Designation: D 3730 – 03

Standard Guide for Testing High-Performance Interior Architectural Wall Coatings[1]

This standard is issued under the fixed designation D 3730; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

1. Scope

1.1 This guide covers the selection and use of test methods for high-performance interior architectural wall coatings (HIPAC) that differ from more conventional coatings by being tougher, more stain-resistant, more abrasion-resistant and, ordinarily, designed to be applied to wall surfaces of steel, masonry (poured concrete, concrete block, or cinder block), and plaster or gypsum wallboard. The tests that are listed in Tables 1 and 2 are designed to measure performance properties. These tests may not all be required for each HIPAC system. 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.

1.2 High-performance architectural coatings are tough, extra-durable organic coating systems that are applied as a continuous (seamless) film and cure to a hard finish. The finish can be high gloss, semigloss, or low gloss as desired. These coatings are resistant to persistent heat, humidity, abrasion, staining, chemicals, and fungus growth. They are used in areas where humidity, wear, or unusual chemical resistance requirements, particularly to soiling, are required and where strong detergents are used to maintain sanitary conditions. Halls and stairways in public buildings, lavatories, stall showers, locker areas, animal pens, and biological laboratories are typical applications. In addition, food processing plants, dairies, restaurants, schools, and transport terminals frequently use HIPAC systems. These are effective in many areas of building interiors compared with tile and are of low materials and maintenance costs. They are used as a complete system only as recommended by the manufacturer since the individual coats in a system are formulated to be compatible with each other. HIPAC systems should be applied only to properly prepared surfaces such as steel or masonry, including cinder blocks and cement blocks. They can be applied over plaster and gypsum wallboard. Ordinarily, a prime or fill coat, if required, is part of the system.

1.3 While they are excellent for walls, HIPAC are not usually intended for ceilings and floors. They would not ordinarily be used in homes, although parents with small children might want to use HIPAC coatings on some walls.

1.4 The types of resin ordinarily used are the following: epoxy-polyamide, two-package; polyester-epoxy, two-package; polyurethane, one-package or two-package. However, other resin types are not excluded provided they can meet the requirements (performance specifications) laid down by the purchaser.

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

1.6 *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.* For a specific hazard statement, see the note in 7.6.

2. Referenced Documents

2.1 *ASTM Standards:*

D 16 Terminology for Paint, Related Coatings, Materials and Applications[2]

D 93 Test Methods for Flash Point by Pensky-Martens Closed Cup Tester[3]

D 154 Guide for Testing Varnishes[4]

D 185 Test Methods for Coarse Particles in Pigments, Pastes, and Paints[4]

D 344 Test Method for Relative Hiding Power of Paints by the Visual Evaluation of Brushouts[2]

D 523 Test Method for Specular Gloss[2]

D 562 Test Method for Consistency of Paints Measruing Krebs Unit (KU) Viscosity Using a Stormer-Type Viscometer[2]

D 869 Test Method for Evaluating Degree of Settling of Paint[5]

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

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[2] *Annual Book of ASTM Standards*, Vol 06.01.

[3] *Annual Book of ASTM Standards*, Vol 05.01.

[4] *Annual Book of ASTM Standards*, Vol 06.03.

[5] *Annual Book of ASTM Standards*, Vol 06.02.

TABLE 1 List of Standards in Sectional Order

Property (or Related Test)	Section	ASTM Test Method	Federal Test Method Standard No. 141
Sampling:	6.2	D 3925	...
Liquid Paint Properties:			
Skinning	7.1	D 154	
Condition in container	7.2	...	3011
Coarse particles and foreign matter	7.3	D 185	
Density or weight per gallon	7.4	D 1475	
Fineness of dispersion	7.5	D 1210	
Flash point	7.7	D 93, D 3278	
Dilution stability	7.8	...	4203
Volatile content	7.9	D 2369	...
Free diisocyanate content	7.10	D 3432	...
Package stability	7.11		
Heat stability	7.11.1	D 1849	
Settling	7.11.2	D 869	
Coating Application and Film Formation:			
Application properties	8.1	...	4541
Brush application	8.1.1	...	2141
Brush drag	8.1.1.1	D 4958	...
Roller application	8.1.2	...	2112
Roller spatter	8.1.2.1	D 4707	...
Spray application	8.1.3	...	2131
Rheological properties	8.2	...	...
Consistency (low-shear viscosity)	8.2.1	D 562	...
Rheological properties of non-Newtonian liquids	8.2.2	D 2196, D 4287	...
Sag resistance	8.2.3	D 4400	...
Leveling properties	8.2.4	D 4062	...
Curing properties	8.3	...	...
Wet-film thickness	8.4	D 1212	...
Touch-up uniformity	8.5	D 3928	
Appearance of Dry Coating:			
Color appearance	9.1.1	...	...
Color differences by visual comparison	9.1.2	D 1729	...
Color differences using instrumental measurements	9.1.3	D 2244	...
Directional reflectance	9.2	E 1347	...
Gloss, 60°	9.3	D 523	...
Hiding power	9.4	D 344, D 2805	...
Yellowness index	9.5	E 313	
Properties of Dry Film:			
Abrasion resistance	10.1	D 4060	...
Adhesion	10.2	D 4541	...
Impact resistance	10.3	D 2794	...
Chemical resistance	10.4	D 1308	...
Washability and cleansability	10.5	...	...
Washability	10.5.1	D 2486, D 4213	...
Cleansability	10.5.2	D 3450, D 4828	...
Mildew resistance	10.6	D 3273	...
Perspiration resistance	10.7	...	...
Heat and cold resistance	10.8	D 1211	...
Heat and humidity resistance	10.9	D 2247	...
Fire hazards	10.10	E 84	
Dry-film thickness	10.11	D 1005, D 1186, D 1400	

