



Designation: D3451 – 06 (Reapproved 2017)

## Standard Guide for Testing Coating Powders and Powder Coatings<sup>1</sup>

This standard is issued under the fixed designation D3451; 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 ( $\epsilon$ ) indicates an editorial change since the last revision or reapproval.

### 1. Scope

1.1 This guide covers the selection and use of procedures for testing coating 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 This guide also refers to methods developed specifically for the coating powder industry by the Powder Coating Institute, PCI, and the International Organization for Standards, ISO.

1.3 This guide describes the testing of coating powders as applied by electrostatic spray, fluidized bed, or any other applicable method.

1.4 The values stated in SI units are to be regarded as standard. No other units of measurement are included in this standard.

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

1.6 *This international standard was developed in accordance with internationally recognized principles on standardization established in the Decision on Principles for the Development of International Standards, Guides and Recommendations issued by the World Trade Organization Technical Barriers to Trade (TBT) Committee.*

### 2. Referenced Documents

#### 2.1 ASTM Standards:<sup>2</sup>

[B117 Practice for Operating Salt Spray \(Fog\) Apparatus](#)

<sup>1</sup> This guide is under the jurisdiction of ASTM Committee D01 on Paint and Related Coatings, Materials, and Applications and is the direct responsibility of Subcommittee D01.51 on Powder Coatings.

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

- [D522 Test Methods for Mandrel Bend Test of Attached Organic Coatings](#)
- [D523 Test Method for Specular Gloss](#)
- [D609 Practice for Preparation of Cold-Rolled Steel Panels for Testing Paint, Varnish, Conversion Coatings, and Related Coating Products](#)
- [D610 Practice for Evaluating Degree of Rusting on Painted Steel Surfaces](#)
- [D658 Test Method for Abrasion Resistance of Organic Coatings by Air Blast Abrasive \(Withdrawn 1996\)<sup>3</sup>](#)
- [D660 Test Method for Evaluating Degree of Checking of Exterior Paints](#)
- [D661 Test Method for Evaluating Degree of Cracking of Exterior Paints](#)
- [D662 Test Method for Evaluating Degree of Erosion of Exterior Paints](#)
- [D714 Test Method for Evaluating Degree of Blistering of Paints](#)
- [D772 Test Method for Evaluating Degree of Flaking \(Scaling\) of Exterior Paints](#)
- [D822 Practice for Filtered Open-Flame Carbon-Arc Exposures of Paint and Related Coatings](#)
- [D870 Practice for Testing Water Resistance of Coatings Using Water Immersion](#)
- [D968 Test Methods for Abrasion Resistance of Organic Coatings by Falling Abrasive](#)
- [D1005 Test Method for Measurement of Dry-Film Thickness of Organic Coatings Using Micrometers](#)
- [D1014 Practice for Conducting Exterior Exposure Tests of Paints and Coatings on Metal Substrates](#)
- [D1308 Test Method for Effect of Household Chemicals on Clear and Pigmented Organic Finishes](#)
- [D1474 Test Methods for Indentation Hardness of Organic Coatings](#)
- [D1535 Practice for Specifying Color by the Munsell System](#)
- [D1654 Test Method for Evaluation of Painted or Coated Specimens Subjected to Corrosive Environments](#)
- [D1729 Practice for Visual Appraisal of Colors and Color Differences of Diffusely-Illuminated Opaque Materials](#)
- [D1730 Practices for Preparation of Aluminum and Aluminum-Alloy Surfaces for Painting](#)

<sup>3</sup> The last approved version of this historical standard is referenced on [www.astm.org](http://www.astm.org).

**TABLE 1 List of Test Methods**

	Section	ASTM Method	PCI Procedure	ISO
<b>Coating Powder Properties:</b>				
Sampling	6	D1898		8130-9
Compatibility	9		#2	8130-12
Lower explosion limit	10			8130-4
Particle size and distribution	11.2	D5861		
Multiple sieve and analysis	11.4.1	D1921, E11		8130-13
Accelerated storage stability	12			
Glass vial method	12.2		#1	8130-8
Pourability	13	D1895		8130-5
Fluidity	14			
Cured weight loss for thermosetting coating powders	15		#9	8130-7
Gel time (stroke cure)	16	D4217	#6	8130-6
Flow test (incline method)	17	D4242	#7	8130-11
Specific gravity	18	D5965	#4	8130-2; 8130-3
Melting point determination	19			
<b>Application Properties:</b>				
Deposition/transfer efficiency of powder coating process	20			8130-10
<b>Powder Coating Properties:</b>				
Abrasion resistance	22			
Air blast abrasion tester	22.2	D658		
Falling sand method	22.2	D968		
Taber abraser	22.2	D4060		
Adhesion	23			
Tape adhesion	23.2	D3359		
Chemical resistance	24			
Household chemical resistance	24.2	D1308		
Detergent resistance	24.3	D2248		
Acid resistance	24.4	D3260		
Stains or reagents on wood substrates	24.5	D3023		
Chip resistance	25			
Gravelmeter	25.2	D3170		
Corner coverage	26.2	D2967		
Elongation (flexibility)	27			
Conical/cylindrical mandrel	27.2	D522		
T-Bend	27.2	D4145		
Film thickness	21.5			
Nonmagnetic coatings on ferrous metals		D7091		
Nonmagnetic, nonconductive coatings on non-ferrous metals		D7091		
On nonmetal base		D6132		
Destructive method		D1005		
Hardness	28			
Pencil	28.2	D3363		
Knoop Indention	28.3	D1474		
Impact resistance	29	D2794		
Molting/blocking resistance	30	D3003		
On Metal substrates	30.2	D3003		
In Wood substrates	30.3	D2793		
Print resistance	31	D2091		
Optical properties	32			
Guide To:	32.1	D5382		
Color pigmented coatings	32.2			
Visual	32.2.2	D1535		
Instrumental	32.3.3	D2244, E308, E1164, E1331, E1345, E1347, E1349		
Color difference	32.3			
Visual	32.3.2	D1535, D1729, D2244		
Instrumental	32.3.3	D2244, E308, E1164, E1331, E1345, E1347, E1349		
Metamerism (visual)	32.4.1	D4086		
Distinction of image (DOI)	32.5.1	D5767, E430		
Hiding power/opacity	32.6.2	D6441	#3	
Gloss	32.7.2	D523		
Surface profile (orange peel)	32.8.2			
Color/Gloss/Texture Standards	32.9			
Preparation, Maintenance, and Distribution	32.9.1			
Tolerances	32.9.2	D5531		
Outdoor exposure (natural)	32.9.3	D3134		
Adhesion	33	D1014, D4141		
Adhesion	33.2.1	D3359		
Blistering	33.2.2	D714		
Chalking	33.2.3	D4214		
Checking	33.2.4	D660		
Cracking	33.2.5	D661		

