Standard Guide for Painting Inspectors (Metal Substrates)¹

This standard is issued under the fixed designation D 3276; 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 is intended as an information aid to painting inspectors in carrying out their task efficiently. It includes the key elements of surface preparation, coatings application, and final approval for both field and shop work. The items should be selected that are pertinent to the specification of a particular job.

NOTE 1—For additional helpful information, refer to the following documents:

Manual of Coating Work for Light-Water Nuclear Power Plant Primary Containment and Other Safety-Related Facilities²
New Concepts for Coating Protection of Steel Structures³
SPC-PA Guide 3 A Guide to Safety in Paint Application⁴
Steel Structures Painting Manual Vol 1 Good Painting Practice⁵
Steel Structures Painting Manual Vol 2 Systems and Specifications⁶
Manufacturers Specifications and Instructions (made available to the inspector for reference to special requirements for proper application)
Material Safety Data Sheets (needed to ensure that personnel take necessary precautions in handling hazardous materials).

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

1.3 This guide is arranged in the following order:

| Section | Steel Surfaces | Galvanized Surfaces | Aluminum Surfaces | Precautions in Preparing Unpainted and Previously Painted Surfaces | Inspections of Surfaces Prior to Field Painting | New Construction | Maintenance Repainting | Inspection Equipment | Surface Profile Gages | Adhesion of Existing Coating | Portable Pull-off Adhesion Testers | Field Inspection Equipment | Drying and Curing Times | Thermometers | Dew Point | Coating Consistency | Consistency Cups | Weight-per-Gallon Cup | Wet-Film Thickness Gages | Interchangeal Gage | Notched Gage | Dry-Film Thickness Gages | Toeke Gage | Nondestructive Film Thickness Gages | Magnetic-Type Gages | Coating Storage and Handling | Storage of Coating and Thinner | Mixing of Coatings | Thinning | Initial Samples | Thinning of Coating | Sampling of Thinned Coating | Heating of Coating | Weather Considerations | Drying | Low Temperature | High Temperature | Moisture | Wind | Coating Application | Residual Contaminants | Quality Assurance | Film Defects | Brush Application | Spray Application | Roller Application | Miscellaneous Methods | Rate of Application | Additional Considerations | Ventilation | Shopcoat Repair | Painting Schedule | Film Thickness | Recoat Time | Coating System Failure | Comparison of Surface Preparation Specifications | Table 1 Inspection Checklist | Appendix

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


² ASTM, 1979.
⁴ Available from Steel Structures Painting Council, 4400 Fifth Ave., Pittsburgh, PA 15213.

2. Referenced Documents

2.1 ASTM Standards:

D 1005 Test Methods for Measurement of Dry-Film Thickness of Organic Coatings Using Micrometers⁵

⁵ 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
D 1212 Methods for Measurement of Wet Film Thickness of Organic Coatings
D 1400 Test Method for Nondestructive Measurement of Dry Film Thickness of Nonconductive Coatings Applied to a Nonferrous Metal Base
D 1475 Test Method for Density of Paint, Varnish, Lacquer, and Related Products
D 1730 Practices for Preparation of Aluminum and Aluminum-Alloy Surfaces for Painting
D 2092 Practices for Preparation of Zinc-Coated (Galvanized) Steel Surfaces for Painting
D 2200 Pictorial Surface Preparation Standards for Painting Steel Surfaces
D 3359 Test Methods for Measuring Adhesion by Tape Test
D 3843 Practice for Quality Assurance for Protective Coatings Applied to Nuclear Facilities
D 4212 Test Method for Viscosity by Dip-Type Viscosity Cups
D 4414 Practice for Measurement of Wet Film Thickness by Notch Gages
D 4417 Test Methods for Field Measurement of Surface Profile of Blast Cleaned Steel
D 4541 Test Method for Pull-Off Strength of Coatings Using Portable Adhesion Testers
E 376 Practice for Measuring Coating Thickness by Magnetic-Field or Eddy-Current (Electromagnetic) Test Methods

2.2 Occupational Safety and Health Administration (OSHA) Standard:
Hazard Communication
2.3 Steel Structures Painting Council Standards:
SSPC-SP 1 Solvent Cleaning
SSPC-SP 2 Hand Tool Cleaning
SSPC-SP 3 Power Tool Cleaning
SSPC-SP 5 White Metal Blast Cleaning
SSPC-SP 6 Commercial Blast Cleaning
SSPC-SP 7 Brush-off Blast Cleaning
SSPC-SP 10 Near-White Blast Cleaning
SSPC-PA 1 Paint Application Specifications
SSPC-PA 2 Measurement of Paint Thickness with Magnetic Gages
SSPC-Guide to Vis 1 Pictorial Surface Preparation Standards for Painting Steel Surfaces
SSPC-Paint 27 Basic Zinc Chromate-Vinyl Butyryl Wash Primer

3. Significance and Use
3.1 This guide is intended as a reference for those concerned with the inspection of industrial coating work. A punch list for use in the field is included as an appendix. Many of the details covered may be in a specification for a particular project. A specification for coating projects should include the coatings to be used. The various items are explained in detail in the appendix.

4. Preparation for Inspection
4.1 The guide describes the duties of the inspector and discusses inspection methods, both visual and instrumental, that can be used to determine that the specification requirements have been met by the painting contractor.
4.2 Before painting is started the project engineer must provide the inspector with information from the official plans and specifications as to coating type, thinner to be used, mixing ratios to be used, recommended application thickness, recommended primer, tie coat, topcoat, time between coats, surface preparation, method of application, and any special precautions to be followed such as limits on ambient conditions. These details should be recorded in an inspector's record book to eliminate any misunderstanding between the inspector and the contractor.

5. Field and Shop Inspection
5.1 Surface Preparation is one of the most important factors affecting the performance of coatings. The specifier should determine the proper level in accordance with the expected service life and type of coating specified.
5.1.1 Pictorial Standard D 2200 (SSPC-Vis 1) should be provided to the inspector on a job involving painting of structural steel. The standard is used by the inspector to determine whether the degree of surface preparation specified in a contract has been attained by the contractor. For large jobs it is recommended that before work starts, an actual steel sample of adequate size be blasted to the satisfaction of the project engineer. This blasted surface should be protected by a clear acrylic coating or encased in plastic and used for reference purposes as the work progresses.
5.2 Factors Affecting Coating Performance—There are a number of factors that must be considered to ensure a proper painting job.
5.2.1 Cleanliness—Many materials if not removed from the surface will affect the life of the coating. These include oil, grease, soil, weld spatter, and slag that make it impossible to obtain proper adhesion to the metal surface. Deposits of salts (such as chlorides and sulfates) must be removed or long-term coating performance will be seriously affected. The Steel Structures Painting Council (SSPC) issues detailed surface preparation specifications that cover methods for solvent cleaning and hand and power tool cleaning as well as the various methods of blast cleaning.
5.2.2 Mill Scale, the bluish-black oxide resulting from the hot-rolling process, is a constant source of trouble leading to coating failure. This scale is very hard and can crack or loosen from temperature changes both in fabricating and weathering in the field.
5.2.3 Surface Profile—The texture of the metal surface has a significant effect on the performance of coatings since it increases the surface area to which the coating can develop adhesion. In fact, the term “anchor pattern” is sometimes used to describe the depth of profile required. This varies both with the type and size of the abrasive used. Coarser abrasives generally produce a coarser and deeper profile. Deep profiles are advantageous for adhesion but require

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6 Annual Book of ASTM Standards, Vols 02.05 and 06.01.
7 Annual Book of ASTM Standards, Vol 06.02.
8 Annual Book of ASTM Standards, Vols 01.06 and 03.03.
more coating to fill in the valleys and cover the peaks of the profile; they cannot be used with low-build coatings that do not cover the peaks even when several coats are applied. A general recommendation is that the surface profile should be one quarter to one third of the dry film thickness of the coating system but does not apply in every case if the resulting profile would be too great.

5.3 Cleaning Procedures—Safety precautions are not addressed separately for each of the following cleaning methods. Each has its own safety-related hazards, and U.S. Occupational Health and Safety Administration regulations should be followed. Material Safety Data sheets (MSDS) for the solvents and cleaning compounds provided by the manufacturer should also be consulted for proper worker protection.

5.3.1 Chemical Cleaning—Solvents are used to remove oil, grease, and related materials. The solvent is applied to the surface by wiping or scrubbing with rags or brushes. The contaminants must be removed (not simply spread out) by a thorough wiping of the affected areas with cloths saturated with clean solvent. Contaminated cloths must not be dipped into clean solvent. The cleaning should be repeated with clean rags and fresh clean solvent. Emulsions, cleaning compounds, steam cleaning, or similar methods and materials may also be used. Where emulsion cleaners, soaps, or detergents are used, they must be removed completely by washing with clean hot water. SSPC SP-1 covers cleaning procedures using these materials.

5.3.1.1 Solvent Vapor Cleaning is a procedure that can be adapted to a production line or a piecework operation. Vapor cleaning removes all soluble contaminants but does not disturb the natural oxide film. If this film must be removed, mechanical cleaning will be necessary as well. The part to be cleaned is placed in the saturated vapor above the heated solvent so that the solvent vapor condenses on the metal surface. Vapor degreasing does not remove particulate matter and parts must be wiped to remove any insoluble soils. Vapor degreasing has the advantage over solvent wiping that hot solvents are used and the solvent condensation removes soils without recontamination.

5.3.2 Hand Tool Cleaning is the method used for the removal of loose mill scale, loose rust, loose or otherwise defective coating, weld flux, slag and spatter from metal surfaces by hand brushing, hand sanding, hand chipping or scraping using wire, fiber, or bristle brushes, sandpaper, steel wool, hand scrapers or chisels, and chipping hammers. The surface is then cleaned to the condition St 2 given in Method D 2200 (SSPC-Vis 1). SSPC also provides a detailed specification, SSPC-SP 2.

5.3.2.1 Hand tool cleaning requires that all tar, oil and grease, weld flux, and other greasy contaminants be removed first by solvent cleaning (5.3.1).

5.3.2.2 Wire brushes should be rigid enough to clean the surface thoroughly and shaped to penetrate into all corners and joints. Brushes should be kept free of all materials that may clog the wires of the brush. Hand scrapers should be made of tool steel, tempered and ground to a sharp edge and should be of the proper size and shape to enable cleaning to be done as specified. Scrapers should be kept sharp at all times.

5.3.3 Power Tool Cleaning is a method used for the removal of loose mill scale, loose rust, loose or otherwise defective coating, and weld flux from metal surfaces by power wirebrushes, power impact tools, power grinders, power sanders, or by a combination of these methods. The surface is cleaned to the condition St 3 given in Pictorial Surface Preparation Standards D 2200. SSPC-SP 3 is the detailed specification for power tool cleaning.

5.3.3.1 Power Tool Cleaning requires that all oil, grease, weld flux, and other contaminants be removed first by solvent cleaning (SSPC-SP 1). Hand tool cleaning in accordance with 5.3.2 may be used prior to power tool cleaning.

5.3.3.2 All equipment must be suitable for the configuration of the work to be cleaned and maintained free of material that clogs the wire or disks making them ineffective. All impact tools should be kept sharp.

5.3.4 Blast Cleaning is used to remove foreign materials from a metal surface and to provide a roughened surface by striking the surface with a stream of small, hard abrasive particles such as (dry) sand, grit, or shot.

5.3.4.1 One method utilizes compressed air, special blast nozzles, and abrasive. In another method used in a fabricating shop, wheels propel the abrasive centrifugally against the work. The minimum and maximum particle size of the abrasive may be specified as a means of controlling the surface profile. Water may be injected into the air stream to control dust. Occasionally a high-pressure water blast, either with or without an abrasive injected into the stream, is used as an alternative to open blasting since it reduces the release of dust into the atmosphere.

5.3.4.2 Blast cleaning requires that all oil, grease, and weld flux be removed by solvent cleaning. The compressed air used for blast cleaning should be free of condensed water or oil by making certain that separators and traps are in working order.

5.3.4.3 Blast-cleaning operations should be performed so that no damage is done to the completed portion of the work. Blast cleaning is often performed from the top to bottom of the structure and should only be carried on downwind from any recently painted areas. Dry blast cleaning operations should not be conducted on surfaces that will be wet after blasting and before painting. Dew point must be at least 5°F (3°C) above the steel temperature.

5.3.4.4 The degree of blast cleaning required should at least be equal to the appropriate SSPC surface preparation specification and the applicable pictorial standard shown in Pictorial Surface Preparation Standards D 2200 (SSPC-Vis 1) or National Association of Corrosion Engineers (NACE) as shown in Table 1.

5.3.4.5 Blast cleaned surfaces must be examined for any traces of oil, grease, or smudges; where present, the contaminants must be removed by solvent cleaning (see 5.3.1).

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TABLE 1 Comparison of Surface Preparation Specifications

<table>
<thead>
<tr>
<th>Preparation Grade</th>
<th>SSPC</th>
<th>ASTM D 2200</th>
<th>NACE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Blast cleaning to white metal</td>
<td>SSPC-SP 5</td>
<td>Sa 3</td>
<td>1</td>
</tr>
<tr>
<td>Blast cleaning to near-white</td>
<td>SSPC-SP 10</td>
<td>Sa 2 ½</td>
<td>2</td>
</tr>
<tr>
<td>Commercial blast cleaning</td>
<td>SSPC-SP 6</td>
<td>Sa 2*</td>
<td>3</td>
</tr>
<tr>
<td>Brush-off blast cleaning</td>
<td>SSPC-SP 7</td>
<td>Sa 1</td>
<td>4</td>
</tr>
</tbody>
</table>

* Pictorial standard B Sa 2–½ shows mill scale and conflicts with the SSPC definition of commercial blast (SPB) which does not allow mill scale.

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Surfaces that have been dry blasted should be brushed with clean brushes, blown with compressed air free of oil and moisture, or vacuum cleaned to eliminate any traces of blast products, dust, or dirt from the surface. This also serves to remove abrasive from pockets and corners.

5.3.4.6 Blast cleaned surfaces should be further treated, primed or painted as specified on the same day they are blasted, preferably within 8 hours, or in any event before any visible rusting occurs. Reblasting will be necessary on any surface if rust bloom forms before the coating can be applied.

5.4 *Cleaning and Preparation of Various Surfaces*—Before application of any coating, all surfaces to be coated must be thoroughly cleaned and properly prepared to the requirements of the specification. All dust, dirt, oil, grease, moisture, soot, tars, or other contaminants should be removed from unpainted surfaces. Previously painted surfaces should be similarly cleaned of all foreign matter; all deteriorated coating must be removed as well. Mortar or cement drippings from earlier repairs must be removed by mechanical or chemical means. Tree limbs or other growth obstructing the structure should be cut away to provide ready access.

5.4.1 *Steel Surfaces*—Removal of rust and scale must be done in the manner and to the degree specified, that is, hand, power tool, or blast cleaned.

5.4.1.1 On bridges, all dirt and debris must be cleaned from around bearing plates, shoes, and other components. The entire surface of the beam or truss seat on each unit of the structure should be cleaned. On truss spans particular attention should be paid to removal of dirt and debris from around bearing plates, shoes, and other components.

5.4.1.2 Galvanized Surfaces that are to be painted should be cleaned and treated in accordance with Method A or D of Practices D 2092. Alternatively, the surface may be allowed to weather a minimum of 6 months before cleaning and painting.

5.4.3 *Aluminum Surfaces*:

5.4.3.1 Complete removal of oil and grease and, for unanodized aluminum, treatment is essential. Vapor degreasing or immersion in an alkaline or acid cleaning solution are commonly used in shop work. In the field a water wash followed by solvent cleaning is a good starting point.

5.4.3.2 Vinyl wash primer is one of the metal pretreatments commonly used on unanodized aluminum. The material is described in Practices D 1730, Type B, Method 8 and is covered by SSPC Paint 27. For exterior work an inhibitive primer is required over this pretreatment. Lead pigmented primers should never be used over aluminum surfaces. The minimum treatment for aluminum is Type B, Method 3 of Practices D 1730, which describes the use of an alcoholic phosphoric acid cleaner.

5.4.4 *Precautions in Preparing Unpainted and Previously Painted Surfaces*—Cleaning should proceed by sections, bays, or other readily identifiable parts of the work. The cleaning of each section, bay, or part of the work must be entirely completed, inspected, and accepted before any coating is applied. The system of alternately cleaning and painting short sections by one workman is not good practice.

5.4.4.1 If, in the opinion of the project engineer, traffic, or any other source produces an objectionable amount of dust, it is customary for the contractor, at his own expense, to control the dust by using tarpaulins, etc., for a sufficient distance around the structure and take any other precaution necessary to prevent dust and dirt from coming into contact with the cleaned or freshly painted surfaces. It may sometimes be necessary between the various coats to clean newly coated surfaces using some of the specified methods.

5.4.4.2 Some areas to be painted or repainted are exposed to chemical fumes and should be washed with water before painting. Washing may also be necessary between coats of paint. If there is reason to suspect the presence of chemicals, the surfaces should be tested before applying subsequent paints.

5.4.4.3 Residual contaminants present on pitted steel can be a problem. Chloride from deicing salts or a marine environment and sulfate contamination from air pollution have recently been recognized as one of the main factors in premature breakdown of coating systems. High-pressure water blasting is often used to remove these contaminants.

5.5 *Inspection of Surfaces Prior to Field Painting*:

5.5.1 *New Construction*—It must be emphasized that the first coat should be applied to the cleaned surfaces before any soiling or deterioration can occur. If painting is done out of doors, the cleaned areas should receive the first protective coat well before sunset brings lower temperatures and possible moisture condensation on the surfaces. When surface preparation and painting are carried on indoors, overnight delays between cleaning and painting may be permissible except onblast-cleaned surfaces.

5.5.1.1 Shop-coated steel that has been shipped to the erection site should be stored on blocks to prevent contact with the ground and where it is least likely to be marred, scratched, or subjected to harmful contamination by grease, oil, salts, etc. Insofar as practicable, the steel should be stored to avoid the formation of waterholding pockets. If outdoor storage lasts for several months, the inspector should check the integrity of the coating from time to time, and have any deficiencies corrected. Correction of these deficiencies may require complete blast cleaning and repriming in the field if the shop primer has weathered so long as to make touch up too extensive. The length of time between shop priming and erection and subsequent topcoating should be kept to a minimum to avoid the problem of intercoat adhesion.

5.5.1.2 Immediately before applying the first field coat, the shop-coated surfaces should be cleaned of dust. If necessary to remove grime and oil substances, they are wiped with solvents selected so as not to soften the film appreciably. Miscellaneous scratches and breaks in the shop coat, including those occasioned by field welds, bolts, or rivets, should be cleaned and touched-up as specified before the steel receives the first overall field coat.

5.5.1.3 The inspector must ensure that field rivets have been cleaned of slag and weld spatter. It is important that every coat of the system be applied over dry, soil-free surfaces, and that all previous coats be free of mechanical damage. Great care should be exercised to prevent trapping
corrosive salts under or between coats.

5.5.1.4 The inspector should determine whether the specifications are being followed with reference to the painting or prohibition of painting of contact surfaces in bolted or riveted surfaces of construction. He must ensure that surfaces not in contact but that will be made inaccessible by assembly or erection, have received the full number of specified coats before they become inaccessible.

5.5.2 Maintenance Repainting—In most cases, maintenance painting will consist of spot-cleaning and priming of small isolated areas of deterioration followed by application of one overall new finish coat to all surfaces of the structure. The inspector of maintenance painting must be alert for several conditions not encountered in the painting of new work.

5.5.2.1 Sound coating not intended to be removed should not be damaged by cleaning operations on adjacent areas. This is particularly important with spot-blast cleaning.

5.5.2.2 The junctions between sound coating and spot-cleaned areas should present a smooth, feathered appearance. The application of coating to spot-cleaned areas should overlap the old, adjacent coating to a slight extent in order to assure full coverage of the cleaned areas. Before the overall finish coat is applied, the inspector must ensure that oil, grime, dust, and other contaminants are cleaned from the old coating surfaces.

5.5.2.3 Before work has progressed too far, adhesion of the newly applied coat to the old coating should be carefully checked. Under the direction of the engineer the inspector may explore beneath the surface of the existing or new coating film for covered-over rust or loosening of the old film, and where he discovers such conditions, require that the surface be cleaned and repainted.

5.5.2.4 The effect of any newly applied coating on the old underlying coating should be noted. Any coating that shows curling, lifting, or excessive wrinkling should be reported to the engineer immediately since it may have to be removed and the area repainted. If the defects are general, rather than existing in a few isolated areas, use of a different type of coating may be necessary.

6. Inspection Equipment

6.1 General—Visual observation is the most important part of inspecting coating application. There are, however, instruments and mechanical aids that are of considerable help to the inspector. They make the painter aware that his work can be checked during progress and even after completion. The different instruments that can be used are described in this section.

6.1.1 Surface Profile Gages—The inspector can determine the surface profile of blast-cleaned steel substrates using Test Methods D 4417 to assure an adequate "tooth" is obtained for the specified material. Some of the common instruments are:

6.1.1.1 Surface profile comparator\(^\text{10}\) for visual comparisons of the profile against a reference disk for sand, grit, and shot blast-cleaned steel.

5.1.2 Depth micrometers with conical points to project into the valleys to determine profile depth.

6.1.1.3 Tape,\(^\text{11}\) to create an exact replica of the profile on a special material. The tape is measured in the field using a spring micrometer to determine average maximum profile height.

6.1.2 Adhesion of Existing Coating—The inspector should carry a pocket knife that can be used to determine the soundness of existing paint where there might be blistering or underfilm corrosion. This is a subjective test and its value depends upon the inspector's experience. The cross-cut test, Methods D 3359, is more reproducible.

6.1.3 Portable Pull-off Adhesion Testers are available. The apparatus measures the force required to remove a metal stud that has been cemented to the coated surface as described in Method D 4541.

6.2 Field Inspection Equipment in good working order should be available to the inspector so that he may perform his function properly.

6.2.1 Drying and Curing Times—These are both important considerations since drying time and curing time can both be affected. Minimum temperatures are required for reactive and water-borne coatings while too high a temperature can make application difficult. Inorganic zinc-rich primers and moisture-cure urethanes require certain minimum humidity conditions for proper cure. The manufacturer's recommendations must be followed.

6.2.1.1 Thermometers—The paint inspector may need several types of thermometers and should have at least an accurate pocket thermometer with a range from about 0 to 150°F (-18 to 65°C) for measuring the ambient air temperature. The same thermometer or a floating dairy thermometer may be used to determine the temperature of liquid coating, solvent, etc. The pocket thermometer may also be used for determining the temperature of metal surfaces by placing it against the metal while shielding the outer (away from the metal) side of the bulb by means of putty or similar material, so that the reading is not affected by the ambient temperature. Flat surface-temperature thermometers are also available for this purpose.

6.2.1.2 Dew Point—A psychrometer containing a wet- and dry-bulb thermometer for determining relative humidity and dew point is a useful inspection tool. Hand-held sling or electrical types are available as well as a direct reading digital type.

6.2.2 Coating Consistency is an important characteristic since durability is related to film thickness and whether a film of the proper thickness can be applied is partly controlled by consistency.

6.2.2.1 Consistency Cups—There are occasions, such as on-site thinning, when it is necessary to check paint consistency during field application. While giving only partial information about the viscosity of a coating, the Zahn cup is a portable device for checking quickly the approximate consistency of coatings and other liquids. It consists of a bullet-shaped, stainless steel cup with an orifice in the bottom. Attached to the cup is a looped handle with a small...
ring at the top to align the cup in a vertical position when withdrawing it from the liquid being tested. To operate, the cup is completely immersed in the liquid to fill it and is then withdrawn rapidly and completely. The time in seconds for the liquid to escape through the orifice is an expression of viscosity, that is, Zahn Cup No. ( ) seconds. It should be noted that Zahn cups are not suitable for all coatings and have poor reproducibility (agreement between different cups is poor—see Test Method D 4212).

6.2.3 Weight-per-Gallon Cup—There are times when the inspector may wish to check the weight-per-gallon of the paint in the field. If the value is low compared to the paint specification, it indicates that unauthorized thinning has been done, while differing values from the same container show that the coating has not been thoroughly mixed for application. The weight-per-gallon cup holds a given quantity of water when filled at 77°F (25°C) or other specified temperature. It is made of corrosion-resistant material and has a closely fitted lid with a small hole in it. In use, the cup is filled with liquid slightly below the specified temperature. As the contents warm up, the excess escapes through the hole and is removed. The filled cup is wiped clean on the outside and weighed. A relatively inexpensive balance having a sensitivity of 0.1 g provides sufficient accuracy. The difference between the full and empty weights divided by 10 is the weight in pounds of 1 gal of the paint. Complete instructions for the procedure are given in Test Method D 1475.

6.2.4 Wet-Film Thickness Gages—This type of instrument is designed to measure the thickness of a wet film of paint immediately after it is applied to a surface. Note that erroneous readings may result when using the gage on fast-drying paints such as inorganic zinc. If a wet-film gage is used to determine the thickness of coats subsequent to the first, great care must be taken that partially hardened undercoats are not indented by the gage, thus giving high readings. If the coat being measured has an appreciable thickness read directly in mils (micrometres). Complete details are given in Method A of Methods D 1212.

6.2.4.1 Interchemical Gage—This instrument is rolled over the newly applied wet film on a smooth flat portion of the surface and the thickness read directly in mils (micrometres). Complete details are given in Method A of Methods D 1212.

6.2.4.2 Notched Gage—This device has a series of calibrated steps for measuring thin to heavy coats. The gage with the proper face is placed squarely on the fresh, wet film. It is then withdrawn perpendicularly without a sliding movement. The true wet-film thickness lies between the highest step coated and the next highest which was not coated. The coating cannot be too brittle or soft, otherwise the cutting tip will tear rather than precisely cut through the coating, making accurate readings impossible.