D 1005 Test Method for Measurement of Dry-Film Thickness of Organic Coatings Using Micrometers[2]

D 1186 Test Methods for Nondestructive Measurement of Dry Film Thickness of Nonmagnetic Coatings Applied to a Ferrous Base[2]

D 1210 Test Method for Fineness of Dispersion of Pigment-Vehicle Systems by Hegman-Type Gage[2]

D 1211 Test Method for Temperature-Change Resistance of Clear Nitrocellulose Lacquer Films Applied to Wood[5]

D 1212 Test Methods for Measurement of Wet Film Thickness of Organic Coatings[2]

D 1296 Test Method for Odor of Volatile Solvents and Diluents[6]

D 1308 Test Method for Effect of Household Chemicals on Clear and Pigmented Organic Finishes[5]

D 1400 Test Method for Nondestructive Measurement of Dry Film Thickness of Nonconductive Coatings Applied to a Nonferrous Metal Base[2]

D 1475 Test Method for Density of Liquid Coatings, Inks,

[6] *Annual Book of ASTM Standards*, Vol 06.04.

TABLE 2 Alphabetical List of Test Methods

Test Method	Section	ASTM Test Method	Federal Test Method Standard No. 141
Abrasion resistance	10.1	D 4060	
Adhesion	10.2	D 4541	...
Application properties	8.1	...	4541
Brush application	8.1.1	...	2141
Brush drag	8.1.1.1	D 4958	...
Chemical resistance	10.4	D 1308[A]	...
Cleansability	10.5.2	D 3450, D 4828	...
Coarse particles and foreign matter	7.3	D 185	
Color appearance	9.1.1	...	...
Color differences by visual comparison	9.1.2	D 1729	...
Color differences uisng instrumental measurements	9.1.3	D 2244	...
Condition in container	7.2	...	3011
Consistency (low-shear viscosity)	8.2.1	D 562	...
Curing properties	8.3	...	...
Density or weight per gallon	7.4	D 1475	...
Dilution stability	7.8	...	4203
Directional reflectance	9.2	E 1347	...
Dry-film thickness	10.11	D 1005, D 1186, D 1400	...
Fineness of dispersion	7.5	D 1210	...
Fire hazards	10.10	E 84	
Flash point	7.7	D 93, D 3278	...
Free diisocyanate content	7.10	D 3432	
Gloss (60-deg specular)	9.3	D 523	
Heat and cold resistance	10.8	D 1211[A]	...
Heat and humidity resistance	10.9	D 2247[A]	...
Heat stability	7.11.1	D 1849	
Hiding power	9.4	D 344, D 2805	...
Impact resistance	10.3	...	...
Leveling properties	8.2.4	D 4062	...
Mildew resistance	10.6	D 3273	...
Package stability	7.11		
Perspiration resistance	10.7	...	...
Rheological properties of non-Newtonian liquids	8.2.2	D 2196, D 4287	...
Roller appliation	8.1.2	...	2122
Roller spatter	8.1.2.1	D 4707	...
Sag resistance	8.2.3	D 4400	...
Sampling	6.2	D 3925	...
Settling	7.11.2	D 869	
Skinning	7.1	D 154	
Spray application	8.3	...	2131
Touch-up uniformity	8.5	D 3928	
Volatile content	7.9	D 2369	...
Washability	10.5.1	D 2486, D 4213	...
Wet-film thickness	8.4	D 1212	...
Yellowness index	9.5	E 313	

[A]Modified.

and Related Products[2]

D 1729 Practice for Visual Appraisal of Colors and Differences of Diffusely-Illuminated Opaque Materials[2]