**TABLE 1** *Continued*

	Section	ASTM Method	PCI Procedure	ISO
Rusting	33.2.6	D610		
Erosion	33.2.7	D662		
Flaking	33.2.8	D772		
Gloss	33.2.9	D523		
Color	33.2.10	D1729, D2244, D4086		
Accelerated artificial weathering	34.3	D822, D4587, D5031, D6695, G141, G147, G151, G152, G153, G154, G155		
Accelerated environmental exposures	35			
Filiform corrosion	35.2.1	D2803		
Salt spray	35.2.2	B117		
SCAB corrosion	35.2.3			
Water resistance	35.2.4			
High humidity/100 % humidity	35.2.4.1	D1735, D2247		
Condensation	35.2.4.2	D4585		
Water immersion	35.2.4.3	D870		

- [D1731](#) Practices for Preparation of Hot-Dip Aluminum Surfaces for Painting
- [D1732](#) Practices for Preparation of Magnesium Alloy Surfaces for Painting
- [D1735](#) Practice for Testing Water Resistance of Coatings Using Water Fog Apparatus
- [D1895](#) Test Methods for Apparent Density, Bulk Factor, and Pourability of Plastic Materials
- [D1898](#) Practice for Sampling of Plastics (Withdrawn 1998)<sup>3</sup>
- [D1921](#) Test Methods for Particle Size (Sieve Analysis) of Plastic Materials
- [D2091](#) Test Method for Print Resistance of Lacquers
- [D2092](#) Guide for Preparation of Zinc-Coated (Galvanized) Steel Surfaces for Painting (Withdrawn 2008)<sup>3</sup>
- [D2201](#) Practice for Preparation of Zinc-Coated and Zinc-Alloy-Coated Steel Panels for Testing Paint and Related Coating Products
- [D2244](#) Practice for Calculation of Color Tolerances and Color Differences from Instrumentally Measured Color Coordinates
- [D2247](#) Practice for Testing Water Resistance of Coatings in 100 % Relative Humidity
- [D2248](#) Practice for Detergent Resistance of Organic Finishes
- [D2369](#) Test Method for Volatile Content of Coatings
- [D2454](#) Practice for Determining the Effect of Overbaking on Organic Coatings
- [D2616](#) Test Method for Evaluation of Visual Color Difference With a Gray Scale
- [D2793](#) Test Method for Block Resistance of Organic Coatings on Wood Panel Substrates
- [D2794](#) Test Method for Resistance of Organic Coatings to the Effects of Rapid Deformation (Impact)
- [D2803](#) Guide for Testing Filiform Corrosion Resistance of Organic Coatings on Metal
- [D2967](#) Test Method for Corner Coverage of Powder Coatings
- [D3003](#) Test Method for Pressure Mottling and Blocking Resistance of Organic Coatings on Metal Substrates
- [D3023](#) Practice for Determination of Resistance of Factory-Applied Coatings on Wood Products to Stains and Reagents
- [D3134](#) Practice for Establishing Color and Gloss Tolerances
- [D3170](#) Test Method for Chipping Resistance of Coatings
- [D3260](#) Test Method for Acid and Mortar Resistance of Factory-Applied Clear Coatings on Extruded Aluminum Products
- [D3359](#) Test Methods for Rating Adhesion by Tape Test
- [D3363](#) Test Method for Film Hardness by Pencil Test
- [D3960](#) Practice for Determining Volatile Organic Compound (VOC) Content of Paints and Related Coatings
- [D4017](#) Test Method for Water in Paints and Paint Materials by Karl Fischer Method
- [D4060](#) Test Method for Abrasion Resistance of Organic Coatings by the Taber Abraser
- [D4086](#) Practice for Visual Evaluation of Metamerism
- [D4141](#) Practice for Conducting Black Box and Solar Concentrating Exposures of Coatings
- [D4145](#) Test Method for Coating Flexibility of Prepainted Sheet
- [D4214](#) Test Methods for Evaluating the Degree of Chalking of Exterior Paint Films
- [D4217](#) Test Method for Gel Time of Thermosetting Coating Powder
- [D4242](#) Test Method for Inclined Plate Flow for Thermosetting Coating Powders
- [D4585](#) Practice for Testing Water Resistance of Coatings Using Controlled Condensation
- [D4587](#) Practice for Fluorescent UV-Condensation Exposures of Paint and Related Coatings
- [D5031](#) Practice for Enclosed Carbon-Arc Exposure Tests of Paint and Related Coatings
- [D5382](#) Guide to Evaluation of Optical Properties of Powder Coatings
- [D5531](#) Guide for Preparation, Maintenance, and Distribution of Physical Product Standards for Color and Geometric Appearance of Coatings
- [D5767](#) Test Methods for Instrumental Measurement of Distinctness-of-Image Gloss of Coating Surfaces
- [D5861](#) Guide for Significance of Particle Size Measurements of Coating Powders
- [D5965](#) Test Methods for Specific Gravity of Coating Powders
- [D6132](#) Test Method for Nondestructive Measurement of Dry Film Thickness of Applied Organic Coatings Using an

Ultrasonic Coating Thickness Gage  
**D6441** Test Methods for Measuring the Hiding Power of Powder Coatings  
**D6695** Practice for Xenon-Arc Exposures of Paint and Related Coatings  
**D7091** Practice for Nondestructive Measurement of Dry Film Thickness of Nonmagnetic Coatings Applied to Ferrous Metals and Nonmagnetic, Nonconductive Coatings Applied to Non-Ferrous Metals  
**E11** Specification for Woven Wire Test Sieve Cloth and Test Sieves  
**E284** Terminology of Appearance  
**E308** Practice for Computing the Colors of Objects by Using the CIE System  
**E430** Test Methods for Measurement of Gloss of High-Gloss Surfaces by Abridged Goniophotometry  
**E1164** Practice for Obtaining Spectrometric Data for Object-Color Evaluation  
**E1331** Test Method for Reflectance Factor and Color by Spectrophotometry Using Hemispherical Geometry  
**E1345** Practice for Reducing the Effect of Variability of Color Measurement by Use of Multiple Measurements  
**E1347** Test Method for Color and Color-Difference Measurement by Tristimulus Colorimetry  
**E1349** Test Method for Reflectance Factor and Color by Spectrophotometry Using Bidirectional (45°:0° or 0°:45°) Geometry  
**G141** Guide for Addressing Variability in Exposure Testing of Nonmetallic Materials  
**G147** Practice for Conditioning and Handling of Nonmetallic Materials for Natural and Artificial Weathering Tests  
**G151** Practice for Exposing Nonmetallic Materials in Accelerated Test Devices that Use Laboratory Light Sources  
**G152** Practice for Operating Open Flame Carbon Arc Light Apparatus for Exposure of Nonmetallic Materials  
**G153** Practice for Operating Enclosed Carbon Arc Light Apparatus for Exposure of Nonmetallic Materials  
**G154** Practice for Operating Fluorescent Ultraviolet (UV) Lamp Apparatus for Exposure of Nonmetallic Materials  
**G155** Practice for Operating Xenon Arc Light Apparatus for Exposure of Non-Metallic Materials  
 2.2 *ISO Standards*:<sup>4</sup>  
**ISO 8130-1** Determination of particle size distribution by sieving  
**ISO 8130-2** Determination of density by gas comparison pycnometer (referee method)  
**ISO 8130-3** Determination of density by liquid displacement pycnometer  
**ISO 8130-4** Calculation of lower explosion limit  
**ISO 8130-5** Determination of flow properties of a powder/air mixture  
**ISO 8130-6** Determination of gel time of thermosetting coating powders at a given temperature  
**ISO 8130-7** Determination of loss of mass on stoving  
**ISO 8130-8** Assessment of the storage stability of thermosetting powders

