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Standard Specification for Pyrolytic and Vacuum Deposition Coatings on Flat Glass[1]

This standard is issued under the fixed designation C1376; 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 specification covers the optical and aesthetic quality requirements for coatings applied to glass for use in building glazing.

1.2 The coatings covered are applied to the glass using either pyrolytic or vacuum (sputtering) deposition methods and are typically applied to control solar heat gain, energy performance, comfort level, and condensation and enhance the aesthetic of the building.

1.3 This specification addresses blemishes related to the coating only. It does not address glass blemishes, applied ceramic frits, and organic films.

1.4 The values stated in inch-pound units are to be regarded as standard. The values given in parentheses are mathematical conversions to SI units that are provided for information only and are not considered standard.

2. Referenced Documents

2.1 Reference to these documents shall be the latest issue unless otherwise specified by the authority applying this specification.

2.2 *ASTM Standards:*[2]

C162 Terminology of Glass and Glass Products

C1036 Specification for Flat Glass

C1048 Specification for Heat-Strengthened and Fully Tempered Flat Glass

D2244 Practice for Calculation of Color Tolerances and Color Differences from Instrumentally Measured Color Coordinates

3. Terminology

3.1 *Definitions*—Refer to Terminology C162, Specification C1036 or Specification C1048 as appropriate:

3.1.1 *blemishes in flat glass*—refer to Specifications C1036 or C1048, as appropriate.

3.1.2 These definitions do not apply to in-service damage.

3.2 *Definitions of Terms Specific to This Standard:*

3.2.1 *coated overhead glass*—glass used in an installation in which the lower edge of the glass is more than 6 ft (1.8 m) above (the viewer's) floor level or cannot be approached within 10 ft (3.0 m); the glass can usually but not always be viewed in both transmission and reflection; the glass is usually sloping in from the vertical plane, however, may also be vertical or sloping out from the vertical plane.

3.2.2 *coated spandrel glass*—glass used in an installation in which the glass is only viewed in reflection from the building's exterior. The glass is usually installed vertically, however, may be at a slope to the vertical plane.

3.2.3 *coated vision glass*—glass used in an installation in which the lower edge of the glass is a maximum of 6 ft (1.8 m) above (the viewer's) floor level; the glass can be viewed in transmission or reflection; the glass is usually vertical, however, may also be sloping in or out from the vertical plane; and the glass can be approached within 10 ft (3.0 m) or less. (If the distance is greater than 10 ft (3.0 m), see coated overhead glass.)

3.2.4 *coating rub*—a surface abrasion of appreciable width that has partial, or complete, removal of the coating producing a hazy appearance.

3.2.5 *coating scratch*—partial, or complete, removal of the coating along a thin straight or curved line.

3.2.6 *corrosion*—change in the color or level of reflected or transmitted light over all or part of the glass surface as a result of degradation of the coating from external sources.

3.2.7 *crazing*—a random conglomeration of fine lines or cracks in the coating.

3.2.8 *cut size*—flat glass sheets cut to specific dimensions.

3.2.9 *mark/contaminant*—a deposit of foreign material on the glass surface.

3.2.10 *nonuniformity*—obvious variation in reflected color of the coating within a lite of glass or between two lites of coated glass in the same building, or both.

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

3.2.10.1 *banding*—wide or narrow areas of nonuniformity with demarcation that appears as a linear line and may occur anywhere on a lite.

3.2.10.2 *edge to edge*—gradient nonuniformity within a lite of glass.

3.2.10.3 *lite to lite*—nonuniformity between individual lites.

3.2.10.4 *mottling*—splotchy or patchy nonuniformity (not to be confused with strain pattern inherent to heat-treated glass or in-service staining, or both, or damage of glass).

3.2.10.5 *picture framing*—perimeter nonuniformity.

3.2.11 *pinhole*—small area in which the coating is entirely or partially absent.

3.2.12 *pyrolytic*—term used to describe a method of manufacture of a coating. Process applies the coating to hot glass, usually at the time of flat glass manufacturing.

3.2.13 *spot*—a small, opaque blemish in the coating.

3.2.14 *stock size*—flat glass sheets cut to standard dimensions that will be cut to smaller sizes in future use.

