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 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 D 1729.

9.2 *Color Differences Using Instrumental Measurements*—The difference in color between a product and its standard, or reference color, 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 Test Method D 2244 the color differences that have been measured instrumentally.

9.3 *Directional Reflectance*—This property is a measure of the appearance of lightness of a coating. It is usually assigned a value in specification for white and pastel shades. In the referenced method the direction of illumination and viewing are specified so as to eliminate the effect of gloss. Determine daylight directional reflectance in accordance with Test Method E 1347.

9.4 *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 commonly referred to as "sheen." This angle is useful in characterizing the low angle appearance of low-gloss coatings. Typically, stains are not high in gloss so 85° sheen is of particular interest. Determine 60° and 85° gloss in accordance with Test Method D 523.

9.5 *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. Stains are formulated so as not to obscure the substrate. [Opaque stains allow the texture of the wood to show through while semi-transparent stains also allow grain and color to show through. See 9.7 for semi-transparent stains.] It is, however, dependent on uniformity of film thickness, which in practical applications is influenced by flow, leveling and application properties of the coating. Test Method D 2805 is precise and gives an absolute rather than a comparative result. Stain is applied with an applicator bar to minimize the effects of flow and leveling, film thickness is rigorously measured, and film opacity is determined instrumentally. Test Method D 344 is a practical test in which stain 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 stain, but results are affected by flow and leveling of the materials. Determine hiding power in accordance with Test Methods D 344 or D 2805.

9.6 *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 E 313. (See also 10.2.1.)

9.7 *Transparency*—Hiding power is inversely related to transparency. Use Test Method D 2805 with appropriate modification in the absence of a method for measuring transparency as such.

9.7.1 *Discussion*—It is very important to note that for stains, especially semitransparent, the final appearance is influenced by the substrate. The more transparent a stain is, the more the wood lends to the overall appearance. Wood differs greatly from specie to specie, so a single stain sample can look distinctly different when applied to various species.

10. Properties of the Dry Coating

10.1 *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, a weighted wheel with abrasive embedded in a resilient rubber matrix is used. Determine dry abrasion resistance in accordance with Test Methods D 968 or D 4060. (See 10.2.1 for wet abrasion resistance.) Test Method D 2486 can be modified to use as a determination of mar resistance for stains used on walking surfaces such as decks.

10.2 *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 D 2197 or D 3359, or both. Test Method D 2197 for scrape adhesion may be useful for deck stains subjected to furniture dragging or foot traffic. ASTM scrub tests can also be adapted to test for performance here.

10.2.1 *Wet Adhesion*—It is essential that a finish adhere tightly to a given substrate or primer under the wet conditions of rain or snow and foot traffic or scraping of furniture or shrubs and trees. There is no adequate test method published by ASTM. Determine the wet adhesion of exterior latex stains in accordance with Method 6301 of Federal Test Method Standard No. 141.

10.2.2 *Adhesion to Chalky Surfaces*—Stains are primarily formulated to be applied directly to wood; however, latex opaque stains are often applied to previous coatings. There are no directly applicable ASTM or Federal Test Method Standard No. 141 test methods for adhesion to chalky surfaces, although work is on going. The industry generally uses a pressure-sensitive tape to test for this property. The tape is pressed firmly onto the dried film (fresh dry films do not adhere as well as aged dry films) and then removed rapidly by pulling back upon itself. Ratings and testing procedure from Test Methods D 3359 are commonly used. Method 6301 of Federal Test Method Standard 141 describes a similar method but includes water exposure.

10.3 *Dirt Pickup*—Low-gloss exterior stains generally have good resistance to dirt pickup. Exterior exposure, particularly under an overhang (soffit), should indicate in a relatively short time (about 1 year) a stain's tendency to this defect. Determine degree of dirt collection in accordance with Test Method D 3719.

10.4 *Flexibility*—Elongation is a measure of the flexibility of a coating film. Stains need good flexibility since wood substrates often swell and shrink, especially decking. For exterior coatings that can be made to form a free- film (primarily water based solid color stains) Test Method D 2370 is a discriminating method.[11] For non-penetrating stains capable of free films, determine flexibility in accordance with Test Methods D 522 and elongation with Test Method D 2370.

10.5 *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 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 D 4585 and Test Method D 714. The uncoated side of the wood should be exposed to the condensing water. This procedure can also be used to evaluate tannin stain resistance.

10.6 *Exposure Resistance*—Evaluation of the resistance to weathering is required. In conducting exterior exposures follow Practice D 1006.

10.6.1 In establishing exterior performance on wood, use the panels described in Specification D 358.

10.6.2 *Degree of Chalking*—Determine the rating using Test Methods D 4214.

10.6.3 *Degree of Checking*—Determine the rating using Test Method D 660.

10.6.4 *Degree of Cracking*—Determine the rating using Test Method D 661.