6.2.5 Dry-Film Thickness Gages—Dry-film thickness measurements are of great importance because the protection of the substrate is directly related to the thickness of the coating. There are two ways of making the measurements, nondestructively or destructively. The latter involves penetrating or cutting through the film to the substrate with a needle or blade and measuring by some means the distance between the top and bottom of the film. Because the dimensions are so small, some cuts are made at an angle in an attempt to increase the accuracy of the measurement.

This type of gage destroys the film at the inspection points, necessitating touch up with primer and finish to prevent corrosion at these spots. One kind of cutting gage is described in 6.2.5.1.

6.2.5.1 Tooke Gage—The Tooke inspection gage is designed to measure coating film thickness by microscopic observation of a cut into the film. The tungsten carbide cutting tip is specially shaped to slice a precise narrow groove through a film and into the substrate at an angle to the surface. Thickness of coating on any type of stable substrate may be determined and individual coats may be measured separately providing they are distinguishable, for example, by color. The coating cannot be too brittle or soft, otherwise the cutting tip will tear rather than precisely cut through the coating, making accurate readings impossible.

6.2.6 Nondestructive Film Thickness Gages are widely used for field and shop inspection. For ferrous metals they are based on magnetism, and for nonmagnetic metals on inductance and eddy currents. There are no satisfactory nondestructive methods for wood or other nonmetallic substrates. All of the different types require calibration with standards the thickness of which is known and in the same range as the coating to be measured. The calibration must be made on metal of the same kind, temper, thickness, and contour as that beneath the coating. Test Methods D 1186 and 1400 describe procedures. Measurements on relatively rough surfaces, such as a surface blasted to a high profile, may be misleading unless the instrument is calibrated on an identical surface.

6.2.6.1 Magnetic-Type Gages—Use either an electromagnet requiring a power supply or a permanent magnet. The principle of the method is that a nonmagnetic coating changes the magnetic force between the magnet and the magnetic base or the magnetic flux between the poles of the magnet. As the change is a function of distance from the metal, the gage can be made to read film thickness directly. Magnetic gages may be affected by the mass of the steel, or if electric welding is being carried out on a structure, for example, a ship's hull, at the time of measurement. Test Methods D 1186 describe the procedure for using magnetic gages. The method is also described in SSPC-PA 2 which includes instructions on the number of measurements for different areas and tolerances on the required film thickness.

6.2.6.2 Nondestructive procedures based on inductance and eddy current techniques are described in Test Method D 1400.

7. Coating Storage and Handling

7.1 Storage of Coating and Thinner—All coatings and thinners should be stored in areas or structures that are well-ventilated and not subject to excessive heat, open flames, electrical discharge, or direct rays of the sun. Storage should be in compliance with applicable regulations. Materials susceptible to damage at low temperatures must be stored in heated areas. If a coating is stocked for a consider-

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12 Type 1—Pull-off gages (such as Mikrotest, Inspector Thickness Gage, and the Pencil Pull-Off Gage, or Tinsley type gage); and Type 2—Fixed Probe Gages (such as Electrohm Thickness Gage, Minitecor, General Electric Type B Thickness Gage, Verimeter, Permascopc, Dermihcot, Posiector, Certotest, Accuform and Minitecor) have been found suitable for this purpose.
7.1 Coating containers should remain unopened until needed and the oldest should be used first. The manufacturer's written instructions should be followed regarding shelf life. Coatings that have livered, gelled, or otherwise deteriorated during storage should not be used. If a particular material is in question, do not use it until it has been tested by the manufacturer or independent laboratory and found to be satisfactory.

7.1.1 Where a skin has formed in the container, the skin should be cut loose from the sides of the container, removed and discarded. If it is felt that the skins are thick enough to have a practical effect on the composition, the remaining paint should not be used until it has been tested and found to be satisfactory.

7.2 Mixing of Coatings—All coatings must be thoroughly and completely mixed in clean containers before use. Where there is noticeable settling and mixing is done either by power stirrers or by hand, most of the vehicle should be poured off into a clean container. The pigment is then lifted from the bottom of the container with a clean broad, flat paddle, lumps broken up and the pigment thoroughly mixed with the vehicle present. The poured-off vehicle should be returned slowly to the original container with simultaneous stirring. It is also useful at this point to mix or pour repeatedly from one container to another (boxing) until the composition is uniform. The bottom of the original container should be inspected for unmixed pigment. The coating should not be mixed or kept in suspension by means of an air stream bubbling under the coating surface.

7.2.1 Some coatings may require straining after mixing to ensure homogeneity and to remove skins and foreign matter. The strainers should be of a type to remove only skins, etc., but not to remove pigment. For example, a 150-mesh (105-μm) strainer is normally satisfactory for most coatings unless some specific size is required in the specification. Coatings should not remain in buckets, spray pots, etc., overnight, but be gathered into a container and remixed before use, provided the manufacturer's stated pot life will not be exceeded. Containers must be covered when not in use, to reduce volatile losses and skinning.

7.2.2 Coatings should be agitated enough during application to ensure homogeneity. Some materials may even require constant agitation during use.

7.3 Thinning—Some specifications permit field thinning of laboratory-accepted coatings while others do not. This section describes some commonly accepted procedures when thinning is permitted.

7.3.1 Initial Samples—When thinning on the job site is permitted and unless other arrangements have been made, (for example using manufacturer-supplied thinner from unopened containers and complying with manufacturer's written thinning instructions), the painting inspector may need to submit to an agreed-upon testing laboratory a 1-qt (1-L) sample from each batch to be thinned, together with a 1-qt sample of the thinner to be used using clean sample containers in both cases. With these samples a request is submitted for advice on the proper thinning rate for the conditions prevailing and the consistency limits of the thinned coating.

7.3.2 Thinning of Coating—All additions of thinner must be made in the presence of the inspector and no other amounts or types of thinner than those permitted by the specification or manufacturer, or both, may be added. Thinning is carried out by pouring about half of the thoroughly mixed coating into an empty, clean container. The required thinner is then added and the two portions are boxed to obtain a homogeneous mixture.

7.3.3 Sampling of Thinned Coating—During the work, additional samples need not be submitted for testing unless a deviation is noted in the coating consistency or if it is suspected that there has been a change in the thinner.

7.3.3.1 When an inspector is qualified and has the necessary equipment available at the field office, arrangements may be made for on-site inspection of thinning and of the thinned coating. This speeds acceptance of a coating and lightens the laboratory workload. The inspector must keep a record of all paint modifications, amount of thinning, weight per gallon, and viscosity. Where dry-film thickness is specified, the inspector must calculate the new wet thickness necessary to obtain the desired dried thickness with the thinned coating. He should make frequent checks of wet-film thickness as work progresses, however compliance with the specification should be based on dry-film thickness where possible.

7.3.3.2 To determine the wet-film thickness of the thinned coating required to obtain the specified dried-film thickness, the percent volume of nonvolatile (solids) in the original coating must be known. This figure is readily obtained from the manufacturer. With this information the calculation may be made as follows:

\[ W = D (1.0 \pm T)/S \]

where:

- \( W \) = wet-film thickness,
- \( D \) = desired dry-film thickness,
- \( S \) = percent by volume of coating solids, and
- \( T \) = percent by volume of thinner added.

7.4 Heating of Coating—Coatings as delivered in the manufacturer's containers and mixed thoroughly, are ready for use, unless the specification permits on-site thinning of high-viscosity material. Should the coating temperature be low, that is, 50°F (10°C) its consistency may increase to the point where application is difficult. Where thinning is not permitted, the coating may be heated. Should the contractor wish to reduce the viscosity by heating to make application easier, the containers may be warmed in hot water, on steam radiators, or by other acceptable indirect heating processes. In-line heaters are also available for application equipment. Direct application of flame to the containers is forbidden by fire regulations. It should be noted, however, that heating of the coating alone will not compensate for ambient or surface temperatures, or both, that are below the minimum specified for that material.

8. Weather Considerations

8.1 Drying—It is well known that most coatings, particularly those for structures, will not dry properly at low temperatures and high relative humidities, nor will they
8.2 Low Temperature—Many specifications indicate temperature limits between which painting may be undertaken either in the shop or in the field. The minimum ambient temperature is usually 40°F (5°C) or for cold-curing epoxy systems 50°F (10°C) with the temperature of the substrate above freezing. The requirements may state further that painting should not be undertaken when the temperature is dropping. However, some authorities believe that many solvent-borne coatings may be applied at (or below) 32°F (0°C) without adverse effects. Within the limitations of the composition of the coating, this may be satisfactory depending upon the type of coating and providing the surface is dry. Painting over ice or frost will result in early adhesion failure of the coating.

8.3 High Temperature—The maximum reasonable surface temperature for application is 125°F (50°C). A surface that is hot may cause the coating solvents to evaporate so fast that application is difficult, blistering takes place, or a porous film results. To keep the temperature down it is desirable, where practical, to paint under cover at a shop or to protect the surfaces from the sun with tarpaulins.

8.4 Moisture—Painting should not be undertaken in rain, snow, fog, or mist, or when the temperature of the metal surface is below the dewpoint. This is especially true in the spring and fall when days are warm and nights are cool. Wet surfaces should not be painted unless the coatings are specifically designed for that condition. Relative humidity is usually a good index of the acceptability of air conditions and specifications often contain an 85% upper limit. If it is suspected that the temperature and humidity conditions are such that moisture is condensing upon the surface, the inspector may make the following test: Use a psychrometer to determine the actual relative humidity and dew point; compare the dew point with the metal temperature measured with a surface temperature thermometer. It is generally accepted that the surface temperature should be at least 5°F (3°C) higher than the dew point. A less accurate test is to lightly moisten a small area with a damp cloth and observe evaporation and drying; if the dampness decreases and evaporates within 15 min, the surface is considered satisfactory for the application of coating from the standpoint of dampness and condensation at that particular time.

8.4.1 When coatings must be applied in damp or cold weather, the substrate should be painted under cover, or protected from the surrounding air, and the steel heated to a satisfactory temperature. The steel should remain under cover until dry or until weather conditions permit its exposure in the open.

8.4.2 Applied coatings exposed to freezing, excessive humidity, rain, snow, or condensation should be permitted to dry. Damaged areas of coating should then be removed, the surface again prepared and painted with the same number of coats of the same kind as the undamaged area.

8.5 Wind—The wind direction and velocity must be considered when applying coatings in areas where airborne overspray could damage automobiles, boats, and structures nearby. Heavy winds result in considerable loss of coating and in excessive drying of the droplets reaching the surface. This results in an inability of the film to flow together and create a continuous barrier free of “holidays.” Such conditions can also create excessive amounts of dry spray that can interfere with adhesion of the applied or subsequent coats. These problems can be avoided by utilizing brush or roller application methods instead of spray, or scheduling the work at the least windy times of day, changing materials to the dry-fog types that do not adhere or damage adjacent property, scheduling the work so that if dry spray becomes attached to adjacent components it will not create a quality problem because it is attached to the final coat.

9. Coating Application

9.1 Residual Contaminants—Visually inspect the surface immediately prior to painting to ensure that spent abrasive, dust, and debris have been completely removed. Dust removal shall be considered satisfactory when the path left by a gloved hand wiped over the surface is barely discernible when viewed from a distance of 3 ft (1 m). During this inspection, also ensure that any oil or grease contamination that may have become deposited on the surface is completely removed. This is accomplished by solvent cleaning in accordance with SSPC-SP1.

9.2 Quality Assurance—The inspector must ensure that: (1) coatings received at the fabricators or in the field meet the description of the products acceptable under the requirements of the specification; (2) they are properly mixed and thinned (where allowed); (3) colors match a visual standard provided that proper precautions have been taken to prevent damage to adjacent areas from cleaning and painting operations; (4) working practices are so scheduled that damage to newly applied coating is minimized; (5) application equipment (brushes, spray) is acceptable for type, cleanliness, and usability; (6) weather conditions are acceptable under the requirements of the specification; (7) field-testing equipment on hand is in satisfactory working order ready for use; and (8) only the methods of application permitted under the specification are used and that their use is in accordance with 9.2.1 and 9.3 through 9.7. SSPC-PA1 is a specification for application of coating.

9.2.1 Film Defects—All coats should have nearly smooth, streamlined surfaces relatively free of dryspray, overspray, orange peel, fish eyes, pinholes, craters, bubbles, or other significant defects. Show through, insufficient hiding skips, and misses are not acceptable. Runs and sags should be brushed out during application. Abrasive, dirt, or other debris that becomes embedded in the paint film should be removed prior to the application of subsequent coats.

9.3 Brush Application—Painting by brush must be done in a neat, workmanlike manner to produce a smooth coat as uniform in thickness as possible. Coating should be worked into all irregularities in the surface, crevices, and corners. Runs, sags, or curtains should be brushed out. Surfaces that are inaccessible for painting with brushes and on which spraying is not permitted should have coating applied by means of sheepskin daubers. To provide adequate film thickness on places prone to premature breakdown, it is recommended that edges and corners of all metal work, rivet heads, bolts and nuts, and all individual members, bars, shapes, and plates should be striped by brush painting in advance of the application of coating to other parts.

9.3.1 Brushes must be of good quality with pliable bristles. They should not exceed 4 in. (100 mm) in width and the
9.4 Spray Application—Spray application may or may not be allowed. Often it is acceptable in fabricating shops but, because of the possibility of damaging surrounding property or coating films from overspray, it may not be permitted in the field. The inspector should be familiar with the different kinds of spraying, which are compressed air spray, airless spray, heat spray, and hot airless spray.

9.4.1 The equipment should be suitable for the intended purpose, capable of properly atomizing the coating to be applied, and be equipped with suitable pressure regulators and gages. The equipment must be kept in a suitably clean condition to permit proper coating application without depositing dirt, dried coating, and other foreign materials in the film. The air supply for conventional and hot spray application should be free of moisture or oil. Airless spray equipment should be properly grounded. Any solvents left in the equipment should be completely removed before applying coating to the surface being painted.

9.4.2 Coating ingredients must be kept properly mixed in spray pots or containers during coating application, either by continuous mechanical agitation or by intermittent agitation. Coating should be applied in a uniform layer, with overlapping at the edge of the spray pattern. The spray pattern should be adjusted so that the coating is deposited uniformly. During application the gun should be held at right angles (perpendicular) to the surface (not arced or fanned) and at a distance that will ensure that a wet layer of coating is deposited on the surface. The trigger of the gun should be released at the end of each stroke. Poor spray technique resulting in excessive overspray (or sand-like finish) should not be tolerated. All runs, sags, or curtains must be brushed out immediately or the coating will have to be removed and these areas repainted.

9.4.3 Usually brush striping of edges and other vulnerable locations as described in 9.3 is required. Brush or sheepskin daubers are used to coat all areas inaccessible to the spray gun and brushes and are used to work coating into cracks, crevices, and blind spots not adequately spray painted.

9.4.4 Particular care should be observed with respect to type and amount of thinner, coating temperature, and operating techniques in order to avoid depositing coating that is too viscous, too dry, or too thin when it reaches the surface.

9.5 Roller Application—Rollers that are clean and of a material not soluble in the coating to be applied should be used. Roller covers are available in a variety of diameters, lengths, types of fabric, and fiber lengths. The nap (length) used on metal surfaces generally varies from 1/4 to 3/8 in. (25 to 75 mm). The longer fibers hold more coating but do not provide as smooth a finish. Therefore their use is generally restricted to rougher surfaces and faster drying coatings. There are also specialized rollers available for use on pipes, fences, and even pressure rollers that continually feed the coating to the roller cover.

9.5.1 The roller cover should be dipped into the coating until it is saturated and then rolled along the tray ramp until the coating is completely wetted in. The first load of coating on the roller should be applied to scrap material to force out air bubbles trapped in the nap. Proper roller technique requires application in the form of a V or W depending on the size of the area involved. The coating should then be cross-rolled to fill in the square created by the boundaries of the initial application. Only moderate pressure should be used as heavy pressure can cause foaming and possible cratering by entrapped air. Application should be finished with light perpendicular strokes in one direction (usually vertical) to provide the smoothest, most uniform finish.

9.6 Miscellaneous Methods—Methods such as pads, mitts, and squeegees or trowels are used for specialized products or in situations where the conventional methods are not suitable due to the location or configuration of the work.

9.6.1 Painter's pads generally consist of a roller-type synthetic fabric attached to a foam pad. The size is generally 4 by 7 in. (100 by 175 mm) and the fiber length is 3/16 in. (5 mm). Application technique with a pad on large surface areas is similar to that used with a roller.

9.6.2 Painter’s mitts are lamb skin gloves that are dipped into the coating and are rubbed across the surface. They are ideal for application of coatings to odd-shaped surfaces such as pipes and railings.

9.6.3 Squeegee or trowel application is generally used for heavy-bodied thick-film coatings that cannot be applied by spray.

9.7 Rate of Application—Properly written specifications require certain minimum and maximum dry-film thicknesses for each coat. The requirements should be augmented with wet-film thickness figures calculated from the composition of the coating so that the proper dry-film thickness is obtained. (Equation shown in 7.3.3.2.) Wet-film thickness figures are useful to the inspector since he can often check as the work progresses to determine reasonably well that the desired amount of coating is being applied. Later, when the films are dry, the inspector should make spot checks with a dry-film measuring gage to ascertain acceptability of the coatings. Film thickness measurements are more informative than visual inspection, which may show only obvious nonuniform film application. Instruments for measuring film thickness and the procedures for their use are described in 6.2.5 and 6.2.6. Nondestructive dry-film thickness gages and measurements are applicable to metal substrates only.

9.7.1 Thickness or coverage requirements apply to the whole structure, not some specific part. It is important that the painting inspector check all areas and determine the film thickness for each coat. For instance, if the "shop coat" requires a minimum of 2 mils (50 μm) dry film, the inspector should ensure that it is obtained within the tolerances permitted in SSPC-PA2. The areas tested should be identified and recorded so that the dry thickness of added coating can be also determined. With nondestructive measuring instruments a 50-ft (15-m) long and 6-ft (1.8-m) high I-beam can be tested in 30 min and low areas if any, properly marked and recorded in the inspector's book. Because the shop prime coat inspector may not be the person doing the field coat application inspection, it is very important to record test results and send a copy to the field inspector in order to better determine thicknesses of subsequently applied coats.
10. Additional Considerations

10.1 Ventilation—It is essential when painting in enclosed spaces that adequate ventilation is provided for removal of solvents.

10.2 Shopcoat Repair—Normally after erection work, such as riveting, bolting, welding, straightening, etc., has been completed satisfactorily, areas of the shopcoat will be found to have been damaged. Damaged or bare areas must be thoroughly cleaned, prepared, and covered with one new coat of shop or field primer. In addition, crevices and small cracks should be thoroughly cleaned and spot-primed. After drying, the crevices and cracks should be filled with an acceptable caulking compound as required by the specification. The specified field coats should then be applied over the entire structure.

10.3 Painting Schedule—As indicated in 5.4.4, painting should proceed by sections, bays, or parts of the work, and each coat on each section should be applied entirely and accepted by the inspector before a succeeding coat is applied. Except for any shop coat touch ups made necessary by welding, etc., none of the metal that will be exposed to view in the completed structure is to be field-painted until all concrete has been placed. Care must be taken by the contractor during painting operations to protect concrete from being stained by the coating being applied. Any stained concrete surface must be restored to its intended color without damage to the concrete.

10.4 Film Integrity—Each coat should be applied as a continuous film of uniform thickness, free of holidays and pores. Any thin spots or areas missed in the application should be repainted and permitted to dry before the next coat is applied.

10.5 Recoat Time—Each coat must be dried throughout the full thickness of the film before application of the succeeding coat. Coating is considered dry for recoating when the next coat can be applied without the development of any detrimental film irregularities such as wrinkling, lifting, or loss of adhesion of the previous coat. For most coatings the time to dry for recoat, even under optimum conditions varies with their composition and that of the subsequent coat. Thus, an oil-based coating may take 2 to 4 days to harden sufficiently to be overcoated with a coating of the same type. However, it may take 3 or 4 months to harden to be satisfactorily overcoated with a vinyl coating or other type of coating containing strong solvents. The coating manufacturer's literature should be consulted for recoat times.

10.6 Coating System Failure—Failure of completed coating work may be the result of several factors. Most obvious is noncompliance with the specifications indicating insufficient inspection of surface preparation, coating quality, coating application, or conditions during application and drying/curing. On the other hand, failure may be due to improper specification of coatings for the intended use. Defective coatings should be removed in their entirety, the surface recleaned, and the specified coatings, or their alternatives, applied.
APPENDIX

Nonmandatory Information

X1. INSPECTION CHECKLIST

X1.1 The checklist in Fig. X1.1 lists the key elements to be used for inspection of industrial coating work. Many of the details covered may be in a specification for a particular project. A job specification for painting should include the coatings to be used. The various items are explained in detail in the text of this guide.

TASK

I Surface Condition Examination
1 Condition of edges, weld splatter
2 Grease or oil, or both
3 Chalk, mildew
4 Protective coverings in place
5 Air temperature
6 Surface temperature
7 Wind direction, velocity
8 Dew Point, RH
9 Visible moisture

II Safety on the Job:
Protective clothing
Respirator
Safety glasses
Ear protection

III Blast Cleaning:
1 Type and size abrasive
2 Clean and dry abrasive
3 Recycled abrasive test
4 Compressed air check
5 Nozzle air pressure

IV Surface Preparation:
1 Dust and abrasive removal
2 Degree of cleanliness
3 Profile measurement
4 Magnetic base reading

FIG. X1.1 Inspection Checklist
V Coatings Application:
1 Time from surface preparation to application
2 Coating viscosity
3 Compressed air check
4 Protective coverings in place
5 Time application began
6 Surrounding air cleanliness
7 Continue to monitor temperature and humidity conditions
8 Correct coating and mixing procedure
9 Induction time observed
10 Proper percent agitation
11 Film thickness
—Wet
12 Recat Times observed
13 Intercoat Cleanliness
14 Film Defects, Voids, etc.

VI Recordkeeping:
1 Record all details
2 Application
3 Manufacturer
4 Batch #’s
5 Container Condition
6 Record Observations from Sections I, III, IV, and V of Fig. 1.1.

Wet (Notched Gage)—This device has a series of calibrated steps for measuring thin to heavy coats. The true wet-film thickness lies between the highest step coated and the next highest that was not coated. This method is not as accurate as the interchemical gage.

Interchemical Gage—This type of instrument is designed to measure the thickness of a wet film of paint. Nondestructive Film Thickness Gages are widely used for field and shop inspection. For ferrous metals they are based on magnetism, and for nonmagnetic metals, inductance and eddy currents. See guide for discussion of types.

Dry (Tooke Gage)—The Tooke paint inspection gage is designed to measure paint film thickness by microscopic observation of a cut into the paint film.

VI Recordkeeping:
12 Record time application completed
13 Tape test D 3559
14 Holiday detector

VI Maintenance of a record book containing all transactions between the inspector and the contractor is essential to eliminate contract disputes. Details of the many steps involved in proper coatings application must be recorded (Section 4).

FIG. XI.1 Inspection Checklist (continued)

This standard is issued under the fixed designation D 3281; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

1. Scope

1.1 This test method describes a method of evaluating the formability of organic coatings intended for application to strip metal substrates by coil-coating or other factory application methods.

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

2. Significance and Use

2.1 This test method is designed to provide a uniform procedure for determining the degree of flexibility and adhesion of factory-applied organic coatings on strip metal.

2.2 It should be recognized that some metal substrates will crack during forming and that the organic coating may crack accordingly.

3. Apparatus

3.1 Impact-Type Wedge Bend, assembly illustrated in Fig. 1.2 The instrument contains a 4-lb (1.82-kg) impactor rod with one flat end that slides in a vertical slotted guide and serves as a falling weight to hammer the wedge mandrel with the flat end. A knurled cover inserted in the wedge mandrel impact test hole serves as the impact point. When positioned properly the lifting knob on the impactor coincides with the zero mark on the guide tube. The spacer block is removed from the front edge of the wedge mandrel so that the taper is 0 to ¼ in. (0 to 3.2 mm) front to back.

3.2 Cellulose Adhesive Tape, ¼ in. (20 mm) wide.

4. Test Specimens

4.1 Suitable substrates for the test specimen (including thickness) shall be employed and agreed upon between the purchaser and the seller. Prior to application of the coating, edges of the specimens that will be bent in the test shall be rounded slightly to remove burrs in order to eliminate effects associated with cracking of a sharp metallic edge when bent.

NOTE 1—When metal thickness exceeds 0.025 in. (0.64 mm), complete compression of the bend may not occur with a single impact.

4.2 The coating under test shall be applied to the clean base metal after the agreed-to surface preparation of the metal substrate has been completed. The coating shall be applied to one or both sides of the metal (as specified) in a manner that will provide a uniform coating thickness. The dry film thickness shall not vary more than 0.1 mil (±2.5 μm) from the specified thickness agreed upon between the purchaser and the seller. The method of application, the cure of the film, the time between the application of the coating and the testing of the specimen, as well as the temperature and humidity environment used for aging the film during this period, shall be agreed upon between the purchaser and the seller.

5. Conditioning and Number of Tests

5.1 Test at least three replicate specimens under the conditions of temperature and humidity mutually agreed upon between the purchaser and the seller. Unless otherwise specified by the purchaser and the seller, make measurements at 73.5 ± 0.5°F (23 ± 2°C) and 50 ± 5% relative humidity after equilibrating at these conditions for at least 24 h.

6. Procedure

6.1 Place the specimen, coated side down, under the ¼-in. (3.2-mm) cylindrical mandrel. Slide the specimen to the rear of the mandrel platform until the edge is flush with the two studs located at the rear of the platform.

NOTE 2—Since the test is usually more severe if the panel is bent parallel to the original rolling direction of the base metal, the direction of the bend with respect to the "grain" of the base metal should be agreed upon between the purchaser and the seller.

6.2 Raise the remainder of the panel at a uniform velocity to bend the specimen 170 to 180° in a time not to exceed 5 s.

6.3 Slide the spacer located under the impact platform to the extreme front of the tester and tighten it in place with the adjustment screws provided. This allows the impact platform to create a wedge that provides stress angles between 170 and 180°.