D 1849 Test Method for Package Stability of Paint[5]

D 2196 Test Methods for Rheological Properties of Non-Newtonian Materials by Rotational (Brookfield type) Viscometer[2]

D 2244 Practice for Calculation of Color Tolerances and Color Differences from Instrumentally Measured Color Coordinates[2]

D 2369 Test Method for Volatile Content of Coatings[2]

D 2486 Test Methods for Scrub Resistance of Interior Latex Flat Wall Paints[5]

D 2794 Test Method for Resistance of Organic Coatings to Effects of Rapid Deformation (Impact)[2]

D 2805 Test Method for Hiding Power of Paints by Reflectometry[2]

D 3273 Test Method for Resistance to Growth of Mold on the Surface of Interior Coatings in an Environmental Chamber[2]

D 3278 Test Methods for Flash Point of Liquids by Small Scale Closed Cup Apparatus[2]

D 3432 Test Method for Unreacted Toluene Diisocyanates in Urethane Prepolymers and Coating Solutions by Gas Chromatography[4]

D 3450 Test Method for Washability Properties of Interior Architectural Coatings[5]

D 3925 Practice for Sampling Liquid Paints and Related

Pigmented Coatings[2]
D 3928 Test Method for Evaluation of Gloss or Sheen Uniformity[5]
D 4060 Test Method for Abrasion Resistance of Organic Coatings by the Taber Abraser[2]
D 4062 Test Method for Leveling of Paints by Draw-Down Method[5]
D 4213 Test Method for Scrub Resistance of Paints by Abrasion Weight Loss[5]
D 4287 Test Method for High-Shear Viscosity Using a Cone/Plate Viscometer[2]
D 4400 Test Method for Sag Resistance of Paints Using a Multinotch Applicator[5]
D 4541 Test Method for Pull-Off Strength of Coatings Using Portable Adhesion Testers[5]
D 4585 Practice for Testing Water Resistance of Coatings Using Controlled Condensation[2]
D 4707 Test Method for Measuring Paint Spatter Resistance During Roller Application[5]
D 4828 Test Methods for Practical Washability of Organic Coatings[5]
D 4958 Test Method for Comparison of the Brush Drag of Latex Paints[5]
E 84 Test Method for Surface Burning Characteristics of Building Materials[7]
E 105 Practice for Probability Sampling of Materials[8]
E 313 Practice for Calculating Yellowness and Whiteness Indices from Instrumentally Measured Color Coordinates[2]
E 1347 Test Method for Color and Color-Difference Measurement by Tristimulus (Filter) Colorimetry[2]

2.2 *U.S. Federal Standard:*

Federal Test Method Standard No. 141[9]
2112 Application by Roller
2131 Application of Sprayed Films
2141 Application of Brushed Films
3011 Condition in Container
4203 Reducibility and Dilution Stability
4541 Working Properties and Appearance of Dried Film
6141 Washability of Paints
6142 Scrub Resistance

2.3 *U. S. Federal Specification:*

TT-F-1098 Filler, Block Solvent-Thinned for Porous Surfaces[9]

3. Terminology

3.1 *Definitions:*

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

4. Conditions Affecting Performance of HIPAC Coating Systems

4.1 Practical requirements for high performance coatings may vary with:

4.1.1 Substrate type such as concrete, poured or precast block, lime-gypsum plaster, etc.

4.1.2 Climatic conditions, both generally and specifically, at the time of coating application. ASTM standard conditions for laboratory testing are 73.5 ± 3.5°F (23 ± 2°C) and 50 ± 5 % relative humidity.

5. Sampling

5.1 Prior to sampling, establish the condition of the container since damage to it may cause evaporation, skinning, or other undesirable effects. Excessive storage time and temperature fluctuations may cause settling or changes in viscosity.

5.2 Sample in accordance with Practice D 3925. Determine the density in pounds per gallon (kilograms/litre) in accordance with Test Method D 1475. Continue sampling and determining density until successive results agree within 0.1 lb (45 g) or as agreed upon between the purchaser and seller. Then take samples for testing.

5.3 Specify the amount required for a representative sample, the package sizes, and an identification code. A 1-U.S. gal (or 4-L) sample is usually sufficient for the recommended tests, but for guidance in selecting a sampling plan consult Practice E 105.

6. Laboratory Tests

6.1 *Preparation of Test Panels*:

6.1.1 Unless otherwise specified, test panels shall be 40 by 190 by 395-mm (1½ by 7½ by 15½-in.) masonry units made from standard lightweight concrete block, having an apparent specific gravity of 1.60 to 1.62.