3.2.15 *vacuum deposition*—term used to describe a method of manufacture of a coating. The process applies the coating in a vacuum chamber to flat glass.

3.2.16 *vacuum sputtering*—see *vacuum deposition.*

4. Significance and Use

4.1 This specification groups coated glass according to application. These groups are: vision, spandrel/nonvision, and overhead. Similar but unique quality tolerances and inspection guidelines have been outlined for each application. The glass to be coated shall comply with the applicable provisions of Specifications C1036 and C1048.

4.2 Coating blemishes are an inherent part of the glass-coating process. In addition, coatings can be damaged as a result of improper transportation, storage, handling, fabrication, or installation.

4.3 Individual manufacturers should be contacted for recommended handling, fabrication, installation, and application guidelines.

5. Classification

5.1 *Kinds*—Coated flat glass furnished under this specification shall be of the following kinds, as specified:

5.1.1 *Kind CV*—Flat transparent glass conforming to the applicable requirements of Specification C1036 or C1048, or both, and having a coating applied to one or more of the glass surfaces which further conforms with the requirements hereinafter specified for coated vision glass.

5.1.2 *Kind CO*—Flat transparent glass conforming to the applicable requirements of Specification C1036 or C1048, or both, and having a coating applied to one or more of the glass surfaces which further conforms with requirements hereinafter specified for coated overhead glass.

5.1.3 *Kind CS*—Flat glass conforming to the applicable requirements of Specification C1036 or C1048, or both, and having a coating applied to one or more of the glass surfaces that further conforms with the requirements hereinafter specified for coated spandrel glass.

6. Requirements

6.1 *Blemishes for Coated Vision Glass*—The type and number of blemishes shall be no greater than those specified in Table 1.

6.2 *Blemishes for Coated Overhead Glass*—The type and number of blemishes shall be no greater than those specified in Table 2.

6.3 *Blemishes for Coated Spandrel Glass*—The type and number of blemishes shall be no greater than those specified in Table 3.

6.4 *Nonuniformity for Coated Glass*—The phenomenon of nonuniformity in coated glass may be visible within an individual lite, or between lites of glass, in a particular building or curtain wall. Consultation with suppliers and viewing full size mock-ups under typical site conditions and surrounding landscape is highly recommended before construction.

6.4.1 The scientific nature of controlling gas flow, electrical charges, and coating layer densities require production tolerances for light transmittance, reflectance, and color of coated glass products. Glass within allowable production tolerances may yield differences in reflected color or intensity of light transmittance or reflectance, or both. Perceivable differences are not immediate cause for rejection.

6.4.2 Glass should be viewed as installed and from the exterior of the building in daylight for color uniformity comparison. Coating nonuniformity may occur from lite to lite in a building (see Appendix X1). It may also occur within a lite in the form of edge-to-edge gradation, banding, mottling, or

TABLE 1 Quality Specifications for Cut Size Coated Vision Glass (Kind CV)[A]

Blemish[B,C]	Central Area, in. (mm)[D]	Outer Area, in. (mm)[D]
Pinhole	1/16 (1.6) max	3/32 (2.4) max
Spot	1/16 (1.6) max	3/32 (2.4) max
Coating scratch	2 (50) max length	3 (75) max length
Mark/contaminant	2 (50) max length	3 (75) max length
Coating rub	none allowed	length plus width not to exceed 3/4 (19)
Crazing	none allowed	none allowed
Corrosion	none allowed	none allowed

[A] These specifications apply to cut size glass only. For specifications of stock size glass, and blemishes not listed, contact the manufacturer.
[B] The glass shall be inspected, in transmission, at a distance of 10 ft (3.0 m) at a viewing angle of 90° to the specimen against a bright uniform background. If a blemish is readily apparent under these viewing conditions, the above criteria applies.
[C] No more than two readily apparent blemishes are allowed in a 3-in. (75-mm) diameter circle, and no more than five readily apparent blemishes are allowed in a 12-in. (300-mm) diameter circle.
[D] The central area is considered to form a square or rectangle defined by the center 80 % of the length and 80 % of the width dimensions centered on a lite of glass. The remaining area is considered the outer area.