NOTE 3—The end of the specimen with the 180° stress angle is defined as having a zero T (0T) bend.

6.4 Center the bent specimen under the impact platform. Place the longest segment of the specimen downward.
6.5 Predetermine the load required to result in a OT bend (180°) and run all tests using the same substrate at this load. The wedge bend required shall be obtained with a single impact representing the minimum force to obtain a OT bend.

6.6 After impact, remove the specimen and visually inspect without magnification the bent portion for cracking and adhesion loss, starting at the most severe bend and progressing outward.

6.7 Measure the distance fractured (cracking) from the edge of the most severe bend outward to the edge with the least severe bend in inches or millimeters.

NOTE 4—Disregard heavy beads of coating on the edges.

6.8 Determine film adhesion loss by firmly applying the adhesive tape to the entire bend area and then removing the tape in a uniform rapid motion. The time between the first bending of the specimen and removal of tape shall not be less than 1 nor more than 5 min. Start removal from the edge of most extreme bending (OT edge) and remove the tape rapidly in a motion parallel to the surface of the longitudinal edge of the bend, such that the tape is pulled back upon itself.

6.9 Examine the taped area and measure the amount of film removed. It should be noted that the primary concern of this rating is the maximum distance of adhesion failure.

7. Precision

7.1 On the basis of an interlaboratory study of this test method in which two operators in each of five laboratories measured two replicates on two days for cracking and adhesion, the standard deviations within and between laboratories were found to be as follows:

<table>
<thead>
<tr>
<th></th>
<th>Cracking, mm</th>
<th>Adhesion, mm</th>
</tr>
</thead>
<tbody>
<tr>
<td>Within laboratory</td>
<td>2.0</td>
<td>3.9</td>
</tr>
<tr>
<td>Between laboratory</td>
<td>4.7</td>
<td>10.0</td>
</tr>
</tbody>
</table>

Based on these standard deviations, the following criteria should be used to judge the precision of results at the 95% confidence level:

7.1.1 Repeatability—Two measurements obtained by the same operator should be considered suspect if they differ by more than

<table>
<thead>
<tr>
<th>Cracking, mm</th>
<th>5.8</th>
</tr>
</thead>
<tbody>
<tr>
<td>Adhesion, mm</td>
<td>11.4</td>
</tr>
</tbody>
</table>

7.1.2 Reproducibility—Two measurements, each the mean of duplicate measurements, obtained in different laboratories should be considered suspect if they differ by more than

<table>
<thead>
<tr>
<th>Cracking, mm</th>
<th>16.8</th>
</tr>
</thead>
<tbody>
<tr>
<td>Adhesion, mm</td>
<td>35.7</td>
</tr>
</tbody>
</table>

The American Society for Testing and Materials takes no position respecting the validity of any patent rights asserted in connection with any item mentioned in this standard. Users of this standard are expressly advised that determination of the validity of any such patent rights, and the risk of infringement of such rights, are entirely their own responsibility.

This standard is subject to revision at any time by the responsible technical committee and must be reviewed every five years and if not revised, either reapproved or withdrawn. Your comments are invited either for revision of this standard or for additional standards and should be addressed to ASTM Headquarters. Your comments will receive careful consideration at a meeting of the responsible technical committee, which you may attend. If you feel that your comments have not received a fair hearing you should make your views known to the ASTM Committees on Standards, 1916 Race St., Philadelphia, PA 19103.
Standard Practice for
Testing Primers and Primer Surfacers Over Preformed Metal

This standard is issued under the fixed designation D 3322; 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 (´) indicates an editorial change since the last revision or reapproval.

1. Scope

1.1 This practice covers the selection and use of procedures for testing primers and primer surfacers. The test methods included are listed in Table 1.

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

2. Referenced Documents

2.1 ASTM Standards:
B 117 Method of Salt Spray (Fog) Testing
C 540 Test Method for Image Gloss of Porcelain Enamel Surfaces
D 16 Terminology Relating to Paint, Varnish, Lacquer, and Related Products
D 522 Test Method for Mandrel Bend Test of Attached Organic Coatings
D 523 Test Method for Specular Gloss
D 609 Practice for Preparation of Steel Panels for Testing Paint, Varnish, Lacquer, and Related Products
D 610 Test Method for Evaluating Degree of Rusting on Painted Steel Surfaces
D 658 Test Method for Abrasion Resistance of Organic Coatings by Air Blast Abrasive
D 660 Test Method for Evaluating Degree of Checking of Exterior Paints
D 661 Test Method for Evaluating Degree of Cracking of Exterior Paints
D 714 Test Method for Evaluating Degree of Blistering of Paints
D 823 Test Methods for Producing Films of Uniform Thickness of Paint, Varnish, and Related Products on Test Panels
D 870 Practice for Testing Water Resistance of Coatings Using Water Immersion
D 968 Test Methods for Abrasion Resistance of Organic Coatings by Falling Abrasive
D 1005 Test Methods for Measurement of Dry-Film Thickness of Organic Coatings Using Micrometers

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2 Annual Book of ASTM Standards, Vols 03.02 and 06.01.

3 Annual Book of ASTM Standards, Vol 02.05.

4 Annual Book of ASTM Standards, Vol 06.01.

5 Annual Book of ASTM Standards, Vol 06.02.

6 Annual Book of ASTM Standards, Vol 06.03.

7 Annual Book of ASTM Standards, Vols 02.05 and 06.02.

8 Discontinued; see 1980 Annual Book of ASTM Standards, Part 27.

9 Discontinued; see 1988 Annual Book of ASTM Standards, Vol 06.01.
3. Terminology

3.1 Definitions:

3.1.1 *primer*—the first of two or more coats of paint, varnish, or lacquer system (same as in Terminology D 16).

3.1.2 *primer surfacer*—a pigmented coating for filling minor irregularities which is sanded to obtain a smooth uniform surface preparatory to applying finish coats. A primer surfacer is not usually applied over a primer.

4. Significance and Use

4.1 Primers and primer surfacers may be used over many different surfaces top coated with one or more of a variety of coatings and subjected to many kinds of wear and exposure.

4.2 The selection of the tests to be used for any given product or system must be governed by experience and by the requirement agreed upon between producer and user.

5. Panel Preparation

5.1 *Treatment of Substrate*—Preparation of test panels should include any cleaning treatment agreed upon between purchaser and seller or one of the following ASTM Practices: D 609, D 1730, D 1731, D 1732, D 1733 and D 2092, and Test Method D 2201.

5.2 *Substrate, Film Thickness and Application Means*—Conduct performance tests on the specified substrate on coatings having a film thickness agreed upon between the purchaser and seller. Primers are generally applied to a dry film thickness of 0.3 to 1.5 mils (8 to 38 μm) and primer surfacers to film thickness of 0.7 to 2.0 mils (17 to 50 μm). Unless otherwise agreed upon, apply primers and primer surfacers in accordance with Test Method D 823.

5.3 *Measurement of Film Thickness*—Since the properties of the primer or primer surfacer can vary considerably with the thickness of the coating, it is important to know the film thickness. Measure the film thickness in accordance with Test Methods D 1400, D 1005, or D 1186.

5.4 *Drying of Primer or Primer Surfacer*:

5.4.1 Before tests are run, air dry or bake the primer or primer surfacer according to the schedule and temperature and age as agreed upon between the purchaser and seller.

5.4.2 Overbake the primer or primer surfacer to determine the time/temperature effect on the physical and chemical properties. Do this in accordance with Practice D 2454.

5.4.3 It may be desirable for some reason (handling, stacking, etc) to determine the various stages and rates of film formation in the drying or curing of primers and primer surfacers at room temperatures. Do this as described in Test Method D 1640.

6. Physical Properties of The Dry Film

6.1 Primers and primer surfacers are usually (but not always) topcoated. Therefore, many of the following tests should be run on the complete system (substrate/primer or primer surfacer/topcoat). Some of the tests however are for the untopcoated primer or primer surfacer. The properties required of a primer or primer surfacer depend on the intended end use and the tests to be used should be selected on the basis of experience and agreed upon between the purchaser and seller.

6.2 *Abrasion Resistance*—Determine the abrasion resistance as described in either Test Method D 658 or D 968.

6.3 *Adhesion*:

6.3.1 The primer or primer surfacer of a specified substrate as agreed upon by the purchaser and seller is subjected to an adhesion test to determine the degree of attachment the coating has to the substrate.

6.3.2 Determine the adhesion of the primer or primer surfacer as described either in Test Methods D 2197 or D 3359.

6.3.3 The above methods, in addition to measuring the adhesion of the coating to the substrate, can also be used to determine the intercoat adhesion between the topcoat and

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D 3170 Test Method for Measuring Adhesion by Tape Test
D 3359 Test Methods for Measuring Adhesion by Tape Test
D 3456 Practice for Determining by Exterior Exposure Tests the Susceptibility of Paint Films to Microbiological Attack

2.2 Federal Test Methods: 10
141B/6011 Immersion Resistance
141B/6271.1 Mildew Resistance
141B/6321 Sanding Characteristics

2.3 U.S. Military Specification:
MIL-P-46105 10

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10 Available from Standardization Documents Order Desk, Bldg. 4 Section D, 700 Robbins Ave., Philadelphia, PA 19111-5094.
the primer or primer surfacer.

6.4 Chemical Resistance:

6.4.1 Coating systems frequently come into contact with various chemicals that may have an effect on the properties of the system. Failure when it occurs is usually in the form of discoloration, change in gloss, blistering, softening, swelling, dissolving, or loss of adhesion. Unless a primer is to be left untopcoated in actual service, primers and primer surfacers should be topcoated with the appropriate product before undergoing chemical resistance tests.

6.4.2 Household Chemical Resistance—Determine the effect of chemicals in accordance with Test Method D 1308.

6.4.3 Detergent Resistance—Determine the resistance to failure under conditions of immersion in a detergent solution in accordance with Practice D 2248.

6.4.4 Hydrocarbon Resistance—Test hydrocarbon resistance in accordance with Method 6011 of U.S. Federal Test Method Standard No. 141B.

6.5 Chip Resistance—The chip resistance of a primer or primer surfacer is the ability of a film to withstand sudden impact from stones, gravel, etc, without being loosened from the substrate. Determine chip resistance by Test Method D 3170.

6.6 Color Difference-Pigmented Dry Film—The color differences between two similarly homogeneously colored, opaque films such as those formed by primers or primer surfacers may be determined using visual evaluating techniques or by instrumental means. Determine color differences visually using Practice D 1729. Determine color differences instrumentally using Test Method D 2244.

6.7 Cracking Resistance—A test for resistance to temperature and humidity changes, or a cold cracking test as it is sometimes called, is designed to give an indication of the resistance of a coating system to cracking or checking caused by temperature and humidity changes and also by aging. The degree of correlation between accelerated crack results and long term room temperature aging varies with the types of coating. The industry uses the test widely and it is felt that a system showing good cold crack resistance will perform satisfactorily in service. Some factors that can affect results are type of substrate, substrate thickness, primer, primer surfacer, topcoat, and film thickness of the different coatings. Determine cracking resistance in accordance with Test Method D 2246.

6.8 Elongation—An elongation test may be used as an indication of the flexibility of an attached primer or primer surfacer. It can also show whether there is any change during aging. Determine elongation by Test Methods D 522 or D 1737.

6.9 Filiform Corrosion Resistance—Filiform corrosion is a type of corrosion that occurs under coatings on metal substances and is characterized by a definite thread-like structure and directional growth. Determine the susceptibility of organic films over metal substrates to this type of corrosion by Test Method D 2803.

6.10 Gloss—Determine the gloss of primers and primer surfacers in accordance with Test Method D 523.

6.11 Hardness—Determine the film hardness of primers and primer surfacers in accordance with Test Methods D 1474, using either Test Method A (Knoop indentation hardness) or Method B (Pfund indentation hardness) as agreed upon by the purchaser and seller. Other methods of determining hardness may be used as agreed between purchaser and seller.

6.12 Holdout—Holdout is the ability of a primer or primer surfacer to give a smooth (nonporous), uniform appearance when topcoated. This property can be evaluated visually or by instrumental means. One method of measuring for holdout is described in Test Method C 540.


6.14 Outdoor Exposure:

6.14.1 Primers and primer surfacers can have an important effect on the durability of any paint system destined for exterior use. While the accelerated tests given in other sections of this recommended practice are intended to enable one to predict performance, actual outdoor exposure should be made. Usage of paint systems is so varied that no one set of conditions (length of exposure or place of exposure) can be given in this practice to cover all situations. These conditions as well as the type of substrate, substrate preparation, etc should be agreed upon between the purchaser and the seller. However, it is suggested that, unless otherwise agreed upon, prepare panels for outdoor exposure in accordance with Section 4 of this practice.

6.14.2 Many properties of organic coating systems should be evaluated periodically throughout the outdoor exposure period. Where failures occur on a topcoated system, experience is required to determine whether or not the primer or primer surfacer is involved. Properties most likely to involve the primer or primer surfacer may be evaluated as follows: Blistering, Test Method D 714; Cracking, Test Method D 661; Rusting, Test Method D 610; Checking, Test Method D 660.

6.15 Print Resistance—A print test can be used to determine the degree of thermoplasticity or solvent retention of a film and hence whether the product can be safely stacked or packaged and, in the case of a thermoplastic film, at what temperature the film prints or mars. A print test can also be used to determine the degree of marring due to pressure. Determine the imprinting and thermoplasticity of primer or primer surfacer films as described in Test Method D 2091.

6.16 Salt Spray Resistance—Salt spray testing of coatings is helpful in determining their resistance to failure in service under conditions of high humidity and salt concentrations. Under accelerated conditions of laboratory testing the temperature, the pH, the concentration of the salt solution and other physical properties can be controlled. The selection of the substrate, the application technique, the choice of the topcoat, the manner in which the coating is scribed, the location or position of the panels within the cabinet, the length of the test, the inspection of panels and the method of reporting results must be agreed upon between the purchaser and seller. Test for salt spray resistance in accordance with Method B 117.

6.17 Sanding Properties:

6.17.1 Sanding properties are normally expected of primer surfacers only. Method 6321 of U.S. Federal Test Method Standard No. 141B covers this property.

6.17.2 Prepare and dry a film of the material to be tested as specified in the product specification. Scuff the surface of
the dried film manually with 400 softback sandpaper. Examine the film for gouging and deep scratches and determine whether there has been any clogging of the sandpaper. Depending on the end use of the primer surfacer involved, other methods of sanding may be used as agreed upon by the purchaser and seller.

6.18 Water Resistance:

6.18.1 Testing of coating systems with water is helpful in determining their resistance to failure under conditions of high humidity or water immersion. Failure in water tests is usually evidenced by blistering, dulling, softening or loss of adhesion which does not disappear or recover upon evaporation of the absorbed water.

6.18.2 Determine the resistance to failure under conditions of high humidity in accordance with Practice D 1735.

6.18.3 Determine the resistance to failure under conditions of water immersion in accordance with Practice D 870. This test is best suited for coating systems that will actually be soaked in water during service.

6.19 Weldability—In some instances it is necessary to weld metal that has been primed. The welding characteristics of a primer or primer surfacer may be tested in accordance with U.S. Military Specification MIL-P-46105 (MR), Section 4.4.11.
Standard Guide for
Testing Interior Solvent-Reducible Flat Wall Paints

This standard is issued under the fixed designation D 3323; 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.

This standard has been approved for use by agencies of the Department of Defense. Consult the DoD Index of Specifications and Standards for the specific year of issue which has been adopted by the Department of Defense.

NOTE—Editorial changes were made throughout, including the title, in October 1988.

1. Scope

1.1 This guide covers the selection and use of procedures for testing interior solvent-reducible flat wall paints, such as alkyd or other solvent-thinned finishes. The test methods included are listed in Tables 1 and 2. All of these test methods may not be required for each paint. Selection of the test methods must be governed by experience and the requirements in each individual case, together with agreement between the purchaser and seller.

1.2 This guide covers the testing of ready-mixed finish coats for application by brushing, roller coating, spraying, or other methods, on wood, plaster, wallboard, masonry, previously painted surfaces, and other interior architectural surfaces.

2. Referenced Documents

2.1 ASTM Standards:
D 16 Terminology Relating to Paint, Varnish, Lacquer, and Related Products
D 93 Test Methods for Flash Point by Pensky-Martens Closed Tester
D 154 Guide for Testing Varnishes
D 185 Test Methods for Coarse Particles in Pigments, Pastes, and Paints
D 344 Test Method for Relative Hiding Power of Paints by the Visual Evaluation of Brushouts
D 522 Test Methods for Mandrel Bend Test of Attached Organic Coatings
D 523 Test Method for Specular Gloss
D 562 Test Method for Consistency of Paints Using the Stormer Viscometer
D 823 Test Methods for Producing Films of Uniform Thickness of Paint, Varnish, and Related Products on Test Panels
D 1208 Test Methods for Common Properties of Certain Pigments
D 1210 Test Method for Fineness of Dispersion of Pigment-Vehicle Systems
D 1310 Test Method for Flash Point and Fire Point of Liquids by Tag Open-Cup Apparatus
D 1475 Test Method for Density of Paint, Varnish, Lacquer, and Related Products
D 1554 Terminology Relating to Wood-Base Fiber and Particle Panel Materials
D 1640 Test Methods for Drying, Curing, or Film Formation of Organic Coatings at Room Temperature
D 1729 Practice for Visual Evaluation of Color Differences of Opaque Materials
D 1737 Test Method for Elongation of Attached Organic Coatings with Cylindrical Mandrel Apparatus
D 2196 Test Methods for Rheological Properties of Non-Newtonian Materials by Rotational (Brookfield) Viscometer
D 2197 Test Methods for Adhesion of Organic Coatings by Scrape Adhesion
D 2244 Test Method for Calculation of Color Differences From Instrumentally Measured Color Coordinates
D 2369 Test Method for Volatile Content of Coatings
D 2371 Test Method for Pigment Content of Solvent-Reducible Paints
D 2372 Practice for Separation of Vehicle from Solvent-Reducible Paints
D 2486 Test Method for Scrub Resistance of Interior Latex Flat Wall Paints
D 2621 Test Method for Infrared Identification of Vehicle Solids from Solvent-Reducible Paints
D 2801 Test Method for Leveling Characteristics of Paints by Draw-Down Method
D 2805 Test Method for Hiding Power of Paints by Reflectometry
D 3278 Test Methods for Flash Point of Liquids by Setaflash Closed-Cup Apparatus
E 105 Practice for Probability Sampling of Materials
E 313 Test Method for Indexes of Whiteness and Yellowness of Near-White Opaque Materials

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


2 Annual Book of ASTM Standards, Vol 06.01.
3 Annual Book of ASTM Standards, Vols 05.01 and 06.01.
4 Annual Book of ASTM Standards, Vol 06.03.
7 Annual Book of ASTM Standards, Vol 06.02.
8 Discontinued; see 1989 Annual Book of ASTM Standards, Vol 06.01.
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† Cancelled U.S. Federal Methods.

2.2 U.S. Federal Test Method Standard 141.10

1022 Sampling (General)

2131 Application of Sprayed Films

2141 Application of Brushed Films

3011 Condition in Container

3021 Skinning (Partially Filled Container)

4042 Volatile and Nonvolatile Content (Vacuum Oven)

4321 Brushing Properties

4331 Spraying Properties

4335 Roller Coating Properties

4421 Absorption Test

4541 Working Properties and Appearance of Dried Film

3. Terminology

3.1 Definitions:

3.1.1 For definitions of terms in these practices, refer to Terminology D 16 and Terminology D 1554.

4. Conditions Affecting Solvent-Thinned Flat Wall Paint Topcoats

4.1 Practical requirements and performance of solvent-thinned flat wall paints may vary with:

4.1.1 Substrate Type, such as type and quality of wood or hardboard, wallboard and joint cement systems, alkalinity, type and quality of plaster, and type and quality of old paint.

4.1.2 Substrate Conditions—Smoothness of substrate and quality of topcoat will affect spreading rate, final appearance, and texture.

4.1.3 Type and quality of primer and the time before topcoating.

4.1.4 Environmental conditions, such as temperature and humidity, at the time of paint application and during drying.

5. Sampling

5.1 Prior to sampling, the condition of the container should be established since damage to it may cause evaporation, skinning, or other undesirable effects in the coating. Determine the condition of the paint in accordance with 6.1 and 6.2.

5.2 Sample in accordance with Section 4.2.1 of Method 1021 of Federal Test Method No. 141. Determine the weight per gallon in accordance with Test Method D 1475. Repeat this procedure until successive values agree within 0.1 lb (45 g) or as agreed upon between the purchaser and the seller. Then take samples for testing.

5.3 Specify the amount of sample, the package sizes, and identification codes to assure a representative sample.
### TABLE 2 Alphabetical List of Test Methods

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A 1-gal (4-L) sample is usually sufficient for the recommended tests, but for guidance in selecting a sampling plan, consult Recommended Practice E 105.

### 6. Liquid Paint Properties

#### 6.1 Skinning—Paints containing a binder which dries by oxidation are subject to skin formation in a partially filled can. Since skins are insoluble in the paint, they must be removed before use. This test in a partially filled container indicates the tendency of a paint to skin. Examine the original sample for skins, both on the surface and in its mass. On a well-mixed, skin-free portion of the sample, perform a skinning test in accordance with Guide D 154.

#### 6.2 Condition in Container—Thickening, settling, and separation are undesirable and objectionable if the paint cannot be reconditioned with a reasonable amount of stirring. The referenced method covers procedures for determining changes in properties of paints after storage. Determine the condition in the container in accordance with Method 3011 of U.S. Federal Test Method Standard No. 141.

#### 6.3 Coarse Particles and Foreign Matter—Paints must be free of coarse particles and foreign matter to form a uniform film of good appearance, a typical maximum being 1 weight % of the total paint. Determine the percent of coarse particles and foreign matter in accordance with Test Method D 185.

#### 6.4 Fineness of Dispersion—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 product down a tapered groove varying in depth from 4 to 0 mils (100 to 0 μm). The point at which continuous groupings of particles or agglomerates, or both, protrude through the surface of the wet film is taken as the dispersion reading. Higher readings in Hegman units or lower readings in mils or micrometers indicate better dispersion. Determine the fineness of dispersion in accordance with Test Method D 1210.

#### 6.5 Weight per Gallon—The density of a paint as measured by weight per gallon or kilograms per litre is used to assure product uniformity, batch to batch, and provides a check against the theoretical weight calculated from the formula. The density is expressed as the weight in pounds avoirdupois of 1 U.S. gal of the paint at a specified temperature. Determine weight per gallon or kilograms per litre in accordance with Test Method D 1475, using a calibrated weight per gallon cup.

#### 6.6 Consistency—Paints of a given type should fall within a stated consistency range for satisfactory reproduction of a specific formula. In the referenced test method, consistency is defined as the load in grams required to produce the specified rate of shear. Determine consistency in accordance with Test Method D 562.

#### 6.7 Flash Point—When the flash point of a material is required for shipping information, use Test Methods D 1310, D 3278, or D 93.

#### 6.8 Color Acceptance—This method gives an indication of the ability of the paint to be tinted with tinting systems in common use. Determine color compatibility as agreed upon between the purchaser and seller.

#### 6.9 Rheological Properties of Non-Newtonian Materials—Rheological properties are related to application and flow
properties of the liquid paint. The referenced test method covers the determination of the rheological properties and is particularly suited for use with paints that display thixotropic characteristics. Determine the rheological properties in accordance with Test Method D 2196.

6.10 Absorption—This method provides a rapid determination of the relative penetration of the binder into the surface. It provides a rough measure of the wetting and penetrating properties of liquid materials. Loss of binder and the resultant change in pigment volume, as the film dries, are indicated by this test. Determine the absorption in accordance with Method 4421 of U.S. Federal Test Method Standard No. 141.

7. Paint Application and Film Formation

7.1 Application of Brushed Films—Refer to Method 2131 or 4321 of U.S. Federal Test Method Standard No. 141 to determine the brushing properties of a coating. Method 4321.1 is quite subjective although someone experienced in the art can obtain consistent results, particularly in the determination of the "drag" properties.

7.2 Applications of Sprayed Films—Refer to Method 2131 or 4331 of U.S. Federal Test Method Standard No. 141 to determine the spraying properties of a coating. Method 4331 is very subjective and should be performed by an individual skilled in the art of using spray equipment.

7.3 Drying Time—The drying time of an interior finish is important in determining when a freshly painted room can be put back to use. The test can also be used to determine whether or not the drying properties of a paint have changed during storage. Any one or several of the test methods that cover the determination of the various stages and rates 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" times will be important. Determine the appropriate drying time in accordance with Test Method D 1640.

7.4 Leveling Properties—Leveling is an important factor when smooth surfaces are to be produced. The referenced test method covers the laboratory determination of the relative leveling characteristics of liquid coatings. Determine leveling characteristics in accordance with Test Method D 2801.

7.5 Producing Films of Uniform Thickness—Method D 823 covers the preparation of coating films of uniform thickness essential in conducting tests.

7.6 Roller Coating Properties—The referenced method outlines a procedure for making an evaluation of a material's characteristics when applied by a roller. Determine roller coating properties in accordance with Method 4335 of U.S. Federal Test Method Standard No. 141.

7.7 Working Properties—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 U.S. Federal Test Method Standard No. 141.

8. Appearance of Dry Paint Film

8.1 Color Difference of Opaque Materials by Visual Comparison—Visual comparison of color is fast and often acceptable. The referenced practice 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. Determine color difference in accordance with Practice D 1729.

8.2 Color Differences of Opaque Materials by Instrument Evaluation—Color difference between a product and the standard can be measured by instrument. The referenced method covers the instrumental determination of small color differences, observable in daylight illumination, between nonfluorescent, nonmetamer, opaque surfaces such as paint specimens. If metamerism is suspected, visual evaluation (8.1) should be used to verify instrumental results. Determine the color difference in accordance with Method D 2244.

8.3 Specular Gloss (Sheen)—The test method given, using the 85° geometry, is useful in characterizing the low angle appearance of flat paints. Determine 85° gloss in accordance with Test Method D 523.