6.1.2 One face only of the test panel shall be coated with the complete system, in a vertical position. The filler shall either comply with U.S. Federal Specification TT-F-1098 or be the material specified and supplied by the manufacturer. The filler coat shall be applied in conformance with the manufacturer's printed directions for surface preparation, mixing, application, coverage, and curing time under standard conditions of temperature and humidity.

7. Liquid Coating Properties

7.1 *Skinning*—Coatings that contain a binder that dries by oxidation may be subject to skin formation in a partially filled can. Since skins are insoluble in the material they must be removed before use. The referenced test in a partially filled container indicates the tendency of the material to skin. A typical minimum time for skinning in accordance with this method is 48 h. Examine the original sample for skins, both on and below the surface. Using a well-mixed skin-free portion of the sample, perform a skinning test in accordance with Guide D 154, Section 10.

7.2 *Condition in Container*—Thickening, pigment settling, and separation are undesirable and objectionable if a coating, 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 and lists characteristics that are undesirable and objectionable in a stored coating. Determine the condition in the container in accordance with Method 3011 of Federal Test Method Standard No. 141.

[7] *Annual Book of ASTM Standards*, Vol 04.07.
[8] *Annual Book of ASTM Standards*, Vol 14.02.
[9] Available from U.S. Government Printing Office Superintendent of Documents, 732 N. Capitol St., NW, Mail Stop: SDE, Washington, DC 20401.

7.3 *Coarse Particles and Foreign Matter*—Liquid coatings must be free of coarse particles and foreign matter to be able to form uniform films of good appearance, a typical maximum being 0.5 weight % of the total material. The referenced method with a 325-mesh (45-µm) screen gives the percent of these particles. Determine content of coarse particles and foreign matter in accordance with Test Methods D 185, Section 10, except using methyl ethyl ketone, xylene or other appropriate solvent as agreed upon between the manufacturer and the purchaser.

7.4 *Density or Weight per Gallon*—The density measured in pounds per gallon (kilograms per litre = g/mL) is used to ensure product uniformity from batch to batch, provides a check against the theoretical weight calculated from the formula, and is useful for determining the similarity of two samples. The referenced method gives a procedure for measuring the density of the coating at a specified temperature. Most coatings have densities of about 10 to 12 lb/gal (1.2 to 1.4 kg/L). Determine density in accordance with Test Method D 1475, using a calibrated weight per gallon cup.

7.5 *Fineness of Dispersion*—Generally, the more finely a pigment is dispersed the more effectively it is being utilized. One method for measuring the degree of dispersion (commonly referred to as "fineness of grind") is to draw the liquid coating down a calibrated tapered groove varying in depth from 4 to 0 mils (100 to 0 µm) (0–8 Hegman units). The depth at which continuous groupings of particles or agglomerates, or both, protrude through the surface of the wet film is taken as the fineness of dispersion value. Higher readings in Hegman units or lower readings in mils or micrometres indicate finer dispersion. A typical fineness requirement for HIPAC is 1.5 mils (5 Hegman or 40 µm). Determine fineness of dispersion in accordance with Test Method D 1210.

7.6 *Odor*—Some solvent combinations produce obnoxious odors, particularly when painting indoors with inadequate ventilation and at elevated temperatures. Although not specifically designed for liquid coatings, Test Method D 1296 may be used with the solvent-reducible type. (**Warning—**Even though the odor may be pleasant, the fumes may be dangerously toxic.)

7.7 *Flash Point*—Organic solvents used in coatings 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 U.S. Occupational Safety and Health Act (OSHA). Determine the flash point in accordance with Part B of Test Methods D 93 or Test Methods D 3278.

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

7.9 *Volatile Content (Weight Percent)*—Calculate the volatile content of the coating by difference after determining the nonvolatile content in accordance with Test Methods D 2369.

7.10 *Free Diisocyanate Content*—It is generally recognized that diisocyanate vapors from polyurethane-type HIPAC coatings are potential health hazards. Therefore, the free diisocyanate content of urethane coating systems must be controlled at an acceptable maximum level, the present accepted maximum being 0.5 % based on total coating weight, which is applicable only to toluene diisocyanate (TDI) and hexamethylene diisocyanate (HMDI). It has not been shown that this level is applicable to all diisocyanates. Determine free toluene diisocyanate content in accordance with Test Method D 3432. See Note 1 in Test Method D 3432 about other diisocyanates.