TABLE 2 Quality Specifications for Cut Size Coated Overhead Glass (Kind CO)[A]

Blemish[B,C]	Central Area, in. (mm)[D]	Outer Area, in. (mm)[D]
Pinhole	3/32 (2.4) max	1/8 (3.2) max
Spot	3/32 (2.4) max	1/8 (3.2) max
Coating scratch	3 (75) max length	4 (100) max length
Mark/contaminant	3 (75) max length	4 (100) max length
Coating rub	length plus width not to exceed 3/4 (19)	Length plus width not to exceed 3/4 (19)
Crazing	none allowed	none allowed
Corrosion	none allowed	none allowed

[A] These specifications apply to cut size glass only. For specifications of stock size glass, and blemishes not listed, contact the manufacturer.
[B] The glass shall be inspected, in transmission, at a distance of 15 ft (4.6 m) at a viewing angle of 90° to the specimen against a bright uniform background. If a blemish is readily apparent under these viewing conditions, the above criteria applies.
[C] No more than two readily apparent blemishes are allowed in a 3-in. (75-mm) diameter circle, and no more than five readily apparent blemishes are allowed in a 12-in. (300-mm) diameter circle.
[D] The central area is considered to form a square or rectangle defined by the center 80 % of the length and 80 % of the width dimensions centered on a lite of glass. The remaining area is considered the outer area.

TABLE 3 Quality Specifications for Cut Size Coated Spandrel Glass (Kind CS)[A]

Blemish[B,C]	Range Number 1, in. (mm)[D]	Range Number 2, in. (mm)[D]
Pinhole	1/8 (3.2) max	5/32 (4.0) max
Spot	1/8 (3.2) max	5/32 (4.0) max
Coating scratch	3 (75) max length	6 (150) max length
Mark/contaminant	3 (75) max length	6 (150) max length
Coating rub	none allowed	length plus width not to exceed 3/4 (19)
Crazing	none allowed	none allowed
Corrosion	none allowed	none allowed

[A] These specifications apply to cut size glass only. For specifications of stock size glass, and blemishes not listed, contact the manufacturer.
[B] The glass shall be inspected, in reflection, at a distance equal to or greater than 15 ft (4.6 m) at a viewing angle of 90° to the specimen under uniform lighting conditions. If a blemish is readily apparent under these viewing conditions, the above criteria applies.
[C] No more than two readily apparent blemishes are allowed in a 3 in. (75-mm) diameter circle and no more than five readily apparent blemishes are allowed in a 12 in. (300-mm) diameter circle.
[D] The specifications separates glass by the distance that it will be viewed when installed. Range No. 1 is for all glass within a viewing distance of 15 ft (4.6 m) or less, and Range No. 2 is all glass viewed from a distance greater than 15 ft (4.6 m).

picture framing. In order to quantify color variation, measurements can be taken in the field with a handheld spectrophotometer.

6.4.3 Color non-uniformity is defined using ΔE*ab as defined in Test Method D2244 for CIE 1976 L*A*B*, Illuminant D65, and 10° Observer looking straight at the glass (normal incidence, or 90°, to the glass plane). Using a reference target established by the manufacturer, or the average color measurements as defined below, no color readings shall exceed a ΔE*ab of 4.5. If a manufacturer's color target is not used, the following procedure for establishing a reference shall be incorporated:

6.4.3.1 Using a mobile/handheld spectrophotometer, color readings will be taken and documented from the exterior of the building from ten units of like construction that have been installed in the same plane and elevation of the building and deemed to be acceptable by the manufacturer in terms of their appearance. If it is not physically practical or possible to measure ten units, as many units as possible shall be measured.

6.4.3.2 For lite to lite nonuniformity, establishing a reference will be done by taking a minimum of one reading per acceptable unit in the central area of each unit within ± 2 in. of geometric center. If access to the glass does not allow you to reach the geometric center, measure the glass as close to center as possible. Average the value of the readings taken on each of the units (ten minimum ideally) to determine the target for calculating ΔE*ab. Once the target has been established, take a measurement on the unit in question and calculate ΔE*