8.4 Hiding Power—Hiding power is a measure of the ability of a coating to hide the substrate. It is, however, dependent on uniform film thickness which is influenced by the flow, leveling, and application properties of the enamel. Test Method D 344 uses brush application and compares the enamel to a standard. Test Method D 2805 uses an applicator bar and is more reproducible and measures smaller differences than D 344. Determine hiding power in accordance with Test Methods D 344 or D 2805.

9. Properties of Dry Paint Film

9.1 Adhesion—Measure the adhesion of the paint by testing in accordance with Test Method D 2197.

9.2 Cleanability—The ability to remove marks satisfactorily without damaging the film is important with interior finishes.

9.2.1 Scrub Resistance—The test for scrub resistance of interior latex flat wall paint can be applied to the solvent-thinned type. Use Test Method D 2486.

9.2.2 Washability—The referenced method determines the washability of a paint by subjecting a soiled film of the dried paint to the cleaning action of a wet sponge and cake grit soap. Determine the washability in accordance with Method 6141 of U.S. Federal Test Method Standard No. 141.

9.3 Elongation—Elongation is a measure of flexibility of a paint film. Determine elongation in accordance with Test Methods D 1737 or D 522.

9.4 Flame Resistance—Some paints exhibit a change in appearance (usually color) when subjected to foul atmospheres, for example, air containing certain sulfur compounds. There is no standard test method for determining the ability of a paint to resist this change.

9.5 Yellowness Index—The referenced test method is used for white or near white specimens to determine color departure from white toward yellow or color change towards yellow on exposure or treatment. Determine the yellowness index in accordance with Test Method E 313.

10. Analysis of Paint

10.1 If a specification requires certain raw materials or certain components in a given amount, then chemical
analysis is required. Chemical analysis determines whether
the specified components are present and if they are, in what
amounts. It does not necessarily establish paint quality which
may be greatly affected by manufacturing techniques. No
single schematic analysis is comprehensive enough to cover
the wide variety of materials used in paint compositions.

10.2 Volatile Content—The percent of volatile matter
indicates the thinner loss from the film as it dries. The
referenced test method covers the determination of the
volatile content of solvent-type paints. The quantity deter-
mined subtracted from 100 % gives the nonvolatile content
of the coating. Determine the volatile content in accordance
with Test Method D 2369.

10.3 Water Content—The referenced test method covers
the determination of water in paint and related materials by
distilling the sample with a volatile solvent. Determine water
content in accordance with Test Method D 1208.

10.4 Pigment Content—Pigment provides the hiding and
color and influences many other properties of a coating. The
referenced test method describes the procedure for the
quantitative separation of the vehicle from the pigment in
solvent-type coatings. It is used to determine the weight
percent pigment in the paint. Determine the pigment con-
tent in accordance with Test Method D 2371.

10.5 Separation of Vehicle—The recommended procedure
describes the separation of vehicle from certain solvent-
type paints. The separated vehicle is subjected to further
analysis. Separate the vehicle in accordance with Method
D 2372.

10.6 Identification of Vehicle Solids—The suggested
method covers the qualitative characterization or identifica-
tion of separated paint vehicle solids by infrared spectroscopy.
It is useful in detecting uniformity, batch to batch, and
the presence of adulterants. Characterize vehicle solids in
accordance with Method D 2621.

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and should be addressed to ASTM Headquarters. Your comments will receive careful consideration at a meeting of the responsible
technical committee, which you may attend. If you feel that your comments have not received a fair hearing you should make your
views known to the ASTM Committee on Standards, 1916 Race St., Philadelphia, PA 19103.
1. Scope

1.1 This guide covers the selection and use of procedures for testing water-borne floor paints. The test methods included are listed in Tables 1 and 2.

Note—Where no ASTM test method exists or there is a comparable (but not necessarily identical) method in Federal Test Method Standard, No. 141, the Federal Method number is listed. However, the Federal Method shall not be considered approved by ASTM.

1.2 The guide covers the testing of ready-mixed finish coats applied by brush or roller on surfaces subjected to traffic, such as floors, decks, platforms, stairs, and adjacent surfaces such as stair risers and railings.

1.3 Floor paints may be intended for interior use only or may also be suitable for use on exterior surfaces exposed to the weather, such as decks, porches, porch steps, and carport floors. Paints intended for both exterior and interior use require certain test procedures not applicable to paints intended for interior use only. Selection of test methods must be governed by the requirements in each individual case, together with agreement between the purchaser and the seller.

2. Referenced Documents

2.1 ASTM Standards:

D 16 Terminology Relating to Paint, Varnish, Lacquer, and Related Products
D 185 Test Methods for Coarse Particles in Pigments, Pastes, and Paints
D 215 Practice for Chemical Analysis of White Linseed Oil Paints
D 344 Test Method for Relative Hiding Power of Paints by the Visual Evaluation of Brushouts
D 358 Specification for Wood to Be Used as Panels in Weathering Tests of Coatings
D 522 Test Methods for Mandrel Bend Test of Attached Organic Coatings
D 523 Test Method for Specular Gloss
D 562 Test Method for Consistency of Paints Using the Stormer Viscometer
D 658 Test Method for Abrasion Resistance of Organic Coatings by Air Blast Abrasive
D 659 Methods for Evaluating Degree of Chalking of Exterior Paints
D 660 Test Method for Evaluating Degree of Checking of Exterior Paints
D 661 Test Method for Evaluating Degree of Cracking of Exterior Paints
D 662 Test Method for Evaluating Degree of Erosion of Exterior Paints
D 772 Test Method for Evaluating Degree of Flaking (Scaling) of Exterior Paints
D 823 Test Methods for Producing Films of Uniform Thickness of Paint, Varnish, and Related Products on Test Panels
D 968 Test Methods for Abrasion Resistance of Organic Coatings by Falling Abrasive
D 1006 Practice for Conducting Exterior Exposure Tests of Paints on Wood
D 1210 Test Method for Fineness of Dispersion of Pigment Vehicle Systems
D 1308 Test Method for Effect of Household Chemicals on Clear and Pigmented Organic Finishes
D 1475 Test Method for Density of Paint, Varnish, Lacquer, and Related Products
D 1640 Test Methods for Drying, Curing, or Film Formation of Organic Coatings at Room Temperature
D 1729 Practice for Visual Evaluation of Color Differences of Opaque Material
D 1737 Test Method for Elongation of Attached Organic Coatings with Cylindrical Mandrel Apparatus
D 1848 Classification for Reporting Paint Film Failures Characteristic of Exterior Latex Paints
D 1849 Test Method for Package Stability of Paint
D 2197 Test Method for Adhesion of Organic Coatings by Scrape Adhesion
D 2243 Test Method for Freeze-Thaw Resistance of Water-Borne Coatings
D 2244 Test Method for Calculation of Color Differences from Instrumentally Measured Color Coordinates
D 2369 Test Method for Volatile Content of Coatings
D 2574 Test Method for Resistance of Emulsion Paints in the Container to Attack by Microorganisms
D 2805 Test Method for Hiding Power of Paints by Reflectometry
D 4062 Test Method for Leveling of Paints by Draw-Down Method

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


2 Annual Book of ASTM Standards, Vol 06.01.

3 Annual Book of ASTM Standards, Vol 06.03.

4 Annual Book of ASTM Standards, Vol 06.02.

5 Discontinued; see 1990 Book of ASTM Standards, Vol 06.01. Replaced by Test Method D 4214.

3. Conditions Affecting Performance of Water-Borne Floor Paints

3.1 Practical requirements affecting and performance of water-thinned floor paints may vary with:

3.1.1 Substrate type, such as type and quality of wood, concrete, metal, or composition flooring. The use of water-borne floor paints is generally restricted to previously painted surfaces or unpainted concrete.

3.1.2 Substrate conditions such as porosity, hardness, smoothness, or in the case of unpainted concrete, alkalinity. Cleanliness is very important as traces of oily contaminants can cause water-borne floor paints to peel.

3.1.3 Environmental conditions such as temperature and humidity at the time of application and during drying. As these paints contain water as a thinner, the floor does not have to be completely dry before application. However, low temperature during the drying period may cause poor film formation.

3.1.4 Substrate Aspects—If construction defects are such that excessive moisture makes its way through the substrate, or if the substrate is in direct contact with damp ground, blistering, flaking, or peeling may result.

4. Terminology

4.1 Definitions:

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

5. Sampling

5.1 Prior to sampling, the condition of the container should be established since damage to it may cause evaporation, skinning, or other undesirable effects in the coating. Determine the condition of the paint in accordance with 6.1 and 6.2.

5.2 Sample in accordance with Section 4.2.1 of Method 1021 of Federal Test Method No. 141. Determine the weight per gallon (or kilograms per litre) in accordance with Test Method D 1475. Repeat this procedure until successive values agree within 0.1 lb (45 g) or as agreed upon between the purchaser and the seller. Samples for testing may then be taken.

5.3 Specify the amount of sample, the package sizes, and identification codes to assure a representative sample. A 1-gal sample is usually sufficient for the recommended tests, but for guidance in selecting a sampling plan, consult Practice E 105.

6. Liquid Paint Properties

6.1 Condition in Container—Thickening, settling, and separation are undesirable and objectionable if a paint cannot be reconditioned and made suitable for application with a reasonable amount of stirring. The referenced methods covers procedures for determining changes in properties of paints after storage. Determine the condition in the container in accordance with Method 3011 of Federal Test Method Standard No. 141.

6.2 Coarse Particles and Foreign Matter—Paints must be free of coarse particles to form uniform films of good appearance, a typical maximum being 1 weight % of total paint. The specified test with a No. 325 (45-μm) sieve gives the percent of these particles in a paint. Determine coarse particles and foreign matter in accordance with Test Methods D 185.
6.3 Density or Weight per Gallon—The density as measured by weight in pounds per gallon (kilograms per litre) is used to assure product uniformity from batch to batch. In the referenced method, density is expressed as the weight in pounds of 1 U.S. gal (or kilograms per litre) of the paint at a specified temperature. Determine density in accordance with Test Method D 1475 using a calibrated cup.

6.4 Fineness of Dispersion—The more finely a pigment is dispersed, the more efficiently it is being used. One method for measuring the degree of dispersion (commonly referred to as “fineness of grind”) is to draw the material down a calibrated, tapered groove in a hardened steel block with the groove varying in depth from 4 to 0 mils (100 to 0 μm) and calibrated Hegman 0-8. The point at which continuous groupings of particles or agglomerates, or both, are visible through the surface of the liquid is taken as the fineness reading. Lower readings in mils or μm or higher readings in Hegman units indicate better fineness of dispersion. Determine fineness of dispersion in accordance with Test Method D 1210.

6.5 Consistency—Consistency is important, relating to application and flow, and should fall within a range agreed upon. In the referenced method consistency is defined as the load in grams required to produce a specified rate of shear and also expressed in Krebs units. Other methods may be used as agreed upon between the purchaser and the seller. Determine consistency in accordance with Test Method D 562.

6.6 pH—The pH of a water-thinned paint depends on the type of latex used and the general formulation. It may vary from about 5 to 10. pH does not determine the quality of the paint and should not be used to assure product uniformity. A change in pH during storage may indicate poor stability or a change in properties of a water-thinned paint. Determine pH in accordance with Test Method E 70.

6.7 Freeze-THaw Resistance—Water-thinned paints may be subjected to freezing conditions during shipping and storage. Suitably stabilized paints resist several cycles of freezing and thawing without showing deleterious changes. The referenced method covers the determination of the extent to which water-thinned floor paints, utilizing synthetic latices or synthetic resin emulsions as vehicles, retain their original properties when subjected to freezing and subsequent thawing. Determine freeze-thaw resistance in accordance with Test Method D 2243.

6.8 Package Stability—Since paints cannot normally be used immediately after manufacture, they must remain stable in the can for some time. At normal temperatures, most water-thinned floor paints can be stored for over a year with little change in properties. The referenced method covers the change in consistency and in certain related properties that may take place in packaged latex paint when stored at temperatures above freezing. Determine package stability in accordance with Test Method D 1849.

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

7. Paint Application and Film Formation

7.1 Application of Brushed Films—Brushed films should be smooth and free of seeds, color streaking, and brush marks. Test brush application in accordance with Method 2141 of Federal Test Method Standard No. 141.

7.2 Brushing Properties—The specified method covers a means for determining the brushing properties of coatings. The test is quite subjective; however, someone experienced in the art can produce quite consistent results, particularly in the determination of “drag” qualities. Floor paints are generally applied to horizontal surfaces but evaluation on vertical surfaces may be necessary to determine performance on stair risers, railings, posts, baseboards, etc. Determine the brushing properties in accordance with Method 4321 of Federal Test Method Standard No. 141.

7.3 Roller Coating Properties—Floor paints are frequently applied by roller. The referenced method outlines a procedure for evaluating a material’s characteristics when applied by a roller. Determine roller coating properties in accordance with Method 4335 of Federal Test Method Standard No. 141.
### Drying Properties

The drying time of a floor paint is important in determining when a freshly painted floor or stair may be subjected to traffic. Slow drying of the film may result in dust pickup, poor appearance and, if used on an exterior surface, rain or dew may cause a nonuniform appearance. Generally, water-thinned paints are dry-to-touch in 1 or 2 h when the water has evaporated from the film. Determine drying time in accordance with Test Methods D 1640.

### Leveling Properties

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

### Producing Films of Uniform Thickness

Test Methods D 823 covers the preparation of various films of uniform thickness essential in conducting tests.

### Appearance of the Dry Film

**Color Difference of Opaque Materials by Visual Evaluation**

Visual comparison of color is fast and often acceptable although numerical values are not obtained. The referenced method covers the spectral, photometric, and geometric characteristics of the 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 in accordance with Practice D 1729.

**Color Differences of Opaque Materials by Instrumental Evaluation**

Color difference between a product and the standard can be measured by instrument. Generally the tolerance is agreed upon between the purchaser and the seller. 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 metamericism is suspected, visual evaluation (8.1) should be used to verify instrumental results. Calculate the color difference measured instrumentally in accordance with Method D 2244.

**Gloss**

Water-thinned floor paints generally have a semi-gloss finish which resists penetration of dirt and improves washability. A range from 20 to 40 may be considered typical. Determine the specular gloss in accordance with Test Methods D 523.

**Hiding Power (Dry Opacity)**

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

### Properties of the Dry Film

**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. Determine abrasion resistance in accordance with Test Methods D 658 or D 968.

**Elongation**

Elongation is a measure of the flexibility of a paint film. Determine elongation in accordance with Test Methods D 1737 or D 522.

**Adhesion**

Adhesion is the property of the film that resists removal from the substrate when scuffed or scraped. It is an important property in a floor paint. Determine adhesion in accordance with Test Method D 1308.

**Exterior Exposure**

If the paint is intended for use on porches, decks, or outside stairways and railings, tests for resistance to exterior exposure may be required and may include the following:

**Conducting Exterior Exposures**

In conducting exterior exposures, refer to Practice D 1006 and Classification D 1848.

**Wood Panel Description**

In establishing exposure performance, use the panels as described in Specification D 358.

**Chalking Resistance**

Determine the chalking resistance rating by reference to Test Method D 659.

**Checking Resistance**

Determine the checking resistance rating by reference to Test Method D 660.

**Cracking Resistance**

Determine the cracking resistance rating by reference to Test Method D 661.

**Erosion Resistance**

Determine the erosion resistance rating by reference to Test Method D 662.

**Flaking Resistance**

Determine the flaking resistance rating by reference to Test Method D 772.

### Analysis of Paint

**Chemical Analysis**

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

**Volatile Content**

The percent of volatile matter indicates the thinner loss from the film as it dries. This quantity subtracted from 100% gives the nonvolatile content. Determine the volatile content in accordance with Test Method D 2369.

**Pigment Analysis**

The analysis of pigment may be required if the product is covered by a specification or if it is
agreed between the purchaser and the seller. Analyze the pigment in accordance with selected test procedures from Methods D 215.

11. Index Terms

11.1 This guide is indexed under the following terms: floor paints/coatings.
1. Scope

1.1 This guide covers the selection and use of procedures for testing solvent-reducible floor paints and enamels. The test methods included are listed in Tables 1 and 2.

1.2 This guide covers the testing of ready-mixed finish coats applied by brush or roller on surfaces subjected to traffic, such as floors, decks, platforms, stairs, and adjacent surfaces such as stair risers and railings.

1.3 Floor paints may be intended for interior use only or may also be suitable for use on exterior surfaces exposed to the weather such as decks, porches, porch steps, and carport floors. Paints intended for both exterior and interior use will require certain test procedures not applicable to paints intended for interior use only. Selection of test methods must be governed by the requirements in each individual case, together with agreement between the purchaser and the seller.

2. Referenced Documents

2.1 ASTM Standards:
D 16 Terminology Relating to Paint, Varnish, Lacquer, and Related Products
D 93 Test Methods for Flash Point by Pensky-Martens Closed Tester
D 154 Guide for Testing Varnishes
D 185 Test Methods for Coarse Particles in Pigments, Pastes, and Paints
D 215 Practice for Chemical Analysis of White Linseed Oil Paints
D 344 Test Method for Relative Hiding Power of Paints by the Visual Evaluation of Brushouts
D 358 Specification for Wood to Be Used as Panels in Weathering Tests of Coatings
D 522 Test Method for Mandrel Bend Test of Attached Organic Coatings
D 523 Test Method for Specular Gloss
D 562 Test Method for Consistency of Paints Using the Stormer Viscometer
D 658 Test Method for Abrasion Resistance of Organic Coatings by Air Blast Abrasive
D 659 Method of Evaluating Degree of Chalking of Exterior Paints
D 660 Test Method for Evaluating Degree of Checking of Exterior Paints
D 661 Test Method for Evaluating Degree of Cracking of Exterior Paints
D 662 Test Method for Evaluating Degree of Erosion of Exterior Paints
D 772 Test Method for Evaluating Degree of Flaking (Scaling) of Exterior Paints
D 823 Test Methods for Producing Films of Uniform Thickness of Paint, Varnish, and Related Products on Test Panels
D 968 Test Method for Abrasion Resistance of Organic Coatings by Falling Abrasive
D 1006 Practice for Conducting Exterior Exposure Tests of Paints on Wood
D 1014 Test Method for Conducting Exterior Exposure Tests of Paints on Steel
D 1210 Test Method for Fineness of Dispersion of Pigment-Vehicle Systems
D 1308 Test Method for Effect of Household Chemicals on Clear and Pigmented Organic Finishes
D 1471 Test Method for Two-Parameter, 60-deg Specular Gloss
D 1475 Test Method for Density of Paint, Varnish, Lacquer, and Related Products
D 1640 Test Methods for Drying, Curing, or Film Formation of Organic Coatings at Room Temperature
D 1729 Practice for Visual Evaluation of Color Differences of Opaque Materials
D 1737 Test Method for Elongation of Attached Organic Coatings with Cylindrical Mandrel Apparatus
D 2197 Test Methods for Adhesion of Organic Coatings by Scrape Adhesion
D 2244 Test Method for Calculation of Color Differences from Instrumentally Measured Color Coordinates
D 2245 Test Method for Identification of Oils and Oil Acids in Solvent-Reducible Paints
D 2369 Test Method for Volatile Content of Coatings
D 2371 Test Method for Pigment Content of Solvent-Reducible Paints

1 This practice is under the jurisdiction of ASTM Committee D-1 on Paint and Related Coatings and Materials and is the direct responsibility of Subcommittee D01.42 on Architectural Finishes. Current edition approved May 25 and Oct. 26, 1979. Originally published as D 3383-75. Last previous edition D 3383-75.

2 Annual Book of ASTM Standards, Vol 06.01.

3 Annual Book of ASTM Standards, Vol 05.01 and 06.01.

4 Annual Book of ASTM Standards, Vol 06.03.

5 Annual Book of ASTM Standards, Vol 06.02.

6 Discontinued; see 1990 Annual Book of ASTM Standards, Vol 06.01. Replaced by Test Methods D 4214.

7 Discontinued; see 1975 Annual Book of ASTM Standards, Part 27.

8 Discontinued; see 1988 Annual Book of ASTM Standards, Vol 06.01.
### TABLE 1 List of Test Methods by Properties

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3. Terminology

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

4. Conditions Affecting Performance of Solvent-Thinned Floor Paints

4.1 Practical requirements and performance of solvent-thinned floor paints may vary with:
4.1.1 Substrate type, such as type and quality of wood, concrete, metal, or composition flooring.
4.1.2 Substrate condition such as porosity, hardness, smoothness, and degree of cleanliness, or in the case of uncoated concrete, alkalinity.
4.1.3 Environmental conditions such as temperature and humidity at the time of application and during drying.
4.1.4 Substrate Aspects—If construction defects are such that excessive moisture makes its way through the substrate, or if the substrate is in direct contact with damp ground, blistering, flaking, or peeling may result.

5. Sampling

5.1 Prior to sampling, the condition of the container should be established since damage to it may cause eva-
### Table 2: Alphabetical List of Test Methods

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6. Liquid Paint Properties

6.1 **Skinning**—Coatings containing 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 method indicates the tendency of a paint to skin. Examine the original sample for skins, both on the surface and in its mass. On a well-mixed, skin-free portion of the sample, perform a skinning test in accordance with Guide D 154.

6.2 **Condition in Container**—Thickening, settling, and separation are undesirable and objectionable if a paint cannot be reconditioned and made suitable for application with a reasonable amount of stirring. The referenced method covers procedures for determining changes in properties of paints after storage. Determine the condition in the container in accordance with Method 3011.1 of Federal Test Method Standard No. 141.

6.3 **Coarse Particles and Foreign Matter**—Paints must be free of coarse particles to form uniform films of good appearance, typical maximum being 1 weight % of total paint. The specified test with a No. 325 (45-μm) screen gives the percent of these particles in a paint. Determine coarse particles and foreign matter in accordance with Test Methods D 185.

6.4 **Density or Weight per Gallon**—The density as measured by weight per gallon or kilogram per litre is used to assure product uniformity from batch to batch. In the referenced test method, the density is expressed as the weight in pounds avoirdupois of 1 U. S. gal (kilogram/litre) of the paint at a specified temperature. A calibrated weight-per-gallon cup is used. Determine density in accordance with Test Method D 1475.

6.5 **Fineness of Dispersion**—The more finely a pigment is dispersed, the more efficiently it is being used. One method for measuring the degree of dispersion (commonly referred to as “fineness of grind”) is to draw the material down a calibrated, tapered groove in a hardened steel block with the groove varying in depth from 4 to 0 mils (100 to 0 μm). The point at which continuous groupings of particles or agglom-
erates, or both, protrude through the surface of the liquid is taken as the fineness reading. Lower readings in mils or micrometres or higher readings in Hegman units indicate better fineness of dispersion. Determine fineness of dispersion in accordance with Test Method D 1210.

6.6 Consistency—Consistency is important, relating to application and flow, and should fall within a range agreed upon. In the referenced test method, consistency is defined as the load in grams required to produce a specified rate of shear. Determine consistency in accordance with Test Method D 562.

6.7 Absorption—The referenced method provides a rapid determination of the relative penetration of the binder into a porous surface. It provides a rough measure of the wetting and penetrating properties of liquid materials. Loss of binder and the resultant change in pigment volume concentration as the film dries, are indicated by the test. Determine absorption in accordance with Method 4421 of Federal Test Method Standard No. 141.

6.8 Flash Point—When the flash point of a material is required for shipping information, use Test Methods D 93, Part B, or D 3278.

7. Paint Application and Film Formation

7.1 Application of Brushed Films—Brushed films should be smooth and free from seeds, color streaking, and brush marks. Test application of a brushed film in accordance with Method 2141.1 of Federal Test Method Standard No. 141.

7.2 Brushing Properties—The specified method covers a means for determining the brushing properties of coatings. The test is quite subjective; however, someone experienced in the art can produce quite consistent results, particularly in the determination of “drag” qualities. Floor paints are generally applied to horizontal surfaces but evaluation on vertical surfaces may be necessary to determine performance on stair risers, railings, posts, etc. Determine the brushing properties in accordance with Method 4321.1 of Federal Test Method Standard No. 141.

7.3 Roller Coating Properties—Floor enamels are frequently applied by roller. The referenced method outlines a procedure for making an evaluation of a material’s characteristics when applied by a roller. Determine roller coating properties in accordance with Method 4335 of Federal Test Method Standard No. 141.

7.4 Drying Properties—The drying time of a floor paint is important in determining when a freshly painted floor or stair may be subjected to traffic. Slow drying of the film may result in dust pickup, poor appearance, and, if used on an exterior surface, rain or dew may cause a nonuniform appearance. The test can also be used to determine whether or not the drying properties of the paint have changed during storage in the container. Determine drying time in accordance with Test Method D 1640.

7.5 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 leveling characteristics in accordance with Test Method D 2801.

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

8. Appearance of The Dry Film

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

8.2 Color Differences of Opaque Materials by Instrumental Evaluation—Color difference between a product and the standard can be measured by instrument. Generally the tolerance is agreed upon between the purchaser and the seller. The referenced method covers the instrumental determination of small color differences, observable in daylight illumination, between nonfluorescent, nonmetameric, opaque surfaces such as paint specimens. If metamerism is suspected, visual evaluation (8.1) should be used to verify instrumental results. Conduct instrumental evaluation of color difference in accordance with Method D 2244.

8.3 Gloss—Floor enamels generally have a high initial 60-deg gloss reading when first applied. Determine the specular gloss in accordance with Test Methods D 523 or D 1471.

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

9. Properties of the Dry Film

9.1 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. Determine abrasion resistance in accordance with Test Methods D 658 or D 968.

9.2 Elongation—Elongation is a measure of the flexibility of paint films. Determining elongation in accordance with Test Methods D 1737 or D 522.

9.3 Adhesion—Adhesion is the property of the film which resists removal from the substrate when scuffed or scraped. It is an important property in a floor paint. Determine adhesion in accordance with Test Methods D 2197.

9.4 Resistance to Chemicals—An important property of a floor paint is its ability to resist spotting, softening, or removal when subjected to household chemicals or strong
cleaners. Determine resistance to chemicals in accordance with Test Method D 1308.