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

7.11.1 *Heat Stability*—Exposure to high temperatures can be used to test for the stability of a packaged coating that frequently encounters such conditions in service, or as an accelerated test to predict stability at normal temperatures. Although indications of long term package stability can usually be obtained in several days or weeks at an elevated temperature, such as 125 °F (50 °C) or 140 °F (60° C), occasionally the results of the accelerated test do not agree with those at prolonged normal storage conditions. In the referenced method the changes in consistency and certain other properties of the accelerated aged material are compared to those occurring in a control kept at normal temperatures for a longer period. When testing for heat stability, as such, changes in viscosity, flow, gloss, foam resistance, color uniformity, and wet adhesion are usually checked. Determine heat stability in accordance with Test Method D 1849.

7.11.2 *Settling*—Modern coatings are generally resistant to hard settling, but do at times show separation and soft settling. The referenced method covers the degree of pigment suspension in and ease of remixing of a shelf-aged specimen to a homogeneous condition suitable for the intended use. Determine settling in accordance with Test Method D 869.

8. HIPAC Application and Film Formulation

8.1 *Application Properties*—Application or working properties of a coating are generally compared to a standard or described by requirements in the product specification. Determine working properties in accordance with Method 4541 of Federal Test Method Standard No. 141.

8.1.1 *Brush Application*—Brushed films should be smooth and free of seeds and on vertical surfaces should show no sagging, color streaking, or excessive brush marks. Brush drag should not be excessive although some degree of drag may be desirable for adequate film thickness application. Wall finishes are tested on vertical surfaces and floor coatings on horizontal surfaces, although evaluation of the latter on vertical surfaces

may be necessary to determine performance on stair risers, railings, posts, etc. The referenced method covers a means for the determination of the brushing properties of a coating. Even though the test is subjective, someone experienced in the art can produce quite consistent results. Determine brushing properties in accordance with Method 2141 of Federal Test Method Standard No. 141.

8.1.1.1 *Brush Drag*—As the brush drag (resistance encountered when applying a coating by brush) increases, any natural tendency of the painter to overspread the material is reduced. All other factors being constant, increased brush drag results in greater film thickness with consequent improvements in hiding and film durability. Conversely, increasing brush drag too much can cause difficulties in spreading the coating easily and uniformly, leading to excessive sagging, prolonged drying time and, in highly-pigmented coatings, possibly to "mud-cracking" due to excessive thickness. The referenced method covers the determination of relative brush drag of a series of coatings applied by brush by the same operator. The coatings in a series, however, must be all of the same type—either water-borne or solvent-borne. It has been established that the subjective ratings thus obtained correlate well with high-shear viscosities obtained instrumentally using Test Method D 4287 (see 8.2.2), provided that the materials differ in viscosity by at least 0.3 poise (0.03 Pa.s). Determine brush drag ratings in accordance with Test Method D 4958.

8.1.2 *Roller Application*—Both wall and floor coatings are frequently applied by roller. This type of application tends to produce some stipple pattern. The referenced method covers the evaluation of a material's characteristics when applied by roller. Since foaming often occurs when water-borne coatings are roller applied, the amount of foam produced, and the number of craters that remain after the bubbles have broken should be determined during the test. Determine roller coating properties in accordance with Method 2112 of Federal Test Method Standard No. 141.

8.1.2.1 Some coatings spatter more than others when applied by roller. The degree to which a material spatters when roller applied can be determined by the density of the spatter. In the referenced method a specially designed notched spool is rolled through a film of the test material that has been applied to a plastic panel. Any spatter generated falls upon a catch paper and after drying is rated against photographic standards. This procedure eliminates the influence of the roller cover, thus determining the spattering characteristics of the paint alone. Determine spatter resistance in accordance with Test Method D 4707.

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

8.2 *Rheological Properties*:

8.2.1 *Consistency (Low-Shear Viscosity)*—Consistency is important, relating to application and flow, and should fall within a stated range for satisfactory reproduction of a specific formula. While consistency is an important property it does not determine the quality of a coating and should be used mainly to ensure product uniformity. In the referenced method, consistency is defined as the load in grams to produce a specified rate of shear. The load value is frequently converted to Krebs units (KU) and the Stormer consistency reported on that basis. A typical range is 85 to 135 KU for base coats and 70 to 95 KU for glaze coats. Two coatings of the same consistency may have quite different rheological properties during application. Determine consistency in accordance with Test Method D 562.

8.2.2 *Rheological Properties of Non-Newtonian Materials*—Rheological properties are related to application and flow characteristics of the liquid coating. The referenced methods cover the determination of rheological properties and are particularly suited for coatings that display thixotropic characteristics. However, they measure viscosity under different shear rates. In Test Method D 4287 there is only one rate but it is similar to that occurring during brush application so that the measured viscosity is related to brush drag, spreading rate, and film build. Test Method D 2196 includes procedures for measuring viscosity at several shear rates to determine the amount of shear thinning and the viscosity change at low shear rates. The results can be used to evaluate sag resistance and leveling ability. Determine rheological properties in accordance with Test Methods D 2196 or D 4287, or both.