**ISO 8130-9** Sampling  
**ISO 8130-10** Deposition efficiency of coating powders  
**ISO 8130-11** Inclined-plane flow test  
**ISO 8130-12** Determination of compatibility  
**ISO 8130-13** Coating Powder – Part B; Particle size analysis by laser diffraction  
**ISO 8130-14** Powder Coating Terminology  
 2.3 *PCI Recommended Procedures*:<sup>5</sup>  
**PCI #1** Accelerated Stability Test – Powder Coatings  
**PCI #2** Compatibility of Powder Coatings  
**PCI #3** Contrast Ratio – Powder Coatings  
**PCI #4** Density of Powder Coating Materials  
**PCI #6** Gel Time Reactivity  
**PCI #7** Inclined Plate Flow  
**PCI #9** Cured Weight Loss for Thermosetting Coating Powders

### 3. Terminology

#### 3.1 *Definitions*:

3.1.1 *contrast ratio, n*—a value related to the hiding powder of a coating.

3.1.1.1 *Discussion*—The ratio of the reflectance of the coating over black and white backgrounds at equal film thickness. In the coatings industry 98 % contrast ratio is by convention characterized as being visually opaque, for hiding power measurement purposes, although it is recognized that visually (just as photometrically) the opacity is actually somewhat less than complete. For the reported hiding power to be significant, the contrast ratio value must be reported at a specific film thickness.

3.1.2 *hiding power, n*—the spreading rate of a coating at a specified level of hiding, which is conventionally 0.98 contrast ratio representing photometric “complete hiding.”

3.1.2.1 *Discussion*—Practically speaking, hiding power is the extent to which a powder coating masks the color and pattern of the substrate at a given film thickness.

3.1.3 *minimum explosive concentration (MEC), n*—the lower point for a range of concentrations of organic particles suspended in air that can be ignited by a sufficient energy source.

3.1.3.1 *Discussion*—Also referred to as *LEL or Lower Explosive Level*.

3.1.4 *orange peel, n*—the appearance of irregularity of a surface resembling the skin of an orange.

3.1.5 *pourability, n*—the ability of a dry coating to flow uniformly or to be continuously poured from a container at a steady rate.

3.1.6 *specific gravity, n*—an expression of ratio of the density of a material to that of water at a given temperature and pressure.

#### 3.2 *Definitions of Terms Specific to This Standard*:

3.2.1 Many of the following definitions specific to this guide were taken from the Powder Coating Institute’s

<sup>4</sup> ISO standards are available from American National Standards Institute (ANSI), 25 W. 43rd St., 4th Floor, New York, NY 10036, <http://www.ansi.org>.

<sup>5</sup> The PCI Recommended Procedures are available from the Powder Coating Institute (PCI), 2121 Eisenhower Avenue, Suite 401, Alexandria, VA 22314, <http://powdercoating.org>.

Publication, “Powder Coating Terms & Definitions,” and are indicated as such by the initials, PCI.<sup>6</sup> Another useful source of terminology for coating powders and powder coatings is ISO 8130-14.

3.2.2 *bulk density, n*—mass per unit volume in powder form including the air trapped between particles. (PCI)

3.2.3 *coating powder, n*—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. (PCI)

3.2.4 *coverage rate, n*—the area covered per unit quantity of coating at a specified film thickness, typically expressed in ft<sup>2</sup>/lb./mil.

3.2.4.1 *Discussion*—The term coverage rate is similar to “spreading rate” as often used in liquid technologies.

3.2.5 *electrostatic deposition, n*—technique of moving and charging coating powder so that it is deposited onto a grounded substrate by one of the following methods: (PCI)

3.2.5.1 *cloud chamber technique, n*—method of moving a charged or uncharged object through a charged or uncharged cloud of coating powder in an enclosed chamber.

3.2.5.2 *fluidized bed technique, n*—method of moving a ground objective over or through a charged fluidized coating powder.

3.2.5.3 *spray technique, n*—method of spraying and charging coating powder so that it is deposited onto a grounded charged substrate.

3.2.6 *film formation of a coating powder, n*—the forming of a continuous film by melting coating powder particles and coalescing them by the application of energy. (PCI)

3.2.6.1 *Discussion*—For thermosetting materials, a chemical reaction, either condensation or addition, also takes place. For thermoplastic materials, no chemical reaction takes place. Thermoplastic materials flow when heat is applied and develop performance properties when cooled. Flow will re-occur if re-heated. Both thermoset and thermoplastic films have uniformity of color, toughness, and other properties associated with protective and decorative coatings.

3.2.7 *fluidity, n*—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.

3.2.8 *gel time, n*—the time interval (measured in seconds) required for a coating powder to be transformed from a dry solid to a gel-like state at a given temperature. (PCI)

3.2.9 *glass plate flow, (GPF), n*—the measurement (in millimetres) of flow-out on an inclined smooth glass surface when powder is in a molten state at a given temperature. (PCI)

3.2.10 *impact fusion, n*—the tendency of finely divided powders to fuse with other particles in the application equipment during the application process. (PCI)

3.2.11 *nonelectrostatic deposition, n*—technique of moving coating powder onto a substrate, which may be heated above the melt point of the coating powder material. (PCI)

3.2.11.1 *Discussion*—The actual application could be the spray or fluidized bed technique as with electrostatic deposition.