9.5 Exterior Exposure—If the paint is intended for use on porches, decks, or outside stairways and railings, tests for resistance to exterior exposure may be required.

9.5.1 Conducting Exterior Exposures—In conducting exterior exposures, refer to Practice D 1006 or Test Method D 1014.

9.5.2 Wood Panel Description—In establishing exposure performance, use the panels as described in Specification D 358.

9.5.3 Chalk Resistance—Determine the chalk-resistance rating by reference to Method D 659.

9.5.4 Checking Resistance—Determine the checking resistance rating by reference to Test Method D 660.

9.5.5 Cracking Resistance—Determine the cracking resistance rating by reference to Test Method D 661.

9.5.6 Erosion Resistance—Determine the erosion resistance rating by reference to Test Method D 662.

9.5.7 Flaking Resistance—Determine the flaking resistance rating by reference to Test Method D 772.

10. Analysis of Paint

10.1 Chemical Analysis—If a specification requires certain raw materials or certain components in a given amount then chemical analysis is required. Chemical analysis determines whether the specified components are present and if they are, in what amounts. It does not necessarily establish paint quality which can also be greatly affected by manufacturing techniques. No single schematic analysis is comprehensive enough to cover the wide variety of floor enamel composition.

10.2 Volatile Content—The percent of volatile matter indicates the thinner loss from the film as it dries. This quantity subtracted from 100% gives the nonvolatile content. Determine the volatile content in accordance with Test Method D 2369.

10.3 Pigment Content—Pigment gives the hiding and color and influences many other properties of a coating. Determine the percent pigment in accordance with Test Method D 2371.

10.4 Pigment Analysis—The analysis of pigment may be required if the product is covered by a specification, or if it is agreed between the purchaser and the seller. Analyze the pigment in accordance with selected test procedures from Method D 215 and other appropriate ASTM Test methods.

10.5 Identification of Vehicle Solids—The type of nonvolatile vehicle used in a coating has a great influence on its properties. The referenced test method gives a procedure for identifying the main components of the binder. Determine the identity of the vehicle solids in accordance with Method D 2621.

10.6 Identification of Oils—The composition of the nonvolatile vehicle can, if desired, be further broken down into the types of oils present. Determine the identity of oils in accordance with Method D 2245.
Standard Test Methods for Evaluating the Lightfastness and Weatherability of Printed Matter

This standard is issued under the fixed designation D 3424; 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 (e) indicates an editorial change since the last revision or reapproval.

1. Scope

1.1 These test methods cover the determination of the lightfastness and weatherability of printed matter under the following seven conditions, of which two involve exposure to natural daylight and five involve accelerated procedures in the laboratory:

1.1.1 Test Method 1—Daylight behind window glass,
1.1.2 Test Method 2—Outdoor weathering,
1.1.3 Test Method 3—Xenon-arc lamp with filters to simulate daylight behind window glass,
1.1.4 Test Method 4—Xenon-arc lamp with water spray and filters to simulate outdoor weathering,
1.1.5 Test Method 5—Enclosed carbon-arc lamp without water spray,
1.1.6 Test Method 6—Enclosed carbon-arc lamps with water spray, and
1.1.7 Test Method 7—Fluorescent lamp apparatus to simulate indoor fluorescent lighting in combination with window-filtered daylight.

1.2 Color changes due to conditions of exposure may be evaluated by visual examination or instrumental measurement.

1.3 These test methods are applicable to prints on any flat substrate including paper, cardboard, metallic foil, metal plate, and plastic film, and are produced by any printing process including letterpress, offset lithography, flexography, gravure, and silk screen.

1.4 This standard does not purport to address all of the safety problems, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use. For specific hazard statements, see Section 8.

2. Referenced Documents

2.1 ASTM Standards:
D1729 Practice for Visual Evaluation of Color Differences of Opaque Materials
D2244 Test Method for Calculation of Color Differences from Instrumentally Measured Color Coordinates
D2616 Test Method for Evaluation of Visual Color Differences with a Gray Scale

D4302 Specification for Artists' Oils, Resin Oil, and Alkyd Paints
D4674 Test Method for Accelerated Testing for Color Stability of Plastics Exposed to Indoor Fluorescent Lighting and Window-Filtered Daylight
D5067 Specification for Artists' Watercolor Paints
D5098 Specification for Artists' Acrylic Emulsion Paints
E284 Terminology of Appearance
E991 Practice for Color Measurement of Fluorescent Specimens
E284 Terminology of Appearance
E991 Practice for Color Measurement of Fluorescent Specimens
E1331 Test Method for Reflectance Factor and Color by Spectrophotometry Using Hemispherical Geometry
E1347 Test Method for Color and Color Difference Measurements of Object-Color Specimens by Tristimulus (Filter) Colorimetry
E1349 Test Method for Reflectance Factor and Color by Spectrophotometry Using Bidirectional Geometry
G7 Practice for Atmospheric Environmental Exposure Testing of Nonmetallic Materials
G23 Practice for Operating Light-Exposure Apparatus (Carbon-Arc Type) With and Without Water for Exposure of Nonmetallic Materials
G24 Practice for Conducting Natural Light Exposures Under Glass
G26 Practice for Operating Light-Exposure Apparatus (Xenon-Arc Type) With and Without Water for Exposure of Nonmetallic Materials

2.2 ANSI Standard:
PH.2.30 for Graphic Arts and Photography—Color Prints, Transparencies and Photomechanical Reproductions, Viewing Conditions

3. Terminology

3.1 Definitions relating to color attributes and color differences are covered in Practice D 1729 and Test Method D 2244. Other appearance terms used in these test methods are defined in Terminology E 284.

3.1.1 radiant exposure, H, n—time integral of the irradiance at a given point over a specified time interval.

3.1.1.1 Discussion—Radiant exposure is usually a spectral quantity, with units of joules per square metre per
4. Summary of Test Methods

4.1 Printed specimens are subjected to exposure conditions appropriate to the end-use application, or as agreed upon between the producer and the user. The durations of exposure may be specified in terms of time or ultraviolet radiant exposure.

4.2 The color changes of the exposed prints are evaluated visually or instrumentally versus either an exposed reference standard, an unexposed control, or the same specimen prior to exposure.

4.3 Typical endpoints are the color change relative to that of a reference standard, the color change after a specified duration of exposure, or the duration of exposure required to produce a predetermined color difference.

5. Significance and Use

5.1 Lightfastness or weatherability for specified periods of time is pertinent for certain types of printed matter such as magazine and book covers, posters and billboards, greeting cards and packages. Since the ability of printed matter to withstand color changes is a function of the spectral-power distribution of the light source to which it is exposed, it is important that lightfastness be assessed under conditions appropriate to the end-use application.

5.2 The accelerated procedures covered in these test methods provide means for the rapid evaluation of lightfastness or weatherability under laboratory conditions. Test results are useful for specification acceptance between producer and user and for quality control.

5.2.1 The xenon-arc lamp with an appropriate filter system exhibits a spectral-power distribution that corresponds more closely to that of daylight than the carbon-arc. In turn, accelerated tests using xenon-arc apparatus may be expected to correlate better with exposure to natural daylight than do those using carbon-arc apparatus.

5.2.2 Exploratory studies demonstrated that the fluorescent-lamp apparatus ranked a series of 16 printed specimens in nearly the same order as did fluorescent lighting prevailing in cooperating laboratories.

5.3 To accommodate variations in light intensity among days, seasons, locations, or instruments, duration of exposure is preferably expressed as the cumulative ultraviolet radiant exposure rather than time. In cases where radiant exposure is not monitored, a mutually agreeable reference standard should be included in the exposure tests.

5.4 Color changes are not a linear function of duration of exposure. The preferred method of determining lightfastness or weatherability is to expose the prints for a number of intervals and to assess the radiant exposure required to obtain a specified color difference.

5.5 For a given printing ink, lightfastness and weatherability or both depend on the type of substrate, the film thickness on the print, and the area printed (solid versus screen). Therefore, it is important that the nature of the test specimens correspond to that expected under actual use conditions.

Note 1—Specifications D 4302, D 5067, and D 5098 provide useful guides to the lightfastness of pigments in several types of artists' paints after 1260 MJ/m² total radiant exposure (equivalent to about 2 or 3 months' exposure to daylight behind glass). However, because of major differences between printing inks and artists' colors, especially in applied film thickness, it cannot be assumed that the lightfastness categories of printed ink films containing these pigments will be comparable to those indicated in the three specifications.

6. Apparatus

6.1 Exposure Apparatus:

6.1.1 Test Method 1 Daylight Behind Window Glass—Outdoor exposure cabinet conforming to Method A of Practice G 24. The cabinet is covered with window glass that transmits typically less than 3.5 % at wavelengths shorter than 310 nm. Accessories include a mutually agreeable radiometer* (for example, 295 to 385 nm), and humidity and temperature recorders.

6.1.2 Test Method 2 Outdoor Weathering—Outdoor exposure rack conforming to Practice G 7. Accessories are the same as in 6.1.1 with the addition of a wetness meter and rain gage.

6.1.3 Test Methods 3 and 4 Xenon-Arc—Xenon-arc lamp apparatus of the water-cooled or air-cooled type conforming to Practice G 26. An alternative air-cooled apparatus is described in Annex 1. According to Practice G 26, the water-cooled apparatus is equipped with a borosilicate/soda lime filter system to simulate natural daylight filtered through window glass for Test Method 3 or with a borosilicate filter system to simulate the spectral-power distribution of unfiltered natural daylight for Test Method 4. Accessories include a narrow-band radiometer* (340 ± 1.0 nm) for water-cooled apparatus or a broad-band radiometer** (for example, 300 to 400 nm) for air-cooled apparatus, black-panel and air temperature thermometers, humidity recorder, and specimen holders.

6.1.4 Test Methods 5 and 6 Enclosed Carbon-Arc—For Test Method 5, single enclosed carbon-arc apparatus type D, DH, H or HH (the second H indicates humidity control) conforming to Practice G 23. For Test Method 6, twin enclosed carbon-arc Type D or DH conforming to Practice G 23. Accessories include glass globes, carbons, specimen holders, and a black-panel thermometer unit.

6.1.5 Test Method 7 Fluorescent-Lamp Apparatus—Exposure cabinet conforming to Test Method D 4674. The cabinet is constructed of UV reflective aluminum with a clear chromatic conversion coating, and the light source is a combination of very high-output cool white fluorescent lamps and soda lime glass-filtered fluorescent UV sunlamps. Accessories include a broad-band detector (250 to 400 nm)

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* The most popular radiometer in the United States is Model TUVR, available from Eppley Laboratories, 12 Sheffield Ave., Newport, RI 02840. It monitors in the wavelength range 295 to 385 nm, which accounts for about 80 % of the solar UV irradiance between 300 and 400 nm. A radiometer that measures a narrow spectral band may also be used.

** Modern devices are equipped with a built-in radiometer calibrated for use in the instrument in which it is installed. Proper radiometers for older equipment are available from the manufacturer.
and a temperature sensing device.

6.2 Apparatus for Print Evaluation:
6.2.1 Standard Daylight, (for visual evaluation), preferably a D50 light source conforming to ANSI Standard PH 2.30.

6.2.2 Gray Scale Chart and Masks, (optional, for visual evaluation) conforming to Test Method D 2616.

6.2.3 Color Measuring Instrument, (for instrumental evaluation), such as a spectrophotometer conforming to Test Method E 1331 or E 1349, or a tristimulus colorimeter conforming to Test Method E 1347, or, if the specimens are fluorescent, to Practice E 991.

7. Materials
7.1 Reference Standard, (optional), such as a printed specimen or other mutually agreeable comparative control or standard reference material; alternatively, AATCC Blue Wool Lightfastness Standards in accordance with Practices G 23 or G 26.

7.2 Mounting Material, such as light-weight card stock, on which to mount non-rigid specimens (paper, plastic, or foil) during exposure tests.

7.3 Masking Material, (optional), such as white card stock, aluminum foil, or other opaque material with a non-UV-reflecting surface.

7.4 Unprinted Stock, (optional), identical to that used for the printed specimens.

7.5 Backing Material, (for use during instrument measurements on nonopaque specimens), such as several sheets of the unprinted stock, a standard white (card) stock, or a spare calibration standard.

8. Hazards
8.1 Precaution: Never look directly at sunlight or the operating light source of an accelerated apparatus unless wearing UV protective eyewear.

8.2 Newer accelerated apparatus are equipped with safety switches that turn the lamps off prior to gaining access. Users of very old carbon-arc apparatus must be certain to turn the switch off before opening the test chamber door.

8.3 Users of carbon-arc apparatus are cautioned that burning carbon rods become very hot. After the device is turned off, wait at least 15 min for the arcs to cool, and wear canvas or other protective work gloves when changing the rods. Avoid inhaling ash dust.

9. Test Specimens
9.1 These test methods do not cover preparation of printed specimens. The substrate, method of printing, and ink film thickness shall be consistent with the anticipated end use, or as mutually agreed upon between the producer and the user.

9.2 It may be useful to include the unprinted substrate and a vehicle print in exposure tests so as to determine the contribution of paper or vehicle yellowing to color changes.

9.3 Unless otherwise agreed upon, at least two specimens are to be exposed at each set of test conditions. The test specimens shall be of uniform color, gloss, and texture; clean and free of fingerprints. For purposes of intercomparison of results, all substrates and print areas should be identical, and the film thickness uniform and equal within the application tolerances.

NOTE 2: Caution—When handling test specimens, be careful not to contaminate the surface by touching with fingers.

9.4 For visual evaluation, the specimen size indicated in Practice D 1729 is a minimum of 3 ½ by 6½ in. (90 by 165 mm). For instrumental evaluation, the specimen must be large enough to cover the specimen port; a minimum size of 1¼ in.² (35 mm²) is satisfactory for many instruments. In the case of samples intended for xenon-lamp or carbon-arc exposure, the specimens should be of sufficient dimensions to be accommodated in the specimen holders.

9.5 If unexposed controls are specified, prepare them in the following manner:

(1) For visually evaluated tests, set aside a replicate print or cut off a segment of suitable size; store in a dark dry place.

(2) For instrumentally evaluated tests, make color measurements on the relevant specimen area(s) prior to exposure; see 11.3.1 and 11.3.2.

9.6 Mount nonrigid specimens onto cardstock. If masking is specified, make certain that the size of each exposed area conforms to 9.4. Place specimens intended for xenon-lamp or carbon-arc exposure in specimen holders; provide a sufficient number of blanks so as to fill the specimen rack.

10. Procedures for Light and Weather Exposure
10.1 Expose the test specimens in the apparatus and under the conditions agreed upon between the producer and the user. When conditions have not been specified, use the following guidelines:

TEST METHOD 1 DAYLIGHT BEHIND WINDOW GLASS
10.1.1 Common commercial exposure sites are southern Florida (a high humidity area) and Arizona (a low humidity area).

Note 4—Either site averages about 0.5 MJ/m² of total ultraviolet radiation under glass per day.

10.1.2 Mount the specimens under glass on open racks at an angle of 45° facing the equator.

10.1.3 Monitor cumulative ultraviolet radiant exposure of the glass-filtered daylight (for example, 295 to 385 nm, little of which will be below 310 nm), relative humidity, and air temperature, in accordance with Practice G 24.

TEST METHOD 2 OUTDOOR WEATHERING
10.2.1 Commercial sites are the same as in 10.1.1.

Note 5—Either site averages about 1 MJ/m² of total ultraviolet radiation per day.

10.2.2 Mount the specimens on a rack faced with unpaired plywood at an angle of 45° facing the equator.

10.2.3 Monitor ultraviolet radiation exposure (for example, 295 to 385 nm), relative humidity, air temperature, hours of wetness, and total rain fall in accordance with Practice G 7.
TEST METHOD 3 XENON-ARC LAMP WITH FILTERS TO SIMULATE DAYLIGHT BEHIND WINDOW GLASS

Note 6—The instructions for Test Methods 3 and 4 refer to the xenon-arc apparatus described in Practice G 26. The apparatus described in Annex 1 may also be used.

10.3.1 Install the xenon-arc and the appropriate filter system and set up the apparatus to operate by Method C in Practice G 26 “Continuous Exposure to Light Without Spray”. Alternatively, see Note 6.

10.3.2 Set the irradiance level. Unless otherwise specified, the suggested minimum is 0.35 watts per square metre per unit wavelength (W/m²/nm) at 340 nm for water-cooled xenon-arc devices, or 70 W/m² over the 300 to 400 nm range of the radiometer used in air-cooled devices. Because of differences in the number of burners used or the technique used, or both, to measure and control irradiance in water-cooled and air-cooled xenon arc devices, do not expect equivalent results between exposures in these devices. When using older model devices without irradiance control, periodically increase the wattage to the lamp according to the schedule outlined in Practice G 26. Make sure to use the schedule appropriate to the wattage of the xenon burner used.

Note 7—The irradiance level used in xenon-arc exposure tests can affect test results. Since exposure to apparently equal amounts of radiant exposure (total UV) in water-cooled and air-cooled apparatus may not produce equivalent results, it is important that the exposure device and irradiance level be agreed upon prior to conducting xenon-arc tests.

10.3.3 Set the black-panel temperature to 63 ± 3°C (145 ± 5°F), and, in apparatus capable of controlling humidity, the relative humidity to 40 ± 5%.

10.3.4 Fill the rack with mounted specimens and blanks, making sure that the specimens face the lamp.

10.3.5 Monitor the cumulative radiant exposure in either the narrow or broad band ultraviolet region.

10.3.6 Reposition the specimens after specified intervals in accordance with Practice G 26.

TEST METHOD 4 XENON-ARC LAMP WITH WATER SPRAY AND FILTERS TO SIMULATE OUTDOOR WEATHERING

10.4.1 Install the xenon-arc and the appropriate filter system and set up the apparatus by Method A in Practice G 26 “Continuous Exposure to Light and Intermittent Exposure to Water Spray”. Alternatively, see Note 6. Unless otherwise specified, use a cycle of 102 min of light followed by 18 min of light and water spray.

10.4.2 Set the irradiance level. Unless otherwise specified, the suggested minimum is 0.40 W/m²/nm at 340 nm for water-cooled xenon-arc devices or 80 W/m² over the 300 to 400 nm range of the radiometer used in air-cooled devices (see 10.3.2 and Note 7).

10.4.3 Same as in 10.3.3 to 10.3.6.

TEST METHOD 5 ENCLOSED CARBON ARC WITHOUT WATER SPRAY

10.5.1 Set up the carbon-arc apparatus to operate by Method 3 in Practice G 23 “Continuous Exposure to Light Without Water Spray”.

10.5.2 Set the black-panel temperature to 63 ± 3°C (145 ± 5°F), and in apparatus with humidity control, the relative humidity to 40 ± 5%.

10.5.3 Fill the rack with mounted specimens and blanks, making sure that the specimens face the lamp.

10.5.4 Insert new carbons and clean the globe after each 20 to 22 h of operation. See specific hazards in 8.2 and 8.3. Reposition the specimens daily in accordance with Practice G 23.

TEST METHOD 6 ENCLOSED CARBON-ARC WITH WATER SPRAY

10.6.1 Set up the carbon-arc apparatus to operate by Method 1 in Practice G 23 “Continuous Exposure to Light and Intermittent Exposure to Water Spray”. Unless otherwise specified, use a cycle of 102 min of light followed by 18 min of light and water spray.

10.6.2 Same as 10.5.2, 10.5.3, and 10.5.4.

TEST METHOD 7 FLUORESCENT LAMP APPARATUS

10.7.1 Load the specimen trays and perform other steps in accordance with the Procedure Section in Test Method D 4674. Select the ultraviolet actinic exposure (UVAE) value equal to 1000 Wh/m² for specimens of poor lightfastness and 2000 for specimens of reasonably good lightfastness.

10.7.2 Reposition the specimen in accordance with Test Method D 4674 at time intervals equal to 25 ± 5% of the total test time.

11. Evaluations

11.1 Exposed Samples Evaluation:

11.1.1 After one or more mutually agreeable intervals, remove the test specimens from the exposure apparatus, make visual (see 11.2) or instrumental evaluations (see 11.3), and, if further exposure is required, return the specimen to the apparatus in a rotated order, when specified. The exposure intervals may be as follows:

11.1.1.1 Specific duration(s) of time,

11.1.1.2 Specific duration(s) of ultraviolet radiant exposure (if measured), and

11.1.1.3 A number of intervals (time or ultraviolet radiant exposure) spanning that required to obtain a predetermined color change.

11.2 Visual Evaluation:

11.2.1 In order to facilitate direct comparisons, it may be necessary to trim off the unprinted paper border and the unexposed part of the print, if any, on the longer side of the exposed specimens.

11.2.2 Using standard daylight, preferably the D 50 light source specified in ANSI PH 2.30, examine the specimens in accordance with Practice D 1729. Compare the exposed specimens with the exposed reference standard (if available) or the unexposed control. If the gray scale is used, follow the procedure in Test Method D 2616.

11.2.3 Where there is a perceptible color difference, note the nature of the changes in accordance with Practice D 1729, for example, turns lighter, darker, greener, redder, bluer, or yellower.

11.3 Instrumental Evaluation:

11.3.1 Set the spectrophotometer or colorimeter for the largest area of view or illumination that can accommodate the respective specimens, and standardize according to Test Methods E 1331, E 1347, or E 1349. If the test substrate is
not completely opaque, provide a background as suggested in 7.5.

11.3.2 Make measurements as prescribed in Test Methods E 1331, E 1347, or E 1349 using either the CIE 1964 (10') Supplementary Standard Observer and Standard Illuminant D65, or the CIE 1931 (2') Standard Observer and Standard Illuminant C, as long as the same basis is consistently used. If hemispherical geometry is used, the specular component may be either included or excluded as long as the same condition is consistently used. Make the measurements on each specimen prior to exposure (see 9.5), each exposed specimen and, if available, the unexposed and exposed reference standard. Make a minimum of three measurements per specimen, moving or rotating the specimen between measurements.

11.3.3 Using the CIE 1976 L* a* b* equation described in Test Method D 2244, calculate ΔL*, Δa*, Δb*, and ΔE*ab between each exposed specimen and its unexposed counterpart.

11.3.4 (Optional) Plot ΔE*ab or other specified color difference parameter versus time or cumulative ultraviolet radiant exposure. Determine by interpolation the duration required to obtain a specified level of color difference. This approach permits the rate of color changes to be determined and lightfastness or weatherability to be more thoroughly analyzed than with tests based on a single duration.

12. Report

12.1 The report shall contain the following information:

12.1.1 Specimen identification, including the method of printing, print area (solid or halftone), and substrate,

12.1.2 Exposure apparatus and conditions as indicated in the appropriate referenced document. If a radiometer is used, include the wavelengths of light that were monitored,

12.1.3 Procedure for evaluating color changes (either visual or instrumental), and

12.1.4 The test results and whether they conformed to the specifications agreed upon between the producer and the user.

13. Precision and Bias

13.1 Precision—The precision of the procedures in these test methods is being determined.

13.2 Bias—Bias of the procedures in these test methods is being determined.

14. Keywords

14.1 accelerated exposure; carbon-arc apparatus; color difference measurements; daylight behind window glass; fluorescent lamp apparatus; gray scale; lightfastness; outdoor exposure; printed matter; printing inks; weatherfastness; xenon-arc apparatus

ANNEX

(Mandatory Information)

A1. DESCRIPTION OF A PORTABLE XENON-ARC EXPOSURE APPARATUS

A1.1 Scope

A1.1.1 This annex covers the operation and use of a small xenon-arc exposure apparatus that does not specifically meet the requirements of Practice G 26, but that has been found useful for determining the lightfastness and weatherability of printed ink films.

A1.2 Apparatus

A1.2.1 The apparatus consists of a laboratory bench-top air-cooled xenon-arc exposure device. The device contains a 1.1 kW xenon-arc lamp positioned approximately 250 mm above a horizontal specimen tray. The lamp is capable of providing spectral irradiance over a bandpass of 300 to 830 nm of 1 kW/m² uniformly distributed over a horizontal specimen area of approximately 0.5 m².

A1.2.2 The device is operated with soda lime glass filters to simulate daylight filters through window glass (Test Method 3), or with pre-aged borosilicate glass filters to simulate unfiltered daylight (Test Method 4).

A1.2.3 The lamp has a useful life of approximately 1500 h during which the spectral irradiance should not decrease by more than 15 %.

A1.2.4 A blower system is provided for cooling specimens in order to maintain the temperature of a black-panel sensor between 45 to 60°C when room temperatures are 20 to 25°C.

NOTE A1.1—The temperature of the black-panel sensor may not be identical to that of the black-panel thermometer described in Practice G 26. Since specimen temperature may influence the rate of photodegradation, exposure results should not be compared with those obtained using other types of apparatus before a correlation has been established.

A1.2.5 For Test Method 4, the specimens are wetted by immersing them in water according to a preset cycle.

A1.3 Procedure

TEST METHOD 3 XENON-ARC WITH FILTERS TO SIMULATE DAYLIGHT EXPOSURE BEHIND WINDOW GLASS

A1.3.1 Install the xenon-arc lamp and soda lime filters. Disconnect the water-immersion cycle.

A1.3.2 For units with a controlled power source, set the irradiance control dial to the 100 % setting. Set the irradiance level to 80 W/m² in the wavelength range 300 to 400 nm (see Note 7).

A1.3.3 Lay the test prints face up on the specimen tray. If necessary, use stainless steel bars to keep the specimens from being lifted up by the blower.

A1.3.4 Operate the exposure unit continuously for the
manufacturer’s specifications. Unless otherwise specified, lamps should be changed at 1500-h intervals. Filters should be cleaned and air filters cleaned or replaced whenever lamps are replaced.

TEST METHOD 4  XENON-ARC WITH WATER IMMERSION AND FILTERS TO SIMULATE OUTDOOR WEATHERING

A1.3.6 Install the xenon-arc lamp and borosilicate-type filter system in accordance with instructions from the manufacturer. Set the water immersion cycle.