8.2.3 *Sag Resistance*—Some coatings sag and form curtains before the film sets. Resistance to this type of flow is an important property particularly for semigloss and gloss finishes because of the unsightly film appearance. Determine sag resistance in accordance with Test Methods D 4400.

8.2.4 *Leveling Properties*—Leveling is an important property when smooth, uniform surfaces are to be produced, because it affects hiding and appearance. Brush marks and imperfections are much more conspicuous in semigloss and gloss finishes than they are in low gloss materials. In the referenced method a series of ridges is produced using a leveling rod and after drying they are compared to levelness standards. Determine leveling in accordance with Test Method D 4062.

8.3 *Curing Properties*—The cure of a HIPAC system is governed by the composition of the coating and by atmospheric conditions during cure. Insufficient cure may result in poor stain and abrasion resistance. Typical cure times are between 3 and 21 days depending upon the system. There are no applicable ASTM or Federal test methods to measure cure of HIPAC systems. However, one commonly used procedure is as follows:

8.3.1 A cloth saturated with methyl ethyl ketone, mineral spirits, xylene or other solvent agreed upon between the manufacturer and the purchaser is wrapped around the finger and rubbed back and forth for a given number of double rubs. Curing time or the degree of cure at a given time is determined in this manner.

8.4 *Wet-Film Thickness*—Measurement of wet film thickness is useful in calculating spreading capacity or adjusting application to an agreed upon square feet per gallon or square metres per litre. Determine wet film thickness in accordance with Test Methods D 1212.

8.5 *Touch-Up Uniformity*—Coatings applied to large, flat surfaces may exhibit localized areas of noticeably different appearance due to variation in film thickness, different methods of application, or localized damage in service. With a coating of suitable touch-up properties, additional material of the same batch or lot can be applied only to these localized areas to provide uniformity of color, gloss, and levelling over the entire surface. Determine touch-up properties in accordance with Test Method D 3928.

9. Appearance of Dry Coating

9.1 *Color Difference*:

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

9.1.2 *Color Differences by Visual Comparison*—Visual comparison of colors is fast and often acceptable although numerical values are not obtained. The referenced method covers the spectral, photometric, and geometric characteristics of light source, illuminating and viewing conditions, sizes of specimens, and general procedures to be used in the visual evaluation of color differences of opaque materials relative to their standards. Determine color differences in accordance with Practice D 1729.

9.1.3 *Color Differences Using Instrumental Measurements*—The difference in color between a product and its standard can be measured by instrument. Generally the tolerance is agreed upon by the purchaser and seller and may also be required if a product specification is involved. Color measuring instruments provide numerical values that can be compared to subsequent measurements. The referenced method covers the calculation of instrumental determinations of small color differences observable in daylight illumination between nonfluorescent, nonmetameric, opaque surfaces such as coated specimens. If metamerism is suspected, visual evaluation (see 9.1.2) should be used to verify the results. Calculate in accordance with Practice D 2244 the color differences that have been measured instrumentally.

9.2 *Directional Reference*—This property is a measure of the appearance of lightness of a coating. It is usually assigned a value in specifications for white and pastel shades, a typical range being 76 to 86 % for white finishes. In the referenced method the directions of illumination and viewing are specified so as to eliminate the effect of gloss. Determine daylight directional reflectance in accordance with Test Method E 1347.

9.3 *Gloss, 60°*—Semigloss HIPAC coatings are particularly sensitive to loss of gloss due to differential absorption on some surfaces. This is often controlled by testing the gloss of a system applied over a nonabsorbent substrate such as glass and an absorbent surface like gypsum board. Determine the specular gloss on appropriate substrates in accordance with Test Method D 523.

9.4 *Hiding Power*:

9.4.1 Hiding power is a measure of the ability of a coating to hide the substrate. However hiding power of a white coating is inversely related to its reflectance so that it decreases with increasing directional reflectance. Hiding power is expressed as area covered per unit volume of coating to produce a reflectance over a black surface that is 98 % of the reflectance over a white surface (contrast ratio of 0.98).

9.4.2 Test Method D 2805 is precise and gives an absolute rather than a comparative result. Coating is applied with an applicator bar to minimize the effects of flow and leveling, film thickness is rigorously measured, and film opacity is determined instrumentally. Test Method D 344 is a practical test in which material is applied with a brush, wet-film thickness is approximately controlled by spreading rate, and hiding power is evaluated visually by comparison with a standard coating, but results are affected by flow and leveling of the materials. Determine hiding power in accordance with Test Methods D 344 or D 2805.

9.4.3 Determine hiding power by one of the above methods consistent with the degree of importance attached to this parameter.