3.2.12 *particle size, n*—average diameter of particles having irregular boundaries that can be determined by various test methods. (PCI)

3.2.13 *particle-size distribution, n*—arrangement of particle size measurements on a coating powder in groups of specified diameters. (PCI)

3.2.14 *powder coatings, n*—coatings that are protective, decorative, or both, formed by the application of a coating powder (3.1.1) to a substrate and fused into a film by the application of heat or radiant energy. (PCI)

3.2.15 *storage stability, n*—the ability of coating powders to maintain physical and chemical properties during specific storage conditions. (PCI)

3.2.16 *tribocharging, n*—the process of creating a static electric charge on powder particles by friction against a nonconductive material. (PCI)

3.2.17 *volatile content, n*—the weight percent of the coating powder which is lost under specified conditions of temperature and time. (PCI)

#### 4. Significance and Use

4.1 This guide provides a useful summary to the selection and use of procedures for testing coating powders and powder coatings. It is applicable to both thermoplastic and thermoset coatings, unless indicated otherwise. By design this guide does not purport to address test methods or procedures developed specifically for the functional powder coating market, those coating powders for application to pipe or reinforced steel bars (rebar). Information on current test procedures for pipe and reinforced steel bar coating powders and powder coatings can be obtained through their respective ASTM Subcommittees, A01.05 and D01.48.

4.2 Selection of the methods to be followed and the interpretation of results must be governed by experience and the requirements in each individual case, together with agreement between the purchaser and seller. It should be noted that many of the methods used for characterizing a coating powder, such as gel time (Section 16) and inclined flow (Section 17), are primarily meant for the relative comparison of two coating powders, rather than to give a test value that can be interpreted as good or bad. Interpretation of the test results will depend on the specific application in question and will also often depend on the chemistry of the coating powder used.

#### 5. General Requirements

5.1 Ideally, all tests shall be conducted under the same conditions as to light source, sample age, temperature, and humidity. These conditions may be indicated by the individual test procedure used or agreed upon between the purchaser and seller. In the absence of other guidance, test conditions of 23 ±

<sup>6</sup> The PCI publication, “Powder Coating Terms & Definitions” is available from the Powder Coating Institute (PCI).

2°C, 50 ± 5 % relative humidity, and a relatively consistent sample (panel) conditioning time, (sample to sample), are recommended.

## 6. Sampling

6.1 Sample the coating powder in accordance with Practice **D1898** or ISO 8130-9.

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

## 7. Equipment

7.1 Use the equipment as specified in each test method.

## 8. Conditions Affecting Coating Powder or Powder Coatings, or Both

8.1 The performance of a coating powder can be affected by damage to container, size of container, storage time, excessive temperature, excessive humidity and temperature fluctuations, which may cause settling, caking, or chemical change.

8.2 The performance of powder coatings may be affected by:

8.2.1 Substrate type, substrate age, substrate condition, and the type, quality, and suitability of the metal treatment or primer used under the powder coating.

8.2.2 Application conditions such as temperature, humidity, voltage, part grounding, and gun to part distance.

## COATING POWDER PROPERTIES

## 9. Compatibility

9.1 The need for compatibility arises when working with coating powders of varying color or chemical composition. Problems such as changes in gloss, surface appearance, physical properties, and color contamination may occur if incompatible powders are mixed. Rather than discover these problems on the production coating line, it is recommended that the compatibility of powders be checked prior to their use.

9.2 Test compatibility of coating powders in accordance with PCI Procedure #2 or ISO 8130-12.

## 10. Minimum Explosive Concentration (Lower Explosive Level (LEL))

10.1 The minimum explosive concentration (MEC) as defined in **3.1.3** is a value that is critical in the proper design of coating powder application and collection systems. To obtain precise and reliable LEL results, it is best to employ the service of an independent laboratory, which has the special apparatus needed. However, a quick calculation method, as listed below, has been proved in practice to be satisfactory when applied to coating application plants.

10.2 Calculate the MEL (or LEL) of a coating powder in accordance with ISO 8130-4.

## 11. Particle Size and Distribution

11.1 A coating powder's particle size distribution (P.S.D.) and the resulting median particle size can have a significant affect on the coating powder's application properties and the

appearance of the cured powder coating. There is unfortunately, no one optimum P.S.D. or median particle size. The optimum P.S.D. and median particle size for each application will be influenced by the part configuration being coated, the desired film thickness range, the desired film appearance, the powder chemistry, and the application equipment.

11.2 Guide **D5861** references a number of commonly used methods for the measurement of particle size.

11.3 Particle Size by Laser Defraction.

11.3.1 Run particle size analysis by laser diffraction using ISO 8130-13.

11.4 *Multiple Sieve Analysis:*

11.4.1 Run multiple sieve analysis in accordance with Test Method **D1921** or ISO 8130-1.

11.4.2 Specification **E11** can be used in specifying the required sieves.

## 12. Accelerated Storage Stability

12.1 For the recommended useful life of a coating powder, the coating powder must be easily fluidized and free-flowing in order to be properly applied. In addition, the coating powder has to melt, flow out, and cure (thermoset coating powders), to form a powder coating possessing the aesthetic and protective properties desired. In the case of a thermoset coating powder, an accelerated storage stability test can allow a powder user to predict the physical and chemical stability of a coating powder in order to determine its long term usability as a function of time and temperature. The physical stability of a thermoplastic coating powder can also be predicted.

12.2 Run accelerated storage stability in accordance with PCI Procedure #1 or ISO 8130-8.

## 13. Pourability

13.1 Test for pourability in accordance with Test Method **D1895**.

## 14. Fluidity

14.1 A coating powder's transport and spraying characteristics are, among other things, highly dependent on it's fluidity, defined as the ability to move freely, uniformly, and continuously (somewhat like a liquid), when subjected to certain conditions of pressure, temperature, and velocity of a carrier gas (air).

14.2 Test fluidity in accordance with ISO 8130-5.

## 15. Cured Weight Loss for Thermosetting Coating Powders

15.1 In comparison to liquid coatings, coating powders will have a relatively small cured weight loss as a result of the cure cycle. Typically, the cured weight loss from a coating powder will consist of water and low molecular weight organic compounds or blocking agents, or both. The cured weight loss may be requested in order to properly determine the exhaust requirements of a bake oven or to comply with state or federal reporting guidelines. At this time, there is not a recognized

ASTM standard test method for determining the cured weight loss for a coating powder; however, the following procedure has proven satisfactory in the field (refer also to PCI Procedure #9 or ISO 8130-7). Please note that this procedure may or may not determine the cured weight percent VOC (Volatile Organic Compounds). The exact identity of the materials lost during the cure cycle would have to be determined by other means to identify what weight percent is organic and inorganic (that is, water—see **Note 1**). Also, it would depend on the identity of any organic compounds as to whether they are exempt or nonexempt VOC under Federal EPA Guidelines. (Refer to Practice **D3960** and local air quality regulations.)

**NOTE 1**—Test Method **D4017** is one method for determining the percent water in an uncured coating powder. In some cases, the cured weight percent VOC may be estimated by subtracting the weight percent water (see Test Method **D4017**) from the total percent cured weight loss.