A1.3.7 Same as A1.3.2 to A1.3.5 except set the irradiance level to 95 W/m² at 300 to 400 nm.
Standard Guide for Testing Solvent-Reducible Interior Semigloss Wall and Trim Enamels

This standard is issued under the fixed designation D 3425; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

NOTE—Editorial changes were made throughout, including the title, in October 1988.

1. Scope

1.1 This guide covers the selection and use of procedures for testing solvent-reducible interior wall and trim semigloss enamels. The test methods included are listed in Tables 1 and 2. All of these tests may not be required for each enamel. Selection of the test 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.

2. Referenced Documents

2.1 ASTM Standards:

D 16 Terminology Relating to Paint, Varnish, Lacquer, and Related Products
D 93 Test Methods for Flash Point by Pensky-Martens Closed Tester
D 154 Guide for Testing Varnishes
D 185 Test Methods for Coarse Particles in Pigments, Pastes, and Paints
D 344 Test Method for Relative Hiding Power of Paints by the Visual Evaluation of Brusheouts
D 522 Test Methods for Mandrel Bend Test of Attached Organic Coatings
D 523 Test Method for Specular Gloss
D 562 Test Method for Consistency of Paints Using the Stormer Viscometer
D 823 Test Methods for Producing Films of Uniform Thickness of Paint, Varnish, and Related Products on Test Panels
D 1038 Terminology Relating to Veneer and Plywood
D 1210 Test Method for Fineness of Dispersion of Pigment-Vehicle Systems
D 1212 Test Methods for Measurement of Wet Film Thickness of Organic Coatings
D 1475 Test Method for Density of Paint, Varnish, Lacquer, and Related Products
D 1543 Test Method for Color Permanence of White Architectural Enamels
D 1554 Terminology Relating to Wood-Base Fiber and Particle Panel Materials
D 1640 Test Methods for Drying, Curing, or Film Formation of Organic Coatings at Room Temperature
D 1729 Practice for Visual Evaluation of Color Differences of Opaque Materials
D 1737 Test Method for Elongation of Attached Organic Coatings with Cylindrical Mandrel Apparatus
D 2196 Test Methods for Rheological Properties of Non-Newtonian Materials by Rotational (Brookfield) Viscometer
D 2244 Test Method for Calculation of Color Differences from仪mentally Measured Color Coordinates
D 2369 Test Method for Volatile Content of Coatings
D 2371 Test Method for Pigment Content of Solvent-Reducible Paints
D 2697 Test Method for Volume Nonvolatile Matter in Clear or Pigmented Coatings
D 2698 Test Method for Determination of the Pigment Content of Solvent-Reducible Paints by High-Speed Centrifuging
D 2801 Test Method for Leveling Characteristics of Paint by Draw-Down Method
D 2805 Test Method for Hiding Power of Paints by Reflectometry
D 3278 Test Method for Flash Point of Liquids by Setafflash Closed-Cup Apparatus
E 97 Test Method for Directional Reflectance Factor, 45-deg 0-deg, of Opaque Specimens by Broad-Band Filter Reflectometry
E 105 Practice for Probability Sampling of Materials

2.2 U. S. Federal Test Methods Standard

1021 Sampling General
2112 Preparation of Gypsum Wallboard Panels
2131 Application of Sprayed Films
2141 Application of Brushed Films
3011.1 Condition in Container
4203.1 Reducibility and Dilution Stability

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


Discontinued; see 1989 Annual Book of ASTM Standards, Vol 06.01.

Discontinued; see 1992 Annual Book of ASTM Standards, Vol 06.01.


Available from Standardization Documents Order Desk, Bldg. 4, Section D, 700 Robbins Ave., Philadelphia, PA 19111-5094.
TABLE 1 List of Test Methods by Properties

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TABLE 2 Alphabetical List of Test Methods

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<tr>
<td>Working properties</td>
<td>7.6</td>
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<td>4541</td>
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</table>

4321.1 Brushing Properties
4401 Odor Test
4421 Absorption Test
4494 Sag Test (Multinotch Blade)
4541 Working Properties and Appearance of Dried Film
6141 Washability of Paints

3. Terminology
3.1 Definitions:
3.1.1 For definition of terms used in this guide, refer to Terminology D 16, Terminology D 1554, and Terminology D 1038.

4. Conditions Affecting Performance of Solvent-Type Interior Semigloss Wall and Trim Enamel
4.1 Performance of solvent-reducible interior semigloss wall and trim enamels may vary with:
4.1.1 Substrate, such as type and quality of drywall, plaster, wood, or hardboard.
4.1.2 Condition of substrates—presence of grease, dirt, and mold; also porosity, adhesion, and general condition of previous coating.
4.1.3 Preparation of previously painted substrates including detergent cleaning, solvent etching, and sanding.
4.1.4 Type and quality of primer or undercoat and time of application.
4.1.5 Environmental conditions, both general and specific, at the time of enamel application and immediately after application.

5. Sampling
5.1 The condition of the container prior to sampling, should be established since damage to it may cause evaporation, skimming, or other undesirable effects. Determine the condition of the enamel in accordance with 6.1 and 6.2.
5.2 Sample in accordance with Section 4.2.1 of Method.
1021 of Federal Test Method Standard No. 141. Determine the weight per gallon in accordance with Test Method D 1475. Repeat this procedure until successive readings agree within 0.1 lb (45 g) or as agreed between the purchaser and the seller. Then take samples for testing.

5.3 Specify the amount of sample, the package sizes, and identification codes to assure a representative sample. A 1-gal (4-L) sample is usually sufficient for the recommended tests but for guidance in selecting a sample plan consult Recommended Practice E 105.

6. Liquid Enamel Properties

6.1 Skinning—Enamels containing a binder, that dries by oxidation may be subject to skin formation in a partially filled can or by diffusion of air into a filled can. Since skins are insoluble in the enamel, they must be removed before use. This test in a partially filled container indicates the tendency of an enamel to skin. A typical minimum time for skinning in accordance with the referenced test method is 48 h. Examine the original sample for skins, both on the surface and in its mass. On a well-mixed, skin-free portion of the sample, perform a skinning test in accordance with Guide D 154.

6.2 Condition in Container—Thickening, settling, and separation are undesirable and objectionable if an enamel, after storage, 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. Determine the condition in the container in accordance with Method 3011.1 of Federal Test Method Standard No. 141.

6.3 Coarse Particles and Foreign Matter—Enamels must be free of oversize particles and foreign matter to form a uniform film of good appearance, a typical maximum being 0.5 weight % of total enamel. The specified test with a No. 325 (45-μm) screen gives the percent of these particles in an enamel. Determine coarse particles and foreign matter in accordance with Test Method D 185.

6.4 Weight per Gallon—The density of an enamel as measured by weight per gallon (or kilograms per litre) is used to assure product uniformity from batch to batch and provides a check against the theoretical weight calculated from the formula. The referenced test method gives a procedure for measurement of the density of an enamel. The density is expressed as weight in pounds of 1 U.S. gal (kilograms per litre) of the enamel at a specified temperature. A calibrated weight-per-gallon cup is used. Determine weight per gallon in accordance with Test Method D 1475.

6.5 Fineness of Dispersion—One method for measuring the degree of dispersion is to draw the enamel down in a tapered groove in a hardened steel block with the groove varying in depth from 4 to 0 mils (100 to 0 μm). The point at which continuous groupings of particles or agglomerates, or both, protrude through the surface of the wet film is taken as the fineness reading. Lower readings in mils or micrometres or higher readings in Hegman units indicate better dispersion. A typical fineness of dispersion requirement is a reading of 1.0 mil (25 μm) or 6 Hegman for interior semigloss wall and trim enamels. Determine fineness of dispersion in accordance with Test Method D 1210.

6.6 Odor—Some solvent combinations produce obnoxious odors, particularly when painting indoors with inadequate ventilation and under adverse temperature-humidity conditions. Test for odor in accordance with Method 4401 of Federal Test Method Standard No. 141.

6.7 Consistency—Enamels of a given type should fall within a consistency range agreed upon. In the referenced test method, consistency is defined as the load in grams required to produce a specified rate of shear. Enamels for professional painters are usually formulated at a higher consistency range than consumer enamels. A typical range is 75 to 90-Krebs unit (KU) for consumer enamels and 90 to 100 KU for professional painter enamels. Determine the consistency of the product in accordance with Test Method D 562.

6.8 Rheological Properties of Non-Newtonian Liquids—Rheological properties are related to the application and flow properties of the liquid coating. The referenced test method covers the determination of the rheological properties of an enamel and is particularly suited for use with enamels that display thixotropic characteristics. In fact, viscosity under varying conditions of time and rotational speed of the spindle is measured. Determine the rheological properties in accordance with Test Method D 2196.

6.9 Dilution Stability—The diluent suggested for reduction should be readily incorporated into the enamel without excessive stirring or shaking. This test is a measure of the stability of an enamel that has been reduced to a desired viscosity, for example, for spray application. Determine dilution stability in accordance with Method 4203 of Federal Test Method Standard No. 141.

6.10 Absorption—The referenced method provides a rapid means for measuring the relative penetration of the binder into a porous surface. It provides a rough measure of the wetting and penetrating quality of liquid materials. Loss of binder and the resultant change in pigment volume concentration, as the film dries, are indicated by this test. Determine the absorption in accordance with Method 4421 of Federal Test Method Standard No. 141.

6.11 Flash Point—Organic solvents used in enamels have characteristic temperatures at which they will support combustion. This temperature is known as the flash point. It is often used for danger classification in shipment by common carriers. It is also used to determine conditions of storage to meet fire regulations and also the safety requirements of the Occupational Safety and Health Act (OSHA). Determine the flash point in accordance with Test Methods D 93 or D 3278.

6.12 Color Compatibility—If tinting colors are not adequately compatible with enamel tint base, lighter, darker, or nonuniform shades of color will develop. Tintability of white bases with colorants of standardized tinting strength is a trade requirement. The test method shall be agreed upon between the purchaser and the seller. An ASTM test method is now being developed.

7. Enamel Application and Film Formation

7.1 Application by Brush—Brushed films should be smooth and free of seeds and on vertical surfaces should show no sagging, color streaking, or excessive brush marks. Test application of brushed films in accordance with Method 2141.1 of Federal Test Method Standard No. 141.
7.2 Application by Roller—Walls are frequently painted with rollers that produce slight stipple effects. Test roller coating properties in accordance with Method 2112 of Federal Test Method Standard No. 141.

7.3 Application by Spray—Interior paints and enamels are sometimes applied by spray. Both air and airless spray are used in commercial work. Test in accordance with Method 2131 of Federal Test Method Standard No. 141.

7.4 Drying Properties—The drying time of an enamel is determined by the composition of the enamel and by atmospheric conditions during drying. Insufficient drying may result in dirt pickup causing a poor appearance. Typical drying times are 1/3 to 2-h set-to-touch and 18-h dry-hard. The test can also be used to determine whether the enamel has lost its drying properties during storage or whether drier was included in the product at the time of manufacture. Determine the drying time in accordance with Test Methods D 1640.

7.5 Leveling Properties—Leveling is a factor in hiding and appearance of wall and trim enamels. The referenced test method covers the laboratory determination of the relative leveling characteristics of liquid coatings. Determine leveling property in accordance with Test Method D 2805.

7.6 Working Properties—Working properties of an enamel are generally compared to a standard or described by requirement in the product specification. Test working properties in accordance with Method 4541 of Federal Test Method Standard No. 141.


7.8 Wet Film Thickness—Measurement of wet film thickness is useful in calculating spreading capacity or adjusting application to an agreed square feet per gallon (or square metres per litre). Determine wet film thickness in accordance with Method D 1212.

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

8. Appearance of Dry Enamel Film

8.1 Color Difference of Opaque Materials by Visual Evaluation—Visual comparison of color is fast and often acceptable although numerical values are not obtained. The referenced practice covers the illuminating and viewing condition to be used in the visual evaluation of color differences. Determine color difference in accordance with Practice D 1729.

8.2 Color Difference of Opaque Materials by Instrument Evaluation—Color difference between a product and the standard can be measured by instrument. Generally the tolerance is agreed upon between the purchaser and the seller, and may also be required if a production specification is involved. Determine the color difference in accordance with Method D 2244.

8.3 Directional Reflectance—This property is a measure of light reflected from the surface of the enamel. It usually is assigned a value in specifications for white and pastel shades. A typical minimum reflectance value is 86 for white. Determine daylight directional reflectance in accordance with Test Method E 97.

8.4 Gloss (60-deg Specular)—Semigloss enamels are particularly sensitive to enamel hold-out of primers and undercoats. Low or uneven gloss readings are indicative of this defect. Interior semigloss enamels after drying 48 h are typically in the range from 40 to 70 when applied to glass. Gloss measurements taken after 7 days are more indicative of the final gloss of the dried film. Determine the specular gloss in accordance with Test Method D 523.

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

8.6 Color Change of White Architectural Enamels—Color permanence is an important requirement in interior white semigloss enamels. Lack of permanence is usually caused by after-yellowing. Determine color change in accordance with Test Method D 1543.

9. Properties of Dry Enamel Film

9.1 Elongation (Flexibility)—Elongation is a measure of flexibility of an enamel film. Determine elongation in accordance with Test Method D 1737 or D 522.

9.2 Washability—Washability is an important property of semigloss enamels in service. It is determined from gloss and reflectance measurements before and after removal of stains. Determine washability in accordance with Method D 6141 of Federal Test Method Standard No. 141.

10. Analysis of Enamel

10.1 Chemical Analysis—If a specification requires certain raw materials or certain components in given amount, then analysis is required. Chemical analysis is primarily a measure of uniformity. It does not necessarily establish paint quality which can also be greatly affected by manufacturing techniques. No single schematic analysis is comprehensive enough to cover the wide variety of semigloss wall and trim enamels.

10.2 Volatile Content—The percent of volatile matter indicates the thinner loss from the film as it dries. Determine volatile content of the paint in accordance with Test Method D 2369.

10.3 Pigment Content—Pigment gives the hiding and color and influences many other properties of the enamel. Determine percent pigment in accordance with Test Method D 2371.

10.4 Analysis of Pigment—The analysis of pigment may be required if the enamel is covered by a specification or if it is agreed between the purchaser and the seller. Determine
analysis of pigment in accordance with selected ASTM test methods.

10.5 Nonvolatile Content (Volume Percent)—Nonvolatile content volume percent 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 of the paint in accordance with Test Method D 2697.

The American Society for Testing and Materials takes no position respecting the validity of any patent rights asserted in connection with any item mentioned in this standard. Users of this standard are expressly advised that determination of the validity of any such patent rights, and the risk of infringement of such rights, are entirely their own responsibility.

This standard is subject to revision at any time by the responsible technical committee and must be reviewed every five years and if not revised, either reapproved or withdrawn. Your comments are invited either for revision of this standard or for additional standards and should be addressed to ASTM Headquarters. Your comments will receive careful consideration at a meeting of the responsible technical committee, which you may attend. If you feel that your comments have not received a fair hearing you should make your views known to the ASTM Committee on Standards, 1916 Race St., Philadelphia, PA 19103.
Standard Test Method for Washability Properties of Interior Architectural Coatings

This standard is issued under the fixed designation D 3450; 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 (e) indicates an editorial change since the last revision or reapproval.

1. Scope

1.1 This test method covers the determination of the relative ease of removing soilant discolorations from the dried film of an interior coating by washing with either an abrasive or nonabrasive cleaner.

1.2 This test method is limited to coatings having a CIE-Y reflectance of 60 % or more, as measured in accordance with Test Method E 97.

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

2. Referenced Documents

2.1 ASTM Standards:

D562 Test Method for Consistency of Paints Using the Stormer Viscometer
D1193 Specification for Reagent Water
D1210 Test Method for Fineness of Dispersion of Pigment-Vehicle Systems
E 70 Test Method for pH of Aqueous Solutions with the Glass Electrode
E 97 Test Method for Directional Reflectance Factor, 45-deg 0-deg, of Opaque Specimens by Broad-Band Filter Reflectometry

3. Terminology

3.1 Description of Term Specific to This Standard:

3.1.1 soilant—a discoloring substance that clings to the surface of a coating, whose dispersed color component is not in solution and therefore does not penetrate into the film.

3.1.1.1 Discussion—Soilant differs from stain in that the colorant of a stain is in solution, and therefore, can penetrate into the film.

4. Summary of Test Method

4.1 The test material is applied to a black plastic panel and allowed to dry for 7 days. The reflectance of the film is measured \( R_i \) and then a soilant consisting of carbon black dispersed in mineral oil is applied on the film. The panel is placed on a glass plate in a washability machine and the film is washed with either an abrasive or nonabrasive scrub medium for 100 cycles. The panel is rinsed and dried and the reflectance in the stained area is read \( R_s \). The ratio of the reflectance, \( R_s/R_i \), is a measure of the degree to which the soilant has been removed.

5. Significance and Use

5.1 Interior architectural paints are often discolored by dirt and other soilant materials. This test method covers the relative ease and completeness of removal of a specific soilant from such a surface by scrubbing. The greater the ease of soil removal with a minimum of film erosion, the greater the useful service life is expected to be.

5.2 Results obtained by this test method do not necessarily correlate with all types of soilants.

5.3 Semigloss finishes generally require only the non-abrasive type cleaner for good soilant removal, whereas flat paints may require the abrasive type.

6. Apparatus

6.1 Washability Tester, also referred to as washability machine.

6.1.1 Accessory Apparatus:

6.1.1.1 Glass Plate, measured to fit, 17/8 by 6/ by 1/4 in. (454 by 165 by 6.3 mm).

6.1.1.2 Stainless Steel Pan.

6.1.1.3 "C" Clamps.

6.1.1.5 White Blotter.

6.2 U-Shaped Film Caster, having both a 7-mil (0.18-mm) clearance by 132 mm width and a 10-mil (0.25-mm) clearance by 138 mm width.

6.3 Film Applicator, 3 in. (76 mm) width with 3-mil (76-μm) clearance.

6.4 Suction Plate for drawdowns (large size).

6.5 45°, 0° Reflectometer, with green filter, as specified in Test Method E 97.

6.6 Balance, with 0.1-g scale graduation.

6.7 Fineness of Dispersion Gage, as specified in Test Method D 1210.

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1 This test method is under the jurisdiction of ASTM Committee D-1 on Paint and Related Coatings and Materials and is the direct responsibility of Subcommittee D01.42 on Architectural Finishes. Current edition approved August 31, 1990. Published November 1990. Originally published as D 3450–75. Last previous edition D 3450–86.

2 Annual Book of ASTM Standards, Vol 06.01.

3 Annual Book of ASTM Standards, Vols 06.01 and 11.01.

4 Annual Book of ASTM Standards, Vol 15.05.

5 Discontinued; see 1992 Annual Book of ASTM Standards, Vol 06.01.

6 Model AG 8100, available from BYK-Gardner, Inc., Gardner Laboratory, 2435 Linden Lane, Silver Spring, MD 20910, and Model "D" available from Paul N. Gardner Company, Inc., 316 N. E. First St., Pompano Beach, FL 33060 have been found suitable for this purpose. Other straight-line washability testers may be adapted to meet the requirements of this method. See RR D01-1065.

7 The Dow film caster has been found satisfactory for this purpose and is available from BYK-Gardner.

8 Available from BYK-Gardner. An equivalent may be used.
7. Reagents and Materials

7.1 Purity of Reagents—Reagent grade chemicals shall be used in all tests. Unless otherwise indicated, it is intended that all reagents shall conform to the specifications of the Committee on Analytical Reagents of the American Chemical Society, where such specifications are available. Other grades may be used, provided it is first ascertained that the reagent is of sufficiently high purity to permit its use without lessening the accuracy of the determination.

7.2 Purity of Water—Unless otherwise indicated, reference to water shall be understood to mean reagent water conforming to Type IV of Specification D 1193.

7.3 Black Plastic Panels.10

7.4 Sponge and Holder.11

7.5 Masking Tape.

7.6 Solvent Medium,12 consisting of the following:

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<th>grams</th>
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<tr>
<td>Mineral oil, USP heavy</td>
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<td>Odorless mineral spirits</td>
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<tr>
<td>Carbon black13</td>
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</table>

7.6.1 Mix components and disperse to a Hegman fineness of 7 (0.5 mils or 13 μm) or when measured in accordance with Test Method D 1210.

7.7 Scrub Media (Note 1).

7.7.1 Nonabrasive Medium12 consisting of the following:

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<td>Water</td>
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<td>Hydroxyethyl cellulose14</td>
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<tr>
<td>Detergent15</td>
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<td>Trisodium phosphate, anhydrous</td>
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<tr>
<td>Acetic acid glacial</td>
</tr>
<tr>
<td>Preservative16</td>
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</table>

7.7.2 Abrasive Medium12, consisting of the following:

<table>
<thead>
<tr>
<th>grams</th>
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<tbody>
<tr>
<td>Water</td>
</tr>
<tr>
<td>Hydroxyethyl cellulose14</td>
</tr>
<tr>
<td>Ammonium hydroxide 28%</td>
</tr>
<tr>
<td>Detergent15</td>
</tr>
<tr>
<td>Trisodium phosphate, anhydrous</td>
</tr>
<tr>
<td>Silica17</td>
</tr>
<tr>
<td>Acetic acid, glacial</td>
</tr>
<tr>
<td>Preservative16</td>
</tr>
<tr>
<td></td>
</tr>
</tbody>
</table>

7.8 Slowly add the hydroxethyl cellulose to the water while stirring mechanically. Stir until uniform and then slowly add 2 to 3 drops of 28% ammonium hydroxide solution while mixing and continue mixing until the solution turns clear. In the order shown, add the other ingredients separately, stirring continuously. Be sure each item is uniformly dispersed before adding the next one. Add the silica slowly to ensure uniform dispersion. Finally, add the preservative and adjust the pH with glacial acetic acid.

NOTE 1—When a referee test is made, prepare fresh medium or use standardized scrub medium11 from a previously unopened container that is no more than 1 year old.

8. Preparation of Apparatus

8.1 Washability Machine—The washability machine should be leveled before use and operated at 37 ± 1 cpm; each cycle consisting of a complete forward and reverse stroke. Adjust tautness of the cables with a spring scale to approximately 5 lb.

8.2 Sponge and Holder—Add sufficient weight to the holder in the form of lead sheets or other flat weights to give a combined weight of 1500 g, including the dry sponge.

NOTE 2—Check the compression of the damp sponge under the 1500-g weight to ensure that the holder does not drag along the panel and tear the film.

9. Procedure

9.1 Clean the top of the glass plate (or preferably the suction plate) and both sides of the black plastic panel to be sure they are free of specks. Place the black panel on the plate and tape one end to the plate. Smooth the panel along the plate to ensure a close fit.

9.2 Stir the test material thoroughly and strain to remove all skins and particles. Draw down the material on the panel, starting from the taped end of the panel. For latex paints, the 10-mil (0.25-mm) side of the applicate will generally be satisfactory, whereas the 7-mil (0.18-mm) side can be used for solvent-based coatings. However, the film thickness of paint to be applied may be varied as mutually agreed upon between the purchaser and the seller. The rate of application should be fairly slow, 3 to 4 s from end to end, to prevent


10 Leneta, P-121-10N dull black plastic panels 6% by 17 in. by 10 mils (432 by 163 by 0.25 mm) in size, obtainable from the Leneta Co., P.O. Box 86, Ho-Ho-Kus, NJ are suitable for this purpose. An equivalent may be used.

11 Sponge is a cellulose type, coarse pore grade, 3% by 1½ in. (95 by 76 by 25.4 mm). Laboratory standardized stain and scrub media have been found suitable and are available from the Leneta Co., 15 Whitney Road, Mahwah, NJ 07430-3129. An equivalent may be used.

12 Printex U Beads, obtainable from Degussa Corp., 65 Challenger Road, Ridgefield Park, NJ 07660, has been found suitable for this purpose. An equivalent may be used.


14 Hydroxyethyl cellulose having a molar substitution (MS) value from 1.8 to 2.5 and a viscosity of a 2% solution in the range from 4400 to 6500 cps. Cellosize OP-4400 is available from Union Carbide Corp., P.O. Box 8720, South Charleston, WV 25303 and Natrosol 250M, available from Aqualon Co., 2711 Centerville Rd., Wilmington, DE 19850 have been found suitable for this purpose.

15 Octyl phenoxypolyethoxyethanol, as represented by Triton X-100, obtainable from Rohm & Haas Co., 2 Executive Campus, Suite 330, Cherry Hill, NJ 08002, has been found satisfactory for this purpose. An equivalent may be used.

16 1,3,5-triethyl hexahydro-sym-triazine (Vancide TH), obtainable from R. T. Vanderbilt Co., 30 Winfield St., Newport, CT 06855, has been found satisfactory. An equivalent may be used.

17 Silica No. 22, obtainable from Whittaker, Clark and Daniels, Inc., 100 Church St., New York, NY 10007, has been found satisfactory for this purpose. This silica is an amorphous grade of 99%+ silicon dioxide. Average particle size is 2.95 μm with 92% being less than 40 μm. Surface area is 7600 cm²/g, and will give a pH from 6.8 to 7.2 in reagent water. An equivalent may be used.
pinholes or holidays in the film. Air dry in a horizontal position for 7 days in a room preferably maintained at 73.5 ± 3.5°F (23 ± 2°C) and 50 ± 5% relative humidity, or under conditions mutually agreeable to the purchaser and the seller.

9.3 On the last day of drying, measure the directional reflectance (green filter) of a portion of the panel in accordance with Test Method E 97. Record this value as \( R_1 \).

9.4 After reading the reflectance, use the applicator with the 3-mil (76-μm) clearance to draw down a film of solvant perpendicular to the coating film and in the area where the reflectance was measured. Permit the stained panel to dry for 16 to 24 h under the same drying conditions specified in 9.2.

9.5 Clean the glass surface on which the test panel is to be mounted and also the back of the test panel. Attach the test panel to the glass plate and place the mounted test panel, coated side up, in the pan. Clamp the assembly securely to the pan with the “C” clamps, centering the pan so that the sponge boat can move lengthwise on the panel.