9.5 *Yellowness Index*—The referenced method is used for white or near white specimens to determine color departure from white toward yellow when first applied. Determine the yellowness index in accordance with Practice E 313.

10. Properties of Dry Coatings

10.1 *Abrasion Resistance*—Abrasion resistance is a measure of the ability of a dried film to withstand wear from foot traffic and marring from objects rolled or pulled across the surface. Wear resistance of HIPAC is one of the outstanding qualities that distinguish them from ordinary interior wall and trim enamels. In the referenced method a weighted wheel with abrasive embedded in a resilient rubber matrix is applied to a coated panel. Determine abrasion resistance in accordance with Test Method D 4060.

NOTE 1—Because of the poor reproducibility of abrasion test methods, testing should be restricted to only one laboratory when numerical abrasion resistance values are to be used. Interlaboratory agreement is improved significantly when rankings are used in place of numerical values.

10.2 *Adhesion*—Adhesion, the ability of a film to resist removal from the substrate, is an important property of a coating. In the referenced method a metal stud is adhered to the coating surface with an adhesive and after curing a portable testing apparatus is attached to the stud and a perpendicular force is applied and increased until either the coating is detached, a specified value is reached, the substrate fails cohesively, or the adhesive fails at its interface with the coating or the stud. Determine pull-off strength (commonly referred to as adhesion) in accordance with Test Method D 4541.

10.3 *Impact Resistance*—An important property of HIPAC coatings is their ability to withstand impact when objects are accidentally knocked against them. Determine impact resistance in accordance with Test Method D 2794, except use zinc phosphate-treated steel panels. Some materials, such as urethanes, require a wash primer or an epoxy primer to give the adhesion needed for this test. Apply top or glaze coat(s) at a

minimum dry-film thickness of 75 mm (3 mils) and examine the surface of the impacted coated area under 7× magnification for cracking and crazing of the coating immediately after testing and 72 h after the test.

10.4 *Chemical Resistance*—An important property of a HIPAC system is its ability to resist spotting, softening, or removal when subjected to household chemicals or strong cleaners. There is no applicable ASTM or Federal test method specifically designated for measuring resistance of HIPAC systems to chemical and cleaning agents, but Test Method D 1308 has been modified as follows: Prepare 5 weight % solutions of sodium hydroxide, sodium hypochlorite, detergent, hydrochloric acid, sodium phosphate, and sulfuric acid. For each solution saturate a small piece of absorbent cotton, place them on the cured surface, and cover with a 25-mm watchglass. After 4 h, remove, blot dry, allow to recover for 24 h, and examine the exposed surface of the coating for evidence of softening or wrinkling.

10.5 *Washability and Cleansability*—The capability of satisfactorily removing marks without damaging the film is essential for good performance of interior finishes. A coating may be washable, that is, unaffected by the detergent solution, but may not have good cleansability. Frequently the difference between the two terms, "cleansability" and "washability," is not clearly understood so that there is confusion as to what is really being tested; for example, the title of Test Method D 3450. Cleansability is evaluated by applying one or more stains and soils and determining how readily they are removed. Washability is evaluated by determining the resistance of the film to wet erosion either by visual assessment or measured film loss. In general, the precision of both types of test is poor because several properties, such as hardness, water and detergent resistance, cohesion and adhesion, are involved and the endpoint, except for the wet abrasion method, is rather indefinite.

10.5.1 *Washability (Also Referred to as Scrubbing or Wet Abrasion Resistance)*—The scrubbing method, Test Methods D 2486, developed for interior latex flat wall paints can be applied to coatings of almost any type. In it the coating is applied to a black plastic panel that, during scrubbing with a nylon brush and abrasive cleaning agent, is raised by a narrow shim to concentrate the test area. The number of back-and-forth strokes (cycles) required to remove the film over the shim is determined. HIPAC are expected to withstand at least 4000 cycles. The wet-abrasion method, Test Method D 4213, is similar except that a sponge is used in place of the bristle brush while the shim is not used. The weight or volume loss per 100 cycles to erode the film almost to exposure of the black substrate is the measure of scrub resistance. Evaluate washability, as just described, in accordance with Test Methods D 2486 or D 4213, except apply the coating system in conformance with the manufacturer's printed directions for surface preparation, mixing, application, and curing time (usually 21 days) under standard conditions.

NOTE 2—The washability and cleansability tests covered by the four referenced methods were previously conducted on cement-asbestos board, thus intending to simulate the type of cementitious substrate on which these coatings are commonly used. In view of the difficulty in obtaining this board, the black plastic panels specified in the tests were substituted on the basis of comments from a manufacturer that no attack had been observed with various epoxy and polyurethane coatings. In cases where solvent attack is likely, the purchaser and the seller should agree on the test panel to be used. Deformation of the panel or wrinkling and blistering of the coating are indications of solvent attack.