### 15.2 Apparatus:

15.2.1 *Analytical Balance*, sensitive to 0.1 mg.

15.2.2 *Small Aluminum Weighing Dishes*. Approximate size: 50 mm (bottom diameter) by 15 mm (height).

15.2.3 *Laboratory Circulating Bake Oven*, capable of holding temperatures from 100°C to 250°C at  $\pm 2^\circ\text{C}$ .

15.2.4 *Desiccator*.

### 15.3 Procedure:

15.3.1 Weigh three aluminum dishes to 0.1 mg. Record this weight as “A.”

15.3.2 To each aluminum dish add  $0.5 \pm 0.01$  g of coating powder. By gentle tilting, spread the coating powder uniformly over the bottom of the dishes, then weigh to 0.1 mg. Record the weight of the dish and powder as “B.”

**NOTE 2**—The recommended sample size of 0.5 g was chosen, in part, based on sample size guidelines in Test Method **D2369**, but also on past experience that showed a 0.5-g sample to yield both realistic results and a fair level of repeatability in a given laboratory. A 0.5-g sample of coating powder should give a cured film thickness of about 6 mils.

15.3.3 Heat the dishes and contents in an oven for 20 min at  $193^\circ\text{C} \pm 2^\circ\text{C}$  (see **Note 3**). It is recommended that the samples be placed on/in a preconditioned heat sink in the oven to insure good heat transfer and relatively constant temperature exposure during the heat cycle.

**NOTE 3**—The standard bake temperature for this procedure is 20 min at  $193^\circ\text{C}$ . There may however, be specific situations where a different bake schedule might be more representative, such as with low cure powders that cure at temperatures less than  $150^\circ\text{C}$ . A deviation from the standard bake must be agreed upon between the purchaser and seller. For test to test repeatability, it is recommended that the same oven be used for all cured weight loss testing.

15.3.4 Cool the dishes and contents in a desiccator and weigh to 0.1 mg. Record this weight as “C.”

### 15.4 Calculations:

15.4.1 Calculate the percent cured weight loss for each trial sample as follows:

$$\text{percent cured weight loss} = \frac{100(B - C)}{(B - A)} \quad (1)$$

where:

A = weight of dish, g,

B = weight of coating powder sample and dish, g,

C = weight of dish and contents after heating 20 min at  $193^\circ\text{C}$  (or other time/temperature), g.

15.4.2 Calculate the average percent cured weight loss for the three trials.

### 15.5 Report:

15.5.1 Report the sample name, cure cycle, (time/temperature) used, and the average percent cured weight loss.

## 16. Gel Time or Stroke Cure (for Thermosetting Powder Only)

16.1 For a powder coating film to exhibit optimum performance properties, the coating powder must be cured properly. A coating powder’s gel time, along with knowledge of the coating powder chemistry being used, can be used to predict whether it will achieve adequate cure under a given set of baking conditions, time or temperature, or both. This test is most useful to the coating powder formulator.

16.2 Test gel time in accordance with Test Method **D4217**, PCI Procedure #6, or ISO 8130-6.

## 17. Flow Test (Incline Method)

17.1 In the uncured state, the required flow or leveling properties of a coating powder depend on the intended cured powder coating application. For a very smooth cured film surface, a coating powder with relatively high flow may be required. On the other hand, if one needs to coat a part with sharp edges, a coating powder with relatively short flow may be required. The inclined flow test provides one means to compare the uncured flow characteristics of two powders. The chemistry of the coating powder can also influence cured film smoothness. This test is most useful to the coating powder formulator.

17.2 Run the inclined flow test in accordance with Test Method **D4242**, PCI Procedure #7, or ISO 8130-11.

## 18. Specific Gravity (Density) of Coating Powders

18.1 A coating powder’s specific gravity (see **3.1.6** for definition) is directly proportional to its coverage (spreading) rate, but independent of particle size and other properties. A coating powder is applied by *volume* (mils thick by square feet), but often is purchased by *weight* (pounds). Knowing the specific gravity allows for the expected coverage (mils/ft<sup>2</sup>) from a given weight of coating powder to be calculated.

18.2 Determine the specific gravity (density) of a coating powder in accordance with Test Method **D5965**, PCI Procedure #4, ISO 8130-2, or ISO 8130-3.

## 19. Melting Point Determination

19.1 Being able to determine the melting point of a coating powder, or the temperature at which it becomes tacky (its tack temperature), can be useful for a number of reasons such as: (1) establishing a maximum storage temperature; (2) establishing the maximum temperature a part can be at as it enters the application booth; and (3) comparing the potential for impact fusion (see **3.2.10**) of one powder versus another. This test is most useful to the coating powder formulator.

NOTE 4—The impact fusion resistance of a coating powder is dependent on many factors, not just its melt temperature. Some coating powder chemistries can be inherently resistant to impact fusion even though their tack temperature might be relatively low.

### 19.2 Apparatus:

19.2.1 *Gradient Heat Bar*, whose temperature capability includes the range 40°C to 100°C.

#### 19.2.2 *Calibrating Test Substances*.

	Melting Point, °C
Azobenzene	68 ± 1
Naphthalene	80 ± 0.5
Benzoic acid	122 ± 1

#### 19.2.3 *Paint brush*, stiff bristle, 12.7-mm.

### 19.3 Procedure:

19.3.1 Calibrate the apparatus as follows. Allow 60 min for the warm up on 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.

19.3.2 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 5—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.

## APPLICATION PROPERTIES

### 20. Determining the Relative Deposition Efficiency of Coating Powders on a Moving Target

20.1 Deposition (or transfer) efficiency can be defined as the ratio of coating powder deposited, compared with the amount directed at the part to be coated, often expressed as a percent deposited or transferred. Field experience has shown that, in general, the higher the first-pass deposition efficiency of a virgin coating powder sample, the better its production application properties will be. It would therefore be beneficial to have a laboratory test method that allows one to compare the first-pass deposition efficiency of two or more coating powder samples. The following test method indicated has been found suitable for this purpose. The results are most meaningful when a control powder, one whose field application characteristics are known, is included in the testing. The comparison of results are only valid for coating powders tested in the same laboratory at about the same time, not results between different laboratories.

20.2 Test the relative deposition efficiency in accordance with ISO 8130-10.

## PHYSICAL PROPERTIES OF POWDER COATINGS

### 21. Panel Preparation

21.1 *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: Practice **D609**, Practices **D1730**, **D1731**, **D1732**, Guide **D2092**, and Practice **D2201**.

21.2 *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.

21.3 *Application of Coating Powders*—The coatings may be applied by fluidized bed, electrostatic spray, or other methods.

#### 21.4 *Curing of Coating Powders*:

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

21.4.2 The powder coating should be over-baked to determine the time/temperature effect on the physical and chemical properties in accordance with Practice **D2454**.