9.6 Remove the sponge from the holder and soak it in water. Wipe off excess stain outside the test area and measure reflectance in the stained area of the panel. Blot the panel and then allow to dry at room temperature. After the panel has dried thoroughly, wipe off excess stain outside the test area and measure reflectance in the soiled and washed area of the panel. Record as \( R_2 \).

9.7 Attach the sponge holder, with the sponge and cleaner face down, to the cables of the washability machine. Add 5 mL of water on the exposed face of the sponge. Stir the scrub medium and spread uniformly across the face of the sponge 10.0 ± 0.1 g of nonabrasive scrub medium. (Use a spatula if necessary, when applying the abrasive scrub medium, to apply uniformly over the sponge.)

9.8 Remove the test panel from the pan, rinse with running tap water, gently moving the palm of the hand over the path of the sponge to remove clinging particles of scrub medium. Blot the panel and then allow to dry at room temperature. After the panel has dried thoroughly, wipe off excess stain outside the test area and measure reflectance in the soiled and washed area of the panel. Record as \( R_3 \).

9.9 Repeat the test on a second panel and, for each, calculate the reflectance recovery in percent as \( (R_3/R_1) \times 100 \).

9.10 If the mean reflectance recovery for the two panels is less than 96%, repeat the test on another set of panels using the abrasive scrub medium specified in 7.7.2 and report the results with both mediums.

10. Report

10.1 Report the mean of the two determinations and the type of scrub medium used.

10.2 Report any deviations from the standard procedure.

10.3 Note if erosion occurred in the soiled area.

11. Precision and Bias

11.1 On the basis of an interlaboratory study in which operators in six laboratories tested six coatings, including solvent and water-based systems, and covering a range of pigment volume concentrations (PVC’s), the following criteria should be used for judging the acceptability of the results at the 95% confidence level:

11.1.1 Repeatability—Two results obtained by the same operator should be considered suspect if they differ by more than 1.5% in reflectance recovery with the abrasive cleaner and 9% in reflectance recovery with the nonabrasive cleaner.

11.1.2 Reproducibility—Two results, each the mean of two measurements, obtained by operators in different laboratories should be considered suspect if they differ by more than 6% in reflectance recovery with the abrasive cleaner and 25% with the nonabrasive cleaner.

11.2 Bias—The concept of bias is not applicable to this test method.

12. Keywords

12.1 soilant resistance; washability

This standard is issued under the fixed designation D 3451; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

1. Scope

1.1 These practices cover the selection and use of procedures for testing polymeric powders and powder coatings. The test methods included are listed in Table 1. Where more than one test method is listed for the same characteristic, no attempt is made to indicate superiority of one method over another. 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.

1.2 These practices describe the testing of polymeric powders as applied by electrostatic spray, fluidized bed, or any other applicable method.

1.3 These practices apply to proper and safe packaging, shipping and receiving, and storage and handling during use and application of polymeric powders.

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

2.Referenced Documents

2.1 ASTM Standards:
B 117 Test Method of Salt Spray (Fog) Testing
D 153 Test Methods for Specific Gravity of Pigments
D 522 Test Method for Mandrel Bend Test of Attached Organic Coatings
D 523 Test Method for Specular Gloss
D 609 Practice for Preparation of Cold-Rolled Steel Panels for Testing Paint, Varnish, Conversion Coatings, and Related Coating Products
D 610 Test Method for Evaluating Degree of Rusting on Painted Steel Surfaces
D 658 Test Method for Abrasion Resistance of Organic Coatings by Air Blast Abrasive
D 659 Test Method for Evaluating Degree of Chalking of Exterior Paint
D 660 Test Method for Evaluating Degree of Checking of Exterior Paint
D 661 Test Method for Evaluating Degree of Cracking of Exterior Paint
D 662 Test Method for Evaluating Degree of Erosion of Exterior Paints
D 714 Test Method for Evaluating Degree of Blistering of Paints
D 772 Test Method for Evaluating Degree of Flaking (Scaling) of Exterior Paint
D 792 Test Methods for Specific Gravity (Relative Density) and Density of Plastics by Displacement
D 870 Practice for Testing Water Resistance of Coatings Using Water Immersion
D 968 Test Methods for Abrasion Resistance of Organic Coatings by Falling Abrasive
D 1005 Test Methods for Measurement of Dry-Film Thickness of Organic Coatings Using Micrometers
D 1044 Test Method for Resistance of Transparent Plastics to Surface Abrasion
D 1186 Test Methods for Nondestructive Measurement of Dry Film Thickness of Nonmagnetic Coatings Applied to a Ferrous Base
D 1193 Specification for Reagent Water
D 1308 Test Method for the Effect of Household Chemicals on Clear and Pigmented Organic Finishes
D 1400 Test Method for Nondestructive Measurement of Dry Film Thickness of Nonconductive Coatings Applied to a Nonferrous Metal Base
D 1474 Test Methods for Indentation Hardness of Organic Coatings
D 1535 Test Method for Specifying Color by the Munsell System
D 1644 Test Methods for Nonvolatile Content of Varnishes
D 1729 Practice for Visual Evaluation of Color Differences of Opaque Materials
D 1730 Practices for Preparation of Aluminum and Aluminum-Alloy Surfaces for Painting
D 1731 Practices for Preparation of Hot-Dip Aluminum Surfaces for Painting
D 1732 Practices for Preparation of Magnesium Alloy Surfaces for Painting
D 1735 Practice for Testing Water Resistance of Coatings Using Water Fog Apparatus
D 1895 Test Methods for Apparent Density, Bulk Factor, and Pourability of Plastic Material
D 1898 Practice for Sampling of Plastics
D 1921 Test Method for Particle Size (Sieve Analysis) of Plastic Materials
D 2091 Test Method for Print Resistance of Lacquers


2 Annual Book of ASTM Standards, Vols 03.02 and 06.01.
3 Annual Book of ASTM Standards, Vol 06.03.
4 Annual Book of ASTM Standards, Vol 06.01.
5 Annual Book of ASTM Standards, Vol 06.02.
6 Annual Book of ASTM Standards, Vol 08.01.
7 Annual Book of ASTM Standards, Vols 06.01 and 11.01.
8 Annual Book of ASTM Standards, Vols 02.05 and 06.02.
9 Annual Book of ASTM Standards, Vol 08.02.
TABLE 1 List of Test Methods

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<td>8.1</td>
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<td>Vacuum sieve analysis</td>
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<td>Sonic sifter analysis</td>
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<td>Electronic counting analysis</td>
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<td>Glass vial method</td>
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<td><strong>Application Properties:</strong></td>
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<td>Efficiency of powder coating process</td>
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<td><strong>Powder Coating Properties:</strong></td>
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<td>Chip resistance</td>
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D2092 Practices for Preparation of Zinc-Coated (Galvanized) Steel Surfaces for Painting
D2197 Test Method for Adhesion of Organic Coatings by Scrape Adhesion
D2201 Test Method for Preparation of Hot-Dipped Non-passivated Galvanized Steel Panels for Testing Paint, Varnish, Lacquer, and Related Products
D2244 Test Method for Calculation of Color Differences from Instrumentally Measured Color Coordinates
D2246 Test Method for Finishes on Primed Metallic Substrates for Humidity-Thermal Cycle Cracking
D2248 Practice for Detergent Resistance of Organic Finishes
D2454 Practice for Determining the Effect of Overbaking on Organic Coatings
D2794 Test Method for Resistance of Organic Coatings to the Effects of Rapid Deformation (Impact)
D2803 Test Method for Filiform Corrosion Resistance of Organic Coatings on Metal
D3170 Test Method for Chipping Resistance of Coatings
D3359 Test Methods for Measuring Adhesion by Tape Test
E11 Specification for Wire-Cloth Sieves for Testing Purposes
E308 Method for Computing the Colors of Objects By Using the CIE System

3. Terminology

3.1 Description of Terms Specific to This Standard:
3.1.1 bulk density—mass per unit volume of a material in powder form including the air trapped between particles.
3.1.2 coating powder—finely divided particles of organic polymer, either thermoplastic or thermosetting, which generally contain pigments, fillers, and additives and which remain finely divided during storage under suitable conditions.
3.1.3 film formation from a coating powder—the forming of a continuous film by melting powder particles and coalescing them by the application of energy.

Discussion—For thermosetting materials, a chemical reaction, either condensation or addition, also takes place. For thermoplastic materials, no chemical reaction takes place. The material flows when heat is applied and develops performance properties when cooled. Flow will reoccur when reheated. Both films have the uniformity of color, toughness, and other properties associated with protective and decorative coatings. This fused film has the uniformity, color, toughness, and other properties associated with protective and decorative coatings.

3.1.4 fluidity—the ability of a powder to move freely, uniformly, and continuously (somewhat like a liquid) when subjected to certain conditions of pressure, temperature, and velocity of a carrier gas.
3.1.5 gel time—interval required at a given temperature for a powder to be transformed from a dry solid to a gel-like state.
3.1.6 particle size—average diameter of an object having
irregular boundaries that can be described in an artificial way as having a diameter.

3.1.7 particle-size distribution—arrangement of particle size measurements on a powder in groups of specified diameters.

3.1.8 pourability—the ability of a powder to flow uniformly or to be continuously poured from a container at a steady rate.

3.1.9 powder coatings—coatings which are protective or decorative, or both, formed by the application of a coating powder (3.1.2) to a substrate and fused into a continuous film by the application of heat or radiant energy.

3.1.10 storage stability—the ability of a powder to maintain uniform physical and chemical properties after being subjected to specified storage conditions.

3.1.11 volatile content—the quantity expressed as weight percent of the powder which is lost under specified conditions of temperatures and time.

3.1.12 cloud chamber technique—method of moving a charged or uncharged object through a charged or uncharged cloud of powder in an enclosed chamber.

3.1.13 electrostatic deposition—technique of moving and charging powder so that it is deposited onto an oppositely charged substrate by one of the following methods.

3.1.13.1 fluidized bed technique—method of moving a grounded object over or through a charged fluidized powder.

3.1.13.2 spray technique—method of spraying and charging powder so that it is deposited onto a grounded substrate.

3.1.14 nonelectrostatic deposition—technique of moving powder onto a substrate which may be heated above the fusion point of the powdered material.

3.1.14.1 spray technique—method of spraying powder onto a substrate which may be heated above the fusion point of the powdered material.

3.1.14.2 fluidized bed technique—method of dipping a hot object into a container holding the powder suspended in a gas stream so that it resembles a fluid and allowing the powder to melt onto the object being coated.

3.1.14.3 flame spread technique—method of applying powder using a compressed gas and melting the powder in a flame before the powder impinges on the surface.

4. General Requirements

4.1 All tests shall be made in diffused light (not direct sunlight) and at 23 ± 2°C and 50 ± 5% relative humidity, after conditioning 16 h unless otherwise specified.

5. Sampling

5.1 Sample the powder in accordance with Practice D 1898.

5.2 Prepare specimens as required for the specific tests on the coating.

6. Equipment

6.1 Use the equipment as specified in each method of test.

7. Conditions Affecting Polymeric Powder or Powder Coatings, or Both

7.1 Practical requirements and performance of powder and powder coating may vary with:

7.1.1 Substrate Type—Ferrous, nonferrous types, plastic, or elastomeric.

7.1.2 Substrate Weathering—Weathering of the substrate will probably adversely affect the performance.

7.1.3 The type, quality, and suitability of the metal treatment or primer used under the powder coating and the time before coating application.

7.1.4 Application conditions.

7.1.5 Contaminants on the surface of the substrate.

7.1.6 Damage to container, size of container, storage time, excessive temperature, and temperature fluctuations which may cause settling, caking, or chemical change.

POLYMERIC POWDER PROPERTIES

8. Particle Size and Distribution

Note 1—Technology in particle size and distribution measurement, such as laser diffraction, has been developed. Instruments are commercially available from several suppliers.

8.1 Multiple Sieve Analysis:

8.1.1 This method employs multiple sieves to determine particle sizes and their distribution. Standard 200-mm (8-in.) diameter sieves and a mechanical shaker are used. A representative quantity of the sample is sifted through a series of sieves and the amount retained on each sieve is weighed and calculated as percent of the total specimen.

8.1.2 Apparatus:

8.1.2.1 Sieves—Half-height sieves, 203.2 mm (8.0 in.) in diameter, conforming to the requirements of Specification E 11. A selection of sieves encompassing the expected range of particle sizes together with a cover and a bottom pan are required.

8.1.2.2 Mechanical Sieve Shaker with Automatic Time Switch—The mechanical sieve-shaking device shall be capable of imparting uniform rotary motion and a tapping action at the rate of 150 ± 10 taps/min.

8.1.2.3 Balance—A laboratory balance with a minimum capacity of 500 g sensitive to 0.1 g, for weighing the specimen and the residues retained on the sieves.

8.1.3 Procedure:

8.1.3.1 If the residues are not to be transferred for weighing, weigh each of the selected sieves and the bottom pan to 0.1 g. Nest the desired sieves in order of diminishing openings with the coarsest sieve on top and the pan on the bottom.

8.1.3.2 Weigh out a 100 ± 0.1-g specimen and transfer it to the top sieve of the stack.

Note 2—If necessary this test may be made on a specimen of any size from 50 to 200 g. The weight of specimen used shall be stated in the report.

8.1.3.3 Place the cover on the top sieve, and place the stack in the mechanical sieve shaker. Operate the shaker for 10 min ± 15 s.

8.1.3.4 After shaking, carefully separate the stack of sieves, beginning at the top, and weigh the quantity of material retained on each sieve and that contained in the pan to 0.1 g. This may be accomplished either by transferring the

11 Ro-Tap Sieve Shaker has been found suitable for this purpose and is available from W. S. Tyler Co., Cleveland, Ohio 44114. An equivalent may be used.
fractions to the balance or by weighing the sieve or pan and its contents, and subtracting the tare weight from the total. If the material is transferred to the balance, carefully brush the sieve on both sides to ensure that adhering particles are transferred.

8.1.3.5 Calculate the percent in each fraction as follows:

\[ \% = \left( \frac{R}{S} \right) \times 100 \]

where:

- \( R \) = residue weight, g, and
- \( S \) = specimen weight, g.

**Note**—Ordinarily there is a small loss of dust as indicated by the cumulative total weight being less than 100%. If this loss is not over 2%, the amount reported through the finest sieve shall be increased until the total of all portions of the sample equals 100%. If the cumulative total is less than 98%, repeat the test.

8.1.4 **Report**—The report shall include the following:

- 8.1.4.1 Complete identification of the sample,
- 8.1.4.2 Specimen weight,
- 8.1.4.3 Percent of material retained on each sieve,
- 8.1.4.4 If required, the total cumulative percent of material retained on each sieve and in the pan,
- 8.1.4.5 Temperature, and
- 8.1.4.6 Relative humidity.

8.2 **Vacuum Sieve Analysis**

8.2.1 **Summary of Method**:

8.2.1.1 In this method sieving is accomplished by aerodynamics so that there is no reduction in particle size and absolutely no wear on the sieves.

8.2.1.2 The housing holds a standard 203.2-mm (8.0-in.) sieve and a transparent sieve cover. A slit nozzle rotates slowly below the sieve. An air current, produced by a standard vacuum cleaner-type device, is blown upwards through a hollow shaft and the slit nozzle to the sieve, where it clears the screen. The particles thus suspended in air between the sieve and the sieve cover are separated as the air current circulates. The fine materials are blown through the sieve and into a filter bag, while the coarse materials remain on top of the sieve. A manometer indicates the vacuum inside the housing.

8.2.2 **Apparatus**:

8.2.2.1 Sieves—As described in 8.1.2.1 and transparent sieve cover.

8.2.2.2 **Vacuum Sieve Apparatus**—A vacuum sieving device\(^\text{12}\) capable of maintaining inside the housing a vacuum of 5 ± 0.05 in. (127 ± 1.27 mm) of water as measured by a manometer. The slit nozzle which rotates below the sieve shall revolve at a speed of 25 ± 2 rpm.

8.2.2.3 **Balance**—See 8.1.2.3.

8.2.3 **Procedure**:

8.2.3.1 If the residues are not to be transferred for weighing, weigh each of the selected sieves to 0.1 g.

8.2.3.2 Weigh out a 100 ± 0.1-g specimen and transfer it to one of the sieves.

8.2.3.3 Place the transparent cover on the sieve and place the sieve in position on the vacuum sieving apparatus. Operate the sieving apparatus for 5 min ± 15 s at a vacuum of 5 ± 0.5 in. (127 ± 12.7 mm) of water.

8.2.3.4 Remove the sieve and cover from the apparatus and weigh the quantity of material retained on the sieve and adhering to the cover to the nearest 0.1 g. This may be accomplished either by transferring the retained material to the balance or by weighing the sieve, cover, and contents, and subtracting the tare weight from the total. If the material is transferred to the balance carefully brush the sieve on both sides, and removed all powder from the cover to ensure that all adhering particles are transferred.

8.2.3.5 Repeat the procedure for each sieve used.

8.2.4 Calculate the percent retained on each sieve as follows:

\[ \% = \left( \frac{R}{S} \right) \times 100 \]

where:

- \( R \) = residue weight, g, and
- \( S \) = specimen weight, g.

8.2.5 **Report**—The report shall include the following:

8.2.5.1 Complete identification of the sample,

8.2.5.2 Specimen weight,

8.2.5.3 Percent of material retained on each sieve,

8.2.5.4 Temperature, and

8.2.5.5 Relative humidity.

8.3 **Sonic Sifter Analysis**

8.3.1 **Summary of Method**:

8.3.1.1 In the sonic sifter, the sieves are stationary and agitation is imparted to the particles by an oscillating column of air. Sieve wear and particle attrition are minimal.

8.3.1.2 The sonic sifter consists of a sieving chamber, a diaphragm at the top vibrating at 60 Hz, and a motor with the necessary controls. The amplitude of vibration is adjustable to the nature of the specimen.

8.3.2 **Apparatus**:

8.3.2.1 Sieves—See 8.1.2.1.

8.3.2.2 **Sonic Sifter**—A sonic sieving device\(^\text{13}\) utilizing a diaphragm vibrating at 60 Hz with controls to adjust the sift amplitude and the pulse amplitude.

8.3.2.3 **Balance**—An analytical balance with a minimum capacity of 150 g sensitive to 1 mg for weighing the specimen and the residues retained on the sieves.

8.3.3 **Procedure**:

8.3.3.1 Weigh and record the weight of each sieve, and of the collar, cover, and fines collector.

8.3.3.2 Weigh out a 2.5 ± 0.001-g specimen.

8.3.3.3 Stack the sieves in descending order, coarsest on top, finest on the bottom, and transfer the specimen to the top sieve.

8.3.3.4 Insert the sieve stack assembly in the sieve chamber and lock. Set the sift amplitude at 3 and the pulse amplitude at 10. Operate the sifter for 3 min ± 15 s.

8.3.3.5 Weigh each sieve, the fines collector, cover, and the collar, subtract the tare weight for each, and calculate the percent retained on each sieve.

---

\(^{12}\) Alpine Air Jet Sieve, Model 200, has been found suitable for this purpose and is available from Alpine American Corp., Michigan Drive, Natick, Mass. 01760. An equivalent may be used.

\(^{13}\) Model L3P Sonic Sifter has been found suitable for this purpose and is available from ATM Corp., P.O. Box 2405, Milwaukee, Wisc. 53214. An equivalent may be used.
8.4.3.3 Dispersing Medium—5 % solution of octyl phenyloxy polyethoxyethanol in reagent water.

8.4.3.4 Electrolyte—Dissolve 10.0 g of reagent grade sodium chloride (NaCl) in 1000 mL of reagent water, add some bactericide such as 70 mg of sodium trichlorophenate then filter twice through the membrane (8.4.2.5).

8.4.3.5 Wash Water—Reagent water filtered twice.

8.4.4 Procedure:

8.4.4.1 Precalibrate the aperture and electrolyte combination following the manufacturer's instruction manual.

Note 6—Calibration should be carried out using a lycopodium of microspheres suspension of 18.04-μm diameter with the half-count procedure as given in the instruction manual. It is necessary to have mutual agreement on monosized system diameters for interlaboratory comparisons.

8.4.4.2 Cone and quarter the sample until a specimen of convenient size is obtained.

8.4.4.3 Disperse the specimen by adding dispersing medium from the eye-dropper. Use gentle spuation until a pasty consistency is obtained. Pick up a small portion of this mixture (about 0.1 mL more or less depending on the particle size of the powder) on a small spatula and rinse with wash water into a 25-mL beaker containing 5 mL of dispersing medium. Place the beaker in the ultrasonic agitator for 30 s and then rinse into 200 mL of electrolyte in the 250 to 500-mL beaker. Fill the beaker to capacity and place in the counting position of the counter stand.

8.4.4.4 Fill the aperture tube with electrolyte. Check the aperture for blockage and clear with a brush if necessary. Set the instrument controls for the smallest particle appropriate for the aperture in use. Typical instrument settings are shown in Figs. 1, 2, or 3.

8.4.4.5 Take three cumulative counts with 500-μL volume manometer and calculate the mean, which should be between 2700 and 5000. If it is not, adjust the particle concentration until it is. If more powder is added, it must be treated the same as the original specimen, except it may be rinsed directly into the beaker after ultrasonic agitation. If the suspension needs dilution, drain some of the suspension through a clean glass tube while agitating and then refill the beaker with electrolyte.

8.4.4.6 Set the instrument controls for normal accumulation of differential data. Typical instrument settings are shown in Figs. 1, 2, and 3. Take three counts at each size level for averaging.

8.4.5 Precautions:

8.4.5.1 Check the aperture for blockage at the end of each count. If blocked clear the aperture with the brush and retake the count.

8.4.5.2 Adjust the sample stand stirrer motor speed to furnish sufficient agitation to maintain a uniform particle suspension but below air bubble generation speeds.

8.4.5.3 Before each analysis flush all the surfaces coming in contact with the specimen. Use clean wash water and wash bottle.

8.4.6 Treatment of Result:

8.4.6.1 The values obtained in 8.4.4.6 represent relative
volume of the particles between two particle size levels. They may be plotted directly on semilog graph paper as a histogram (see Fig. 4).

8.4.6.2 The values obtained in 8.4.6.1 may be added cumulatively. All of these cumulative values may then be normalized to 100 % and a cumulative volume percent curve drawn (see Fig. 4).

8.4.6.3 Relative volume and relative weight are interchangeable if a constant density of the particle system is assumed. Therefore, the curves in 8.4.6.1 and 8.4.6.2 can be interpreted as weight histogram and weight percent curves.

9. Package Stability

9.1 Glass Vial Method:

9.1.1 Apparatus:

9.1.1.1 Aluminum-Foil Disk.

9.1.1.2 Steel Shot.

9.1.1.3 Glass Vial, 4-oz (120-ml), approximately 40-mm inside diameter.

9.1.1.4 Balance, sensitive to 0.1 mg.

9.1.1.5 Oven, maintained at 50 ± 0.5°C unless otherwise agreed upon between the purchaser and the seller.

9.1.1.6 Particle Size Determination Apparatus—See Section 8.

9.1.1.7 Powder Coating Application Apparatus—See 19.2.

9.1.2 Procedure:

9.1.2.1 Weigh 45 g or as otherwise specified of powder into the glass vial. Place an aluminum-foil disk on top of the powder. Prepare a sufficient number of glass vials for determining sprayability and other properties that may be tested.

9.1.2.2 Weigh 150 g of steel shot onto the disk and seal the vial. Place the vial in an oven maintained at 50 ± 0.5°C unless otherwise agreed upon between the purchaser and the seller.

9.1.2.3 At 24-h intervals perform the following tests until failure or as agreed upon between the purchaser and the seller.

(a) Particle size and particle size distribution (see Section 8).

(b) Gel time (see Section 14).

(c) Spray a panel of the powder coating and bake as specified. Compare with a panel prepared with unheated powder.

(d) If there is noticeable caking, test for pourability by Method D 1895.

9.1.3 Report:

9.1.3.1 Duration of test and storage oven temperature,
FIG. 2 Model "T" Typical Worksheet

9.1.3.2 Particle size distribution before and after testing.
9.1.3.3 Gel time before and after testing.
9.1.3.4 General appearance of panels coated with aged and unaged powders, and
9.1.3.5 Degree of caking.

9.2 Package Stability (Moisture):
9.2.1 Open-Dish Method—Weigh 10 g of powder into an uncovered 50-mm diameter aluminum dish and place at 40 ± 3°C, 95 ± 5% relative humidity, or conditions as agreed upon between the purchaser and the seller. Check for caking or change of gel time after 48 h.

10. Pourability
10.1 Test for pourability in accordance with Test Method D 1895.

11. Fluidity
11.1 A method of determination is under consideration.
12. Nonvolatile Content

12.1 Apparatus:

12.1.1 Analytical Balance, sensitive to 0.1 mg.

12.1.2 Aluminum Dishes, 60 mm in diameter and 17 mm deep.

12.2 Procedure:

12.2.1 Weigh two aluminum dishes to 0.1 mg and weigh by difference two specimens of 1.9 to 2.1 g or as otherwise specified of coating powder into them.

12.2.2 By gentle tilting spread the powder uniformly over the bottom of the dishes.

12.2.3 Heat the dishes and contents in an oven for 2 h at 60 ± 2°C or at 100 ± 2°C or at the temperature specified between the purchaser and the seller. Cool in a desiccator and weigh.