10.5.2 *Cleansability*—The older referenced method, Test Method D 3450, is similar to the wet-abrasion method, Test Method D 4213, except that the sponge is used with either the nonabrasive or abrasive cleaning agent to remove a carbon black-oil stain. The ability to remove the stain is expressed as the ratio (in percent relative) of the reflectance of the cleaned area to that of the area before application of the stain. In Test Method D 4828, referred to as a "practical" test, numerous staining and soiling agents found in service and commercial abrasive or nonabrasive cleaners as well as the standardized cleaning agents can be used. In the revised edition the film may be cleansed manually or mechanically but only the latter is suitable for interlaboratory testing. Evaluate ease of removability in accordance with Test Methods D 3450 or D 4828.

10.5.3 *Coating Application*—Coat a test panel approximately 300 by 100 mm (12 by 4 in.) with the complete system of the product under test, applying the glaze or top coating to at least 75-mm (3-mils) dry-film thickness is not more than two coats. Allow to cure under standard conditions for the time specified by the manufacturer but not more than 21 days.

10.6 *Mildew Resistance*—Since HIPAC coatings may be used in food processing plants and locations of high humidity, they should be resistant to mold growth on the surface. For this test, an environmental chamber is needed. Determine the resistance to mold growth in accordance with Test Method D 3273.

10.7 *Perspiration Resistance*—HIPAC coatings can sometimes come in contact with perspiration that could stain the coating. There are no ASTM test methods to measure perspiration resistance of HIPAC systems but where considered important the following method can be used:

10.7.1 Prepare synthetic perspiration fluid having the following composition by weight:

Urea	1.30
K_2CO_3	0.11
$Na_2SO_4 \cdot 10\ H_2O$	0.65
NaCl	2.71
Acetic acid (5 % solution)	1.08
H_2O	10.85
Anhydrous lanolin	83.30

10.7.1.1 Dissolve the urea and inorganic salts in the acetic acid solution and water. Heat the lanolin to 45°C and add the solution to form an emulsion. Combine with a dye and wetting agent in the following proportions:

Scarlet red	0.1
Methanol	3.7
Wetting agent	3.8
Synthetic perspirant	92.4

10.7.1.2 Dissolve the dye in the methanol, then mix with the wetting agent and synthetic perspirant. Apply an excess of the mixture to a small area of a test panel, using a 25 mm (1 in.) wide artist's brush. Cover with a 25-mm watchglass and place the panel in an oven at 120 ± 3.5°F (49 ± 2°C), for 4 h. Remove the panel and allow to cool at room temperature for 1 h. Wipe off the excess with a soft dry cloth. If the stain is not completely removed, subject the panel to not more than 25 cycles of the washing procedure described in Method 6141 of Federal Test Method Standard No. 141. Examine the film under 7× magnification for stain retention.

10.8 *Heat and Cold Resistance*—Buildings can undergo cycling of temperatures that could, through differential thermal expansion between the coating and the masonry substrate, cause failure. There are no applicable ASTM or Federal test methods specifically designated for measuring resistance of HIPAC systems to cold and heat cycles but Test Method D 1211 has been modified as follows:

10.8.1 Place coated panels of the substrate of interest in a cold chamber maintained at 5°F (−21°C) for 1 h. Remove and immediately place in an oven maintained at 120°F (49°C) for 1 h. Repeat this cycle 10 times and examine the coating for cracks, checks, or other defects.

10.9 *Heat and Humidity Resistance*—HIPAC coatings can be subjected to environmental conditions where high heat and humidity are present. There is no applicable ASTM or Federal test method specifically designated for measuring resistance of HIPAC systems to heat and humidity but Practice D 4585 has been modified as follows:

10.9.1 Coat panels with the complete system and expose to an environment of 95 % relative humidity minimum and 100°F for seven days on the cabinet, or as agreed upon between the manufacturer and the purchaser. Determine the 60-deg gloss before and after by Test Method D 523 and color change by Practice D 2244.

10.10 *Fire Hazards*—For some uses HIPAC coatings should not increase the fire hazard. Where required, determine flame spread and smoke development ratings in accordance with Test Method E 84.

10.11 *Dry-Film Thickness*—Measure total dry film thickness from the top of the substrate to the top of the applied coating system. When applied to steel, use Test Methods D 1186. When applied to nonmagnetic surfaces, use Test Methods D 1005 or D 1400 if the surface is plain and rigid.

11. Keywords

11.1 high performance; HIPAC; industrial maintenance; maintenance, industrial