21.5 *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 Methods **D1005**, **D6132**, or **D7091**.

## 22. Abrasion Resistance

22.1 Many powder coating applications require that the coating’s surface resist degradation (scratching, etc.) as other objects are rubbed against it. There are many types of abrasion tests available and often one, more than the others, will best simulate the abrasion resistance required in a particular end use application.

22.2 Test abrasion resistance in accordance with Test Method **D658** (Air Blast Abrasion), Practice **D968** (Falling Sand Method), or Test Method **D4060** (Taber Abraser).

## 23. Adhesion

23.1 A powder coating of a specified film thickness and over a specified substrate as agreed to between the purchaser and the seller is subjected to an adhesion test to determine the degree of attachment the coating has to the substrate. Adhesion tests can also be used for testing the degree of attachment between a primer (powder coating or other coating type) and a second coat of coating powder (that is, intercoat adhesion).

23.2 Determine the adhesion of the powder coating to the specified substrate or first coat (primer, etc.) in accordance with Test Method **D3359** (Tape Adhesion).

## 24. Chemical Resistance

24.1 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, changes in gloss, blistering, softening, swelling, or loss of adhesion.

24.2 *Household Chemical Resistance*—Determine the effect of chemicals in accordance with Test Method **D1308**.



24.3 *Detergent Resistance*—Determine the resistance to failure when immersed in a detergent solution in accordance with Practice [D2248](#).

24.4 *Acid Resistance (Extruded Aluminum Products)*—Determine the resistance to acid in accordance with Test Method [D3260](#).

24.5 *Stain and Reagents (Wood substrates)*—Determine the resistance to stains and other reagents on wood substrates in accordance with Practice [D3023](#).

## 25. Chip Resistance

25.1 In many end uses, the ability of a powder coating to withstand sudden impact from stones, gravel, etc., without being loosened from the substrate is important.

25.2 Determine chip resistance (gravelometer) in accordance with Test Method [D3170](#).

## 26. Corner Coverage

26.1 Edge coverage, the ability of a coating powder to flow over, build, and adhere to sharp corners, angles, and edges can be important in field applications where a corrosive atmosphere is likely.

26.2 The relative edge coverage of two powders can be compared using Test Method [D2967](#).

## 27. Elongation (Flexibility)

27.1 An elongation test may give an indication of the flexibility of a powder coating. It can also show whether there is any change in flexibility due to the aging of the film. Elongation is dependent on substrate type and film thickness, therefore, these test parameters should be agreed upon between the purchaser and the seller. For powder coatings applied to coil strip or blanks, the standard elongation test used is the T-bend.

27.2 Test elongation (flexibility) in accordance with Test Method [D522](#) (Conical and Cylindrical Mandrel) or Test Method [D4145](#) (T-Bend).

## 28. Hardness

28.1 A powder coating's surface hardness can be an indication of its ability to resist abrasion or scratching from contact with other objects. The most widely recognized test for hardness is the pencil test. It should be noted however, that pencil hardness is not the most reproducible test and interpreting the results is somewhat subjective. The results are highly dependent on such factors as; the pencil type used, the pressure exerted by the operator, and the care taken in preparing the pencil lead. Some industries (that is, automotive) have also adopted the use of Knoop Indentation Hardness. There is no consistent correlation between the two tests.

28.2 Test pencil hardness in accordance with Test Method [D3363](#).

28.3 Test Knoop Indentation Hardness in accordance with Test Methods [D1474](#) (Method A).

## 29. Impact Resistance

29.1 A powder coating may be subject to sudden impact in certain end uses. Impact resistance is dependent on the substrate type and its preparation, the thickness of the substrate, and the film thickness of the powder coating. Therefore, these test parameters should be agreed upon between the purchaser and the seller. Impact resistance has also been found to be a good indication of whether a coating powder has been adequately cured.

29.2 Determine impact resistance in accordance with Test Method [D2794](#).

## 30. Mottling/Blocking Resistance

30.1 These tests are directed at powder coatings applied to metal coil or blanks, and wood substrates. They cover determination of the pressure mottling and sticking, or blocking resistance of powder coatings applied to metal coil and blanks, or wood as they are stored prior to the final fabrication operation.

30.2 Test resistance to mottling/blocking on metal substrates in accordance with Test Method [D3003](#).

30.3 Test resistance to blocking on wood substrates in accordance with Test Method [D2793](#).

## 31. Print Resistance

31.1 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 thermoplastic film, at what temperature the film prints or mars. The print test can determine the degree of marring due to pressure.

31.2 Determine the imprinting and thermoplasticity of a powder coating film in accordance with Test Method [D2091](#).

## 32. Optical Properties

32.1 The term optical properties of coatings refers to those properties associated with the interaction of visible light with a coated surface. Common terms associated with optical properties are defined in Guide [D5382](#). Key test methods or practices are as follows:

### 32.2 *Color - Pigmented Coatings:*

32.2.1 The colors of opaque objects such as coated surfaces may be specified by visual or instrumental color values. In either case, it is important that the viewing and measurement conditions under which the color is to be evaluated are agreed upon between the purchaser and seller. Viewing conditions include the light source, the illuminating and viewing conditions (such as illuminate at a 45° angle and view along the sample normal), and the background against which the sample is evaluated. Instrumental conditions include the type of instrument, the measurement geometry (such as 45/0), and the illuminant/observer combination (such as D65/10° Observer).

32.2.2 For visual evaluation, determine the color of a coated surface in accordance with Practice [D1729](#). If need be, color can also be visually evaluated using Practice [D1535](#), which determines the Munsell Coordinates of the color of a coated surface.

32.2.3 Determine (calculate) the color of a coated surface instrumentally in accordance with Test Methods [E1331](#), [E1347](#) or [E1349](#), and Practices [E308](#), [E1164](#), and [E1345](#). A spectrophotometer, the preferred instrument, measures reflectance as a function of wavelength over the visible spectrum. Spectrophotometers offer a choice of two standard observers, specified by the CIE, 2° and 10°. The former is recommended when the colored surface is small, subtending no more than 4° at the eye. The 10° observer is for larger specimens, and is the preferred observer whenever possible. Large area view is also recommended whenever possible.

#### 32.3 *Color Difference - Pigmented Coatings:*

32.3.1 The color difference between two homogeneously colored opaque films can be determined by visual evaluation or instrumental means, or both. In either case, it is important that the viewing and measurement conditions under which color difference is to be evaluated are agreed upon between the purchaser and seller (see [32.2.1](#) and [32.2.3](#)).