12.3 Calculation—Calculate the nonvolatile content as follows:

\[
\text{Nonvolatile content, weight } \% = \frac{(C - A) 	imes 100}{S}
\]

---

### FIG. 3 Model TA and TAI Typical Worksheet

<table>
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<tr>
<th>Geometric Mean μ</th>
<th>Volume μ</th>
<th>Diameter μ</th>
<th>Channel (W)</th>
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<td>0.198</td>
<td></td>
</tr>
<tr>
<td>0.0115</td>
<td>0.008181</td>
<td>0.250</td>
<td></td>
</tr>
<tr>
<td>0.0231</td>
<td>0.01636</td>
<td>0.315</td>
<td></td>
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<tr>
<td>0.0462</td>
<td>0.02272</td>
<td>0.397</td>
<td></td>
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<tr>
<td>0.0929</td>
<td>0.06545</td>
<td>0.500</td>
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<tr>
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<td>24.88 × 10⁶</td>
<td>17.59 × 10⁶</td>
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<td>49.75 × 10⁶</td>
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<td>99.50 × 10⁶</td>
<td>70.27 × 10⁶</td>
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<td>199.0 × 10⁶</td>
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<tr>
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<td>281.1 × 10⁶</td>
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<tr>
<td>796.0 × 10⁶</td>
<td>562.2 × 10⁶</td>
<td>1024.</td>
<td></td>
</tr>
</tbody>
</table>

Note—Typical setting for smallest particle (8.4.4.4). Cumulative count data readout required for (8.4.4.5).
where:
\[ A = \text{weight of dish, g}, \]
\[ S = \text{weight of specimen, g}, \] and
\[ C = \text{weight of dish and contents after heating, g}. \]

13. Volatile Content at Baking or Fusion Temperature

13.1 Use the apparatus and procedure given in Section 12 but heat the specimen at the normal baking temperature and time unless otherwise specified.

13.2 Calculate the percent volatile matter by subtracting the nonvolatile content from 100.

14. Gel Time or Stroke Curve (for Thermosetting Powders Only)

14.1 Apparatus:
14.1.1 Hot Plate, capable of operating at temperatures of 200°C.
14.1.2 Stop Watch or Electric Timer, 0.1 s interval.
14.1.3 Wooden Tongue Depressor, 6 by 1 in. (150 by 25 mm) or Wooden Splints, 6 by \( \frac{1}{4} \) in. (150 by 6 mm).
14.1.4 Aluminum Foil.
14.1.5 Analytic Balance.
14.1.6 Pyrometer, capable of measuring temperatures to 200°C.

14.2 Procedure:
14.2.1 Measure 0.5 ± 0.1 g of powder.
14.2.2 Cover the hot plate with aluminum foil or use a non-silicon mold release lubricant. Set the heat to 190 ± 1°C or as agreed between the purchaser and seller, and check with the pyrometer.

NOTE 7—A shroud may be required to prevent air circulation from cooling the hot plate.

14.2.3 Drop the powder specimen on the foil and start the timer. Rub the powder with the edge of the tongue depressor in 1 in. (25 mm) diameter circular strokes. Continue this motion with slight pressure until a solid gel is produced as found by lifting the depressor at least 2 in. (50 mm) from the hot plate. If the material produces a continuous filament from the plate to the depressor it has not gelled.
14.2.4 Stop the timer when the strand breaks readily. Repeat the test with a fresh specimen. Calculate and report the mean gel time.

15. Melting Point Determination

15.1 Apparatus:
15.1.1 Kofler Hot Bench, hot bench agreed upon be-
15.1.2 Calibrating Test Substances:

Melting Point, °C

- Azobenzene: 68 ± 1
- Naphthalene: 80 ± 0.5
- Benzoic acid: 122 ± 1

15.2 Procedure:

15.2.1 Calibrate the apparatus as follows. Allow 60 min for the warm up of the heating bar. Sprinkle a calibrating substance having the closest melting point to that of the powder on the heating bar. Observe the sharp division between solid and liquid. Place the pointer between these two divisions. Slide the reading device to the melting point of the calibrating substance.

15.2.2 Sprinkle the specimen over the heating bar in a uniform manner. Observe the specimen after 1 to 2 min. Brush the material towards the lower temperature and note the location where particles of powder adhere to the bar when brushed lightly. Place the pointer at this point. Read the temperature and report in degrees Celsius.

NOTE 8—Powder will fuse and “set” on the hot bar. Remove the powder quickly and thoroughly before the setting occurs. Do not use abrasives to clean the bar.

16. Viscosity Measurement for Molten Powder Coatings by Weissenberg Rheogoniometer

16.1 Summary of Method—This method covers the determination of the viscosity of powder coatings at baking temperatures and consists simply of preheating the cone and plate of a Weissenberg rheogoniometer, pouring an adequate sample of powder onto the plate, closing the apparatus and recording revolutions per minute and the corresponding steady torque transducer deflection.

16.2 Apparatus—Weissenberg rheogoniometer with at least capability for constant-speed rotational shear, high-temperature electric oven, and cone and plate shearing surfaces.

16.3 Procedure:

16.3.1 By consulting the rheogoniometer instruction manual, select the cone, plate, and torsion wire adequate to measure the largest anticipated viscosity in no more than 10 min.

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19 Weissenberg Rheogoniometer is available from Diano Corp., Midwest Technical Center, 1966 Production Dr, Louisville, KY 40299.

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s. After alignment of the cone and plate, use the electric oven to bring them to the baking temperature of the coating (as agreed upon between the purchaser and the seller), or to a few degrees above that temperature.

16.3.2 As quickly as possible, with the air bearing functioning, open the oven, raise the cone a few inches, pour sufficient powder to fill the volume between the cone and the plate onto the center of the plate, and lower the cone sufficiently to close the oven. Continue to lower the cone until the proper gap between the cone and plate, as specified by the manufacturer of the rheogoniometer, has been reached.

16.3.3 Start the plate rotating at 1 to 5 rpm, with the torque transducer at the largest possible full-scale setting. Caution—Stop the plate rotation if the full-scale torque is exceeded since this may damage the instrument. Start again at a lower rpm. Record torque reading at this rpm. At several lower rotational speeds, record rpm, steady torque reading and the ratio of torque to rpm until the ratio of these two becomes essentially constant, indicating a low shear rate Newtonian (constant viscosity) behavior.

16.3.4 If lack of sensitivity prevents measurements at low shear rates, repeat the above procedure with a more sensitive torsion wire. If there is no low shear rate Newtonian region evident, the powder may be crosslinking or increasing in viscosity because of loss of volatiles. Repeated measurements on the same specimen at a given shear rate should indicate this. Several measurements made quickly at very low shear rates on fresh specimens may allow calculation of viscosities before crosslinking or volatile loss causes a significant change.

16.4 Report—The viscosity and shear rate values obtained, the value of the low shear rate Newtonian viscosity and the temperature at which the test was conducted.

16.5 Precision—Repeatability and reproducibility of viscosity readings at any given shear rate should be within 10% relative. However, sample age and storage history may well affect the results obtained.

17. Inclined Plate Flow Test

17.1 Apparatus:

17.1.1 Constant-Temperature Convection Electric Oven, thermostatically controlled to maintain temperature of 150 ± 2°C or as agreed upon between the purchaser and the seller.

17.1.2 Metal Plate Rack Assembly, 8 by 11 in. (203 by 280 mm) that fits into inner oven chamber and is capable of being maintained in either a horizontal position or at a 65°-deg angle by means of an exterior lever.

17.1.3 Tin Plate Panel, 8 by 11 in. (203 by 280 mm).

17.1.4 Analytical Balance, sensitive to 1.0 mg.

17.1.5 Steel Pellet Mold Press and knockout rod to make pellets 0.25 in. (6 mm) thick by 0.50-in. (12.7-mm) diameter.

17.1.6 Stop Watch.

17.1.7 Steel Rule.

17.2 Procedure:

17.2.1 Weigh out 0.50 g of coating powder and transfer to the steel pellet mold. Press to 0.25-in. (6-mm) thickness and push the pellet out of the mold with the knockout.

17.2.2 Place the pellet on a tin plate panel in a ½-in. circle scribed or marked on the panel.

17.2.3 Place the panel holding the pellet(s) on the metal rack assembly in the oven in a horizontal position. Close the oven door quickly. Allow the assembly to remain in the horizontal position for 3 min.

17.2.4 Tilt the rack assembly holding the panel to 65° from the horizontal without opening the oven door and allowing the oven to cool. Allow the rack and panel to remain in this position for 30 min.

17.2.5 After 30 min remove the panel from the oven and allow to cool to room temperature. Measure the amount of flow from the original diameter and line scribed on the panel.

17.3 Report—Maximum flow in millimetres from the original diameter.

Note 9—A control pellet if possible of known reactivity and flow should be run in each test. Sample material should be stored in sealed polyethylene bags prior to use and likewise pressed pellets should be stored in a desiccator or sealed bags to prevent moisture absorption.

Note 10—The 0.5-g charge should be sufficient for most powders with a cured specific gravity of 1.1 to 1.4. For denser powder, it may be necessary to increase the pellet weight. If so, this should be recorded as a variance in specimen size.

18. Density and Specific Gravity

18.1 Apparent Density—Determine in accordance with Method A of Test Method D 1895.

18.2 Bulk Factor—Determine in accordance with Test Method D 1895.

18.3 Specific Gravity—Determine in accordance with Test Methods D 153 or D 792 or as follows.

18.3.1 In place of the pycnometer, a weight-per-gallon cup may be substituted. Because of its wide opening, the cup allows ready transfer of powder without loss. In addition the powder can be more readily wet with kerosine (or other suitable carrier agreed upon between the purchaser and the seller) by thorough use of a glass stirrer to remove the entrapped air. Care must be exercised to return any powder particles adhering to the glass rod to the weight-per-gallon cup to ensure accuracy of the method.

APPLICATION PROPERTIES

19. Determining the Relative Deposition Efficiency of Organic Polymeric Powders on Moving Targets

19.1 Summary of Method—The method essentially consists of spraying powder at a known flow rate on a number of similarly shaped targets moving at a known rate past a powder spraying device mounted in a spray booth.

19.2 Apparatus:

19.2.1 Set of Targets, consisting of 15 flat steel panels 6 by 36 by 0.063 in. (152 by 915 by 1.6 mm) wrapped in aluminum foil. (Use other targets as agreed upon between the purchaser and the seller.) The panels should have holes drilled at one end for hanging from a conveyor. The aluminum foil should be of the lowest possible temper and should be 13¼ by 37 by 0.0015 in. (340 by 940 by 0.04 mm)
(these characteristics have been found to be the best for easy wrapping of the panels). Other tempers, thicknesses, and dimensions may be used, however (for example, regular commercial aluminum foil is satisfactory).

19.2.2 Fifteen Target Hangers constructed so that the targets will hang from the conveyor in one plane within ±½ in. (±13 mm) with the flat surfaces perpendicular to the source of the powder spray. The target hangers should be long enough so the source of the powder spray can be pointed at the center of the targets.

19.2.3 Powder Flowmeter, consisting of a vacuum cleaner attached to a small vacuum chamber (powder receiver) constructed as shown in Fig. 5.

19.2.4 Balance, sensitive to 100 mg.

19.2.5 Balance, sensitive to 1 mg.

19.2.6 Stop Watch, accurate and readable to ½ s.

19.2.7 Powder Spray System.

19.3 Procedure:

19.3.1 Cut the number of aluminum-foil wrappings necessary for the desired number of tests and number (with a felt tip pen, grease pencil, etc.) on one corner. If the available balance can weigh the entire target, weigh the panels with the aluminum-foil wrappings. If the balance cannot weigh the entire target, weigh the aluminum-foil wrappings alone.

Record the numbers and corresponding weights.

19.3.2 Wrap the targets with the foil. The best method of doing this is simply to lay the foil on a flat surface with the numbered side down. Place the target on the foil so that it is centered on the foil and ½ to 1 in. (13 to 25 mm) from the long edge of the foil. For convenience, the top of the target (where the hanger holes are) should be at the numbered end of the foil wrap. Fold the ½ to 1-in. (13 to 25-mm) piece of foil over the edge of the target, creasing it firmly. Then turn the panel over so that it wraps the foil around itself, and crease the new edge firmly. Then turn the panel over again (this will fold the remaining foil over) and crease it firmly.

19.3.3 Determine the conveyor speed by measuring the distance between two points on the conveyor track at least 10 ft (3.05 m) apart and by measuring, with the stop watch, the time it takes a location on the conveyor chain to travel the distance between the two points. If possible, adjust the conveyor speed to as close to 10 ft/min as possible (±2%).

19.3.4 If possible, hang the 15 targets on the conveyor on 12-in. (305 mm) centers far enough ahead of the spray booth to allow the conveyor to come up to speed (at least 1 min travel) or for this test, 10 ft (3.05 m).

19.3.5 Break up any powder agglomerates in the powder by mixing or sieving before adding to the powder hopper. Determine the powder flow by first weighing the vacuum cleaner bag with the balance and then installing it in the bag chamber. The vacuum cleaner bag alignment holes should go on the alignment pins on the bag chamber. Install the cover on the bag chamber (simply place on bag chamber). Start the vacuum cleaner and adjust the damper so that very little air is felt moving through the hole in the cover (vacuum in the vacuum bag should be 0.3 to 0.7 in. (8 to 17 mm) of water, vacuum in the flowmeter should be 1.5 to 2.5 in. (38 to 64 mm) of water).

19.3.6 Insert the powder spray device into the opening in the top of the powder flowmeter and turn on the dust collector. Turn on the powder spraying device for 30 or 60 s. (Caution—Be sure high voltage is turned off or, if that is not possible, at the lowest possible adjustment), measuring the time with the stop watch. Disassemble the powder flowmeter and reweigh the vacuum cleaner bag on the balance. The increase in weight divided by the time the powder was flowing is the rate of powder flow. The powder in the vacuum cleaner bag can be recovered simply by tearing the bag in half and dumping the powder in the booth or hopper.

19.3.7 Adjust the powder flow, if possible, to 300 g/min ± 5 % by successive process changes. Also adjust or record, or both, all the process variables possible including the following:

19.3.7.1 The powder and its state of use,

19.3.7.2 The particle size distribution if available,

19.3.7.3 The high-voltage power supply output potential and output current,

19.3.7.4 The resistor in the gun,

19.3.7.5 The potential of the powder gun’s charging tip,

19.3.7.6 The distance between the target and the charging tip,

19.3.7.7 The pattern adjustment mechanism (measure such things as the relative locations of the parts),

19.3.7.8 The conveyor speed,

19.3.7.9 The powder flow,

19.3.7.10 The powder collector system air flow or some pressure which changes as a function of air flow only,

19.3.7.11 The powder transfer air flow and air pressure,

19.3.7.12 The powder quantity control pressure or whatever variable controls this,

19.3.7.13 For fluidized beds; air flow, air pressure, the amount of powder, and bed depth,

19.3.7.14 Other variables such as vortex air, dosing air, powder density air, pattern air, etc, and

19.3.7.15 The atmospheric variables: temperature, barometric pressure, and humidity.

19.3.8 Mount and level the powder spray device in the spray booth so that it is aimed at the centers of the targets as they pass. Position it so that its charging tip is 8 ± ½ in. (203 ± 13 mm) from the plane in which the targets will pass.

19.3.9 Turn on the powder flow, adjust the high voltage to 60 ± 1 kV (use other voltages as agreed upon between the purchaser and the seller), turn on the powder collection system, etc. Start the conveyor and spray the targets after all other systems seem to be operating normally and powder is spraying into the spray booth.

19.3.10 After spraying the targets, stop the conveyor and remove the targets, taking care not to knock or jar the powder off of them. If it is desired to cure the powder, place the targets in an oven for the time and temperature recommended for the specific powder being used. This is also an excellent time to determine the weight percent retained after curing the powder. Weigh 1 g of powder in a preweighed 5-in. (127-mm) diameter aluminum foil “pan.” Place this in the oven along with the targets.

19.3.11 After curing, remove the targets from the oven and pull the aluminum foil down 1 to 2 ft (305 to 610 mm) as soon as possible using thick workman’s gloves. This facilitates the final removal of the aluminum foil because the coated foil tends to contract slightly with cooling and become very difficult to remove when cool enough to handle. If necessary, also remove the pan of powder from the
oven. After they are reasonably cool, remove the aluminum-foil wrappings, if they are to be weighed alone.

19.3.12 Weigh the center 11 targets or aluminum wrappings from the center 11 targets excluding the two targets on each end of the target set. (The end targets are excluded because they tend to collect excessive amounts of powder relative to the other targets.) Determine the amount of powder added to each target. If necessary, weigh the pan of powder and determine the weight percent retained. If the powder was not cured, the targets may be blown off and then wiped off to prepare them for the next test.

19.3.13 Calculate the mean weight of powder deposited. Calculate the percent deposition efficiency using the following equation:

\[ \% E = \frac{(\overline{W_p} \times V_c \times 10000)}{(D_T \times Q_p \times \% R)} \]

where:
- \( \% E \) = percent deposition efficiency,
- \( \overline{W_p} \) = mean powder deposition, g,
- \( V_c \) = conveyor speed cm/min,
- \( D_T \) = distance between target centers, cm,
- \( Q_p \) = powder flow, g/min, and
- \( \% R \) = percent by weight powder retained after curing (100 % if not cured).

19.3.14 To determine the variation in application of the coating, calculate the coefficient of variation using the following equation:

\[ V = \left( \frac{\sum W_p^2 - n \overline{W_p}^2}{n - 1} \right)^{1/2} \overline{W_p} \]

where:
- \( V \) = coefficient of variation %,
- \( W_p \) = weight of powder on a foil wrapping, g,
- \( n \) = number of targets used (11), and
- \( \overline{W_p} \) = mean powder deposition, g.

19.3.14.1 If the coefficient of variation exceeds 10 % it indicates that the powder cloud is fluctuating excessively. This is usually due to poor (slugging) powder pump operation, sometimes to unstable booth air flow profiles, and sometimes to unstable air flow patterns created by spray gun powder cloud control system.

19.3.15 Repeat the above procedure until two consecutive results agree within ±10 %. Use the set of conditions under which these results were obtained as a standard to which to relate future work. It is wise to run the test within the standard conditions at the beginning and end of each day. If results do not agree within ±10 % the day's work should be suspect. Results will vary from day to day and even during the day due to variables beyond the user's control. Long-term variations may even be as large as 50 %. Tests run with different powders or under different conditions should have the results reported in terms of the standard test results. For example, if the efficiency results under the standard conditions were 50 % with one powder and 75 % with another powder, the second powder would be 50 % more efficient than the first powder.

19.4 Report:

19.4.1 Report the variables and their values as recorded for 19.3.7. Report the percent deposition efficiency and its coefficient of variation, the percent efficiency compared to the average percent efficiency obtained using the standard conditions on the day of the test.

19.5 Precision—Deposition efficiency results should be repeatable within ±10 % during a day.

PHYSICAL PROPERTIES OF POWDER COATING

20. Panel Preparation

20.1 Treatment of the Substrate—Clean and prepare test panels in accordance with one of the following standard test methods or recommended practices or as agreed upon between the purchaser and the seller:

- 20.1.1 Method D 609.
- 20.1.2 Practices D 1730.
- 20.1.3 Practices D 1731.
- 20.1.4 Practices D 1732.
- 20.1.5 Practices D 2092.
- 20.1.6 Test Method D 2201.

20.2 Priming and Sealing—In many instances, the use of a primer, primer surfacer or sealer is required. The type, application, and treatment of any undercoat system should be agreed upon between the purchaser and the seller.

20.3 Application of Powder Coatings—The coatings may be applied by fluidized bed, electrostatic spray, or other methods.

20.4 Curing of Powder Coatings:

20.4.1 Fuse or bake the powder coating to a uniform film according to the established schedule and temperature and age as agreed upon between the purchaser and the seller before running tests.

20.4.2 The powder coating should be overbaked to determine the time/temperature effect on the physical and chemical properties in accordance with Practice D 2454.

20.5 Measurement of Film Thickness—Since the properties of a powder coating can vary considerably with its thickness, it is important to know the film thickness. Measure the film thickness in accordance with Test Method D 1005, D 1186, or D 1400.

21. Abrasion Resistance

21.1 Determine the abrasion resistance in accordance with Test Method D 658, D 968, or D 1044.

22. Adhesion

22.1 The powder coatings of a specified thickness and over a specified substrate as agreed upon between the purchaser and the seller is subjected to an adhesion test to determine the degree of attachment the coating has to the substrate.

22.2 Determine the adhesion of the powder coating to the specified substrate in accordance with Test Methods D 2197 or D 3359.

23. Chemical Resistance

23.1 Coating systems frequently come into contact with various chemicals which may have an effect on the properties of the system. Failure, when it occurs, is usually in the form of discoloration, change in gloss, blistering, softening, swelling, or loss of adhesion.

23.2 Household Chemical Resistance—Determine the effect of chemicals in accordance with Test Method D 1308.

23.3 Detergent Resistance—Determine the resistance to
22. Impact Resistance

32.1 Films formed from powder coatings may be subject to sudden impact in certain end uses. Determine impact resistance in accordance with Test Method D 2794.

33. Outdoor Exposures

33.1 While the accelerated tests given elsewhere in this recommended practice are intended to enable prediction of probable performance, actual outdoor exposures should be made on coatings intended for exterior use. Usage of paint systems is so varied that no one set of conditions (length or place of exposure) can be given in this practice to cover all situations. These conditions as well as the type of substrate, substrate preparation, etc., should be agreed upon between the purchaser and the seller. However, it is suggested that unless otherwise agreed upon, panels for outdoor exposure should be prepared in accordance with Section 20 of this practice.

33.2 Many properties of powder coating films should be evaluated periodically throughout the outdoor exposure period. These properties may be evaluated as follows:

33.2.1 Blistering—Test Method D 714.
33.2.2 Chalking—Test Method D 659.
33.2.3 Checking—Test Method D 660.
33.2.4 Cracking—Test Method D 661.
33.2.5 Rusting—Test Method D 610.
33.2.6 Erosion—Test Method D 662.
33.2.7 Flaking—Test Method D 772.

34. Print Resistance

34.1 A print test may be used to determine the degree of thermoplasticity or solvent retention of a film and hence whether the product can be safely stacked or packaged and, in the case of a thermoplastic film, at what temperature the film prints or mars. The print test can also determine the degree of marring due to pressure.

34.2 Determine the imprinting and thermoplasticity of a powder coating film in accordance with Test Method D 2091.

35. Salt Spray Resistance

35.1 Salt spray testing of coatings may be helpful in determining their resistance to failure in service under conditions of high humidity and salt concentrations. Under the accelerated conditions of the laboratory test the temperature, pH, concentration of the salt solution and other physical parameters can be controlled. The selection of the substrate, the coating system, the manner in which the coating is scribed, the location or position of the panels within the cabinet, the length of the test, the inspection of panels and the method of reporting results must be agreed upon between the purchaser and the seller.

35.2 Test for salt spray resistance in accordance with Test Method D 2091.

36. Water Resistance

36.1 Testing of coating systems with water is helpful in determining their resistance to failure under conditions of high humidity or water immersion. Failure in water tests is usually evidenced by blistering, dulling, softening, or loss of adhesion which does not disappear or recover upon evaporation of the absorbed water.
36.2 Determine the resistance to failure under conditions of high humidity in accordance with Practice D 1735.
36.3 Determine the resistance to failure under conditions of water immersion in accordance with Practice D 870. This test is best suited for coating systems that will actually be soaked in water during service.

37. Safety and Handling Precautions

37.1 This recommended practice covers the safe packaging, shipping, receiving, storage, and handling during use and application of organic powders used for protective and decorative coatings. Procedures for handling large and small volumes of powder are included.
37.2 Where required, attention shall be directed to ecological aspects and pertinent Occupational Safety and Health Administration (OSHA) regulations.
37.3 Packaging:
37.3.1 Container—For small and medium operations, containers designed to give moisture protection, such as plastic-lined boxes or drums, should be used.
37.3.2 Labeling—All containers should be clearly identified as to type material, color, batch number, and date of manufacture. Each shipment must be accompanied by Material Safety Data Sheets (MSDS).
37.4 Shipping and Receiving:
37.4.1 Palletizing—Containers should be palletized in a manner to avoid crushing or packing.
37.4.2 Bulk Shipment—Large shipments should be handled in a manner agreeable to the purchaser and the seller. Precautions should be taken to avoid hard packing or caking of the powder.
37.5 Storage:
37.5.1 All containers must be sealed when not in use.
37.5.2 Temperature and relative humidity during storage should not exceed 80°F (27°C) and 50%, respectively, or as specified on the label.
37.6 Precautions in Handling and Application:
37.6.1 All metal equipment must be properly grounded.
37.6.2 The fluid bed must be cleaned periodically to ensure proper operation.
37.6.3 Under certain conditions organic powders may be subject to dust explosions. Trade association bulletins such as the National Fire Protection Association Bulletins No. 33, Spray Finishing and No. 654, Dust Explosion Prevention—Plastics Industry, may be helpful in identifying conditions and minimizing their occurrences.
37.6.4 Spraying:
37.6.4.1 Spray booths, dust collectors, and ducts should be built with smooth surfaces to facilitate cleaning. If possible, surfaces should be of a material to which the powder will not stick.
37.6.4.2 During nonoperating periods all equipment should be flushed with air or the manufacturer's recommended procedure should be followed.
37.6.5 Blending—If reclaimed or recycled powder is to be blended with virgin material, a suitable device for sifting, drying, and blending should be used.
37.6.6 Dust Collection and Ventilation—All handling and application equipment should be fitted with a suitable dust collector and filter system.
37.6.7 Suitable electrical grounding is required. Precautions are necessary to ensure ratio of powder to air are held below or above the explosive mixture.
37.7 Ecology:
37.7.1 Exhaust stacks should be equipped with dust collectors or absorbers or both to avoid air pollution.
37.7.2 Waste Disposal—Powder must be disposed of in the manner governed by local laws and regulations.
37.8 OSHA Requirements:
37.8.1 Operator Safety—All personnel should be equipped with suitable air masks, gloves, and any other specified devices for personal protection.

38. Data Report
38.1 The report shall include the following:
38.1.1 Complete identification of the powder coating material tested,
38.1.2 Description of specimens, including numbers, preparation method, and thickness of coating,
38.1.3 Temperature of test if other than specified by test method,
38.1.4 Type and manufacture of test equipment,
38.1.5 All specific information called for on the individual test method report,
38.1.6 Test results as calculated or observed values on the basis of data, median or mean value, and
38.1.7 Date of test.

39. Keywords
39.1 polymeric powders; organic powder coatings

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