10.6.5 *Degree of Erosion*—Determine the rating using Test Method D 662.

10.6.6 *Degree of Flaking*—Determine the rating using Test Method D 772.

10.6.7 *Mildew Resistance*—Virtually all exterior stains 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 D 3456 or Test Method D 3274.

10.6.8 *Fade Resistance*—Exterior latex stains usually have good color retention. Solvent-borne stains tend to be inferior in color retention compared to latex stains. Additionally, the use of an improper latex, pigment volume concentration, or improper pigments can lead to fading. There are no ASTM nor Federal test methods specifically designed for evaluating fade resistance, but the change in color on exposure can be measured in accordance with Test Method D 2244 (see 9.2).

10.7 *Water Resistance*—Section 4.1 cited cycles of ingress and egress of moisture as damaging to wood, and consequently damaging to the coating. Many semitransparent and opaque, or solid color, exterior stains are formulated to repel water to protect the substrate from moisture, thereby reducing the tendency of the wood to swell. Determine the effectiveness of the coating to prevent swelling with Test Method D 4446. Also, coatings can lose this effectiveness over time with exterior exposure. As a coating wears away, the protection from moisture damage can diminish. Determine the effectiveness of a coating to protect from water uptake, after exterior exposure, with Test Method D 5401.

10.8 *Tannin Stain Resistance*—Tannin and other chromophoric extractives are naturally occurring materials in wood and wood-based substrates. Tannins are prevalent to a high degree in cedar, redwood, and oak and to a lesser degree in white and yellow pine. These extractives are solubilized and darkened in color by aqueous coatings, resulting in unsightly yellow or brown discolorations. Tannin Stain Resistance is the ability of a coating to prevent the appearance of tannins or other wood-based chromophores in or on the surface of a stain. There are no currently available test methods to evaluate tannin stain resistance in an exterior wood stain.

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 conformity and does not necessarily establish quality, which can also be greatly affected by manufacturing techniques. No single schematic analysis is comprehensive enough to cover the wide variety of stain compositions. Select test procedures from Practice D 215 and other ASTM methods that are pertinent to the components of solvent-borne or water-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.

[11] H. E. Ashton, "Flexibility and its Retention in Clear Coatings Exposed to Weathering," *Journal of Coatings Technology*, Vol 51, No. 653, June 1979, p. 41.

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 (by weight) in accordance with Test Method D 2369.

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 Method D 2697.

11.4 *Water Content*—If too much water is incorporated in a solvent-reducible coating it may retard the drying at high relative humidity. The amount of water in a coating is required in the calculation of the volatile organic content (VOC) of coatings. One referenced method covers the determination of water in stain and related materials by distilling with a volatile solvent. The newer method utilizes the Karl Fischer reaction. Determine water in accordance with Test Method D 4017. The amount of water is required in the calculation of the VOC of water borne coatings. The referenced method covers the determination of the total water content of water-borne coatings, one using gas-liquid chromatography and the other the Karl Fischer reaction. Determine water content in accordance with Test Method D 4017.

11.5 *Pigment Content*:

11.5.1 *Solvent-borne*—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 stain. Determine the percent pigment content in accordance with Test Method D 2371.

11.5.2 *Water-borne*—Pigment provides the hiding and color and influences many other properties of a coating. The referenced method describes the procedure for the low-temperature ashing of water-borne coatings. Some of these coatings may contain ingredients that lose water of hydration or decompose at the test temperature. Consequently, caution must be exercised in applying the method to materials containing unknown pigment compositions. If difficulties or disagreements are encountered with this procedure, the pigment should be separated from the binder using a centrifuge. Determine the pigment content in accordance with Test Method D 3723.

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 D 215 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 D 215. 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 D 2372.

11.9 *Identification of Nonvolatile Vehicle*:

11.9.1 *Solvent-borne*—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 D 2621. 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 D 2245.

11.9.2 *Water-borne*—The type of binder used in a coating has a great influence on its properties. The referenced method covers the qualitative characterization or identification of the extracted vehicle by infrared spectroscopy and pyrolysis of the paint followed by gas-liquid chromatography. It is useful in detecting batch to batch uniformity and the presence of major adulterant. Identify the nonvolatile vehicle in accordance with Practice D 3168.

11.10 *Volatile Organic Compound (VOC) Content*—Many local jurisdictions have adopted air pollution controls that severely limit the amount of VOC permitted in stains. Since even water-borne stains may contain solvent such as coalescent and co-solvent wet-edge aids, it is essential that these products not exceed the established VOC limits. Determine VOC content in accordance with Practice D 3960.

12. Field Testing

12.1 Although many of the recommended test methods attempt to simulate conditions under which coatings are applied and used, it is not possible to duplicate accurately all possible conditions. Testing materials, including appropriate controls, under field conditions is recommended for the final evaluation of suitability.