32.3.2 Determine color differences visually in accordance with Practice [D1729](#) or [D2616](#).

32.3.3 Calculate the instrumental color differences in accordance with Practice [D2244](#). The color difference equation used should be agreed upon between purchaser and seller. Instrumental color differences are most accurate and correlate best to the visual perception of color when the standard and trial specimens are alike with respect to characteristics such as their physical state (metal or paper), gloss, and film appearance (textured or smooth). Instrumental measurements of the standard and trial should be made in accordance with Test Methods [E1331](#), [E1347](#) or [E1349](#), and Practices [E308](#), [E1164](#), and [E1345](#).

#### 32.4 *Metamerism - Pigmented Coatings:*

32.4.1 Metamerism, as defined in Terminology [E284](#), can be determined by Practice [D4086](#).

#### 32.5 *Distinctness-of-Image Gloss (DOI):*

32.5.1 Distinctness-of-Image Gloss, as defined in Terminology [E284](#), was a test first developed by the automotive industry to describe observed differences found among very high gloss paint films. A mirror has a very high DOI, and a matte paint film has a low DOI. The DOI of a paint film can be described in accordance with Test Method [D5767](#). Test Methods [E430](#) is also a useful standard for evaluating the reflective properties of high-gloss surfaces by goniophotometry.

#### 32.6 *Hiding Power (Opacity):*

32.6.1 A powder coating must be opaque to hide variations in substrate color. It is also important to know at what film thickness the coating attains opacity so that it may be applied at the minimum film thickness necessary for adequate hiding.

32.6.2 Determine a powder coating's hiding power in accordance with PCI Procedure #3 or Test Methods [D6441](#).

#### 32.7 *Specular Gloss:*

32.7.1 Specular gloss, as defined in Terminology [E284](#), is the perceived surface brightness associated with the luminous specular (regular) reflection of a surface. The illuminating/viewing angle must be agreed upon between the purchaser and the supplier. It is recommended that a 20° angle be used for high gloss surfaces, a 60° angle for medium gloss surfaces, and

an 85° angle for low gloss surfaces. In general, the lower the measuring angle, the greater the influence surface characteristics (such as orange peel or haze) have on the gloss reading.

32.7.2 Determine the specular gloss of a powder coating surface in accordance with Test Method [D523](#).

#### 32.8 *Surface Profile:*

32.8.1 The surface profile of a cured powder coating (any irregularities or waviness in appearance) is often a specified requirement of the coating powder. The surface profile requirement can range from a very smooth finish, as for an automotive clear coating powder, to a fine, grainy texture, as is typically seen on computer or communication equipment. Surface profiles in between very smooth and textured are typically described by their degree of orange peel (see Terminology [E284](#)). A powder coatings surface profile is primarily controlled by the coating powder formulation; however, many other factors such as substrate condition, film thickness, curing conditions, and application conditions can also influence or change the surface profile of a given powder coating. Slight differences in the degree of orange peel are often difficult to quantify, and the evaluation can be somewhat subjective. In general, as the gloss of the powder coating is lowered, orange peel or other surface irregularities will become less noticeable.

32.8.2 There are several methods available to help quantify differences in the surface profile (orange peel) of cured powder coatings. One method requires a subjective visual comparison to a set of ten "Visual Smoothness Panels" that are available from the Powder Coating Institute<sup>5</sup>. A second method uses a portable instrument that when scanned across the surface acts like the human eye and detects differences in reflectance (light → dark areas), then transforms them into a numerical number relating to orange peel. A good correlation between this type of instrument and visual evaluation has been reported. A more sophisticated surface profile instrument is also available that actually measures the wavelength and amplitude of the surface waviness (orange peel). Numerical ratings derived from this type of instrument have proven difficult to correlate with subjective visual evaluation.

#### 32.9 *Color/Gloss/Appearance Standards:*

32.9.1 The color, gloss, and appearance (that is, texture) of a powder coated part can be important to its perceived quality. It is therefore important that the seller and purchaser of a coating powder agree to a master standard that adequately represents what the finished powder coated part is to look like, and that appropriate working standards be distributed to all concerned parties for visual or instrumental assessment of color, gloss, and texture on production parts. It is highly recommended that working standards be of a size and shape to adequately determine color, gloss, and texture both visual and instrumentally. A3 by 5 in. flat panel has proven satisfactory for this purpose. It is also recommended that the standards be prepared over the same substrate, at the same film thickness, and be of the same gloss and texture, as the intended part to be coated. For example, avoid the use of paper or plastic standards for metal applications, or low gloss standards for a higher gloss part. This will give the best chance of long term control, and minimize day to day variation caused by the color instrumentation itself, and different people visually assessing color. Once

a master standard and working standards have been established and agreed to, tolerances for acceptability must be established to the standards. How much variation will be acceptable (tolerances) must be weighed carefully, and will likely change depending on the type of part, the market application, and other factors deemed important to the end user.

32.9.2 Guide **D5531** is a useful guide to the preparation, maintenance, and distribution of standards for color, gloss, or texture.

32.9.3 Practice **D3134** describes the practice for establishing color and gloss tolerances.

### 33. Outdoor Exposures (Natural)

33.1 While the accelerated tests given elsewhere in this guide are intended to enable prediction of probable performance, actual outdoor exposures should be made on powder 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 guide 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 **21** of this guide.

33.2 Practices **D1014** and **D4141** are useful references when conducting outdoor exposures. 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 Adhesion—Test Method **D3359**,
- 33.2.2 Blistering—Test Method **D714**,
- 33.2.3 Chalking—Test Method **D4214**,
- 33.2.4 Checking—Test Method **D660**,
- 33.2.5 Cracking—Test Method **D661**,
- 33.2.6 Rusting—Test Method **D610**,
- 33.2.7 Erosion—Test Method **D662**,
- 33.2.8 Flaking—Test Method **D772**,
- 33.2.9 Gloss—Test Method **D523**,
- 33.2.10 Color—Test Methods **D1729**, **D2244**, **D4086**, **E308**, **E1164**, **E1331**, **E1345**, **E1347**, **E1349**, and
- 33.2.11 Filiform—Test Method **D2803**.

### 34. Accelerated Artificial Weathering

34.1 The intention of the accelerated weathering test is to cause the degradation of coating films to occur much faster than weathering in various field conditions. The degradation of a coating exposed outdoors is influenced not only by light, but also moisture and elevated temperatures. These three influences can react synergistically to yield degradation that is different from degradation caused by one influence. Artificial radiation (light) apparatuses, that typically also include heat and moisture (in the form of either water spray, condensation, immersion, or humidity) in the test cycle, can produce more rapid failure of films than natural sunlight, but not necessarily the same type of failure. It is important to point out that the relation between hours of artificial light exposure and outdoor exposure varies not only with the type of accelerated test device, its intensity and other parameters, but with the material

to be tested itself. Thus, it is not possible to assign an acceleration factor to a specific type of accelerated test device. Also, it is recommended that comparisons in artificial light sources (outdoor exposures also) be made with materials having similar resin vehicles, and include a standard of known durability, whenever possible.

34.2 Practice **G151** describes the performance requirements for any device used to conduct laboratory accelerated weathering tests. Practice **G147** describes procedures for conditioning and handling of specimens that are being tested in laboratory accelerated or outdoor exposures. Guide **G141** provides information on sources of variability in weathering tests, and suggests procedures that can be used to cope with this variability. It is important to document the conditions for a particular test. The most common weathering devices can be characterized by their light source.

34.2.1 *Enclosed Carbon Arc, Practices **D5031**, **G151**, **G153***—Enclosed carbon arc was first used as a solar simulator back in 1918. The spectral power distribution of light from an enclosed carbon-arc is significantly different from solar radiation and the radiation from light sources used in other accelerated weathering devices. The rate and type of degradation caused by exposure to the enclosed carbon-arc can be much different from that caused by exposure to the outdoor environment or other types of laboratory light sources.

34.2.2 *Filtered Open Flame Carbon Arc, Practices **D822**, **G151**, **G152***—The open flame carbon-arc with Corex D filters was an improvement over the enclosed carbon-arc. The spectrum of this source gives a better match to solar UV radiation, but it is also deficient in visible radiation and has excessive long wavelength UV radiation. While it gives a better match than the enclosed carbon arc to solar radiation between 300 and 350 nm, it emits energy below the solar cut-on into the UV-C portion of the spectrum. These short wavelengths can cause unrealistic degradation compared with natural exposures. Filters that screen out more of the short wavelengths than the Corex D filters can provide better simulation of the solar cut-on.

34.2.3 *Xenon Arc, Practices **D6695**, **G151**, **G155***—Xenon arc lamps use filters to reduce short wavelength UV radiation below the solar cut-off. Practice **G155** specifies the spectral power distribution of xenon arcs, which gives good simulation of the full spectrum of the solar radiation for weathering. Xenon arc exposure produces temperature differences between dark and light color materials that is similar to those in outdoor exposure. However, at unrealistically high irradiance levels, high amounts of near infrared energy can cause unrealistic temperature differences in differently colored materials. The xenon arc source decays as the lamp and filter ages, but it can be controlled by adjusting the lamp wattage.

34.2.4 *Fluorescent UV Devices, Practices **D4587**, **G151**, **G154***—Fluorescent UV lamps used as the light sources in these devices do not replicate the entire sunlight spectrum. However, some fluorescent UV lamps replicate solar UV wavelengths that cause most of the damage to many durable coatings. Practice **G154** specifies the spectral distribution for three different fluorescent UV lamps. The fluorescent UVA-340 lamps are recommended for testing materials intended for

outdoor exposure. Fluorescent UVA lamps with a peak emission at 351 nm are recommended for testing materials exposed behind window glass. Practice **G154** also specifies the spectral distribution for fluorescent UVB lamps with peak emission at 313 nm. These lamps emit significant amounts of UVB radiation and produce very fast, but often unrealistic degradation reactions. Because fluorescent UV lamps lack the visible and near infrared radiation present in solar radiation, they do not produce the temperature differences between light and dark colors found in outdoor exposure.

34.3 To summarize, conduct accelerated weathering testing on powder coating finishes in accordance with Practices **D822**, **D4587**, **D5031**, **D6695**, **G141**, **G147**, **G151**, **G152**, **G153**, **G154** or **G155**, or a method agreed upon between the purchaser and seller. As with outdoor exposure, many properties of powder coatings should be evaluated periodically throughout the accelerated weathering period. These properties may be evaluated following the test methods listed in **33.2** of this guide.

### 35. Accelerated Environmental Exposure

35.1 As with accelerated weathering, the intention of an accelerated environmental exposure test is to cause the degradation of powder coating films to occur much faster than would occur under various actual service (in the field) environments. It is important to choose a test that is believed to, by its design, to best simulate the appropriate environmental conditions present in service and can therefore be relied upon to predict the long term service of a product. This is true whether the test is an established test, like salt spray (Practice **B117**), or a new test developed to simulate an environmental service condition unique to one given industry. For example, the appliance industry has developed accelerated tests to simulate the long term service exposure of range (stove) components to heat cycles or food soils, or both.

35.2 A list of some established accelerated environmental exposure tests follows. Many film properties may need to be evaluated periodically throughout the exposure period. In addition to tests specified in each test method, refer to **33.2** of this guide for possible tests to run.

35.2.1 *Filiform Corrosion*—Filiform corrosion is a type of corrosion that occurs under coatings on metal substrates and is characterized by a definite thread-like structure and directional growth often initiating from sharp edges or exposed metal. Determine the susceptibility of a powder coating to filiform corrosion by Guide **D2803**.

35.2.2 *Salt Spray*—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 salt, and other physical parameters can be controlled. The selection of 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 (time intervals and tests to be run), and the method of reporting results must be agreed upon between the purchaser and the seller. Test for salt spray in accordance with Practice **B117**. Test Method **D1654** can be a useful guide in evaluating corrosion results if no other guidance is given.

35.2.3 *Simulated Corrosion Atmospheric Breakdown (SCAB)*—SCAB is a relatively new cyclic corrosion test (first developed by the automotive industry) and is thought to offer advantages over salt spray (Practice **B117**) as a test to predict the service life of coatings in corrosive environments, particularly over galvanized substrates. There are many variations of the SCAB test available so it is important that the test conditions, etc, are agreed upon between the purchaser and the seller. A typical SCAB corrosion test will consist of exposing tests panels to repeated cycles of dry heat (60°C), freezing temperatures (−23°C), immersion in 5 % NaCl solution plus room temperature drying time, and a high temperature/high humidity atmosphere (≈60°C at 85 % relative humidity). Some SCAB test methods will also include an accelerating weathering test (see Section **35** of this guide).<sup>7</sup>

35.2.4 *Water Resistance*—Testing of coating systems with water is helpful in determining their resistance to failure under conditions of high humidity or water immersions. 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.

35.2.4.1 Determine the resistance to failure under conditions of water fog or 100 % humidity in accordance with Practices **D1735** or **D2247**, respectively.


35.2.4.2 Determine the resistance to failure under conditions of controlled condensation in accordance with Practice **D4585**.

35.2.4.3 Determine the resistance to failure under conditions of water immersion in accordance with Practice **D870**. This test is best suited for coating systems that will actually be soaked in water during service.

### 36. Keywords

36.1 accelerated testing, cured weight loss; coating powders; gel time; optical properties; particle size distribution; plate flow; powder coatings; transfer efficiency

<sup>7</sup> Four recognized SCAB tests are General Motor's GM9511P and GM9540P, Ford's FLTM BI-123-01, and Chrysler's LP463 PB52-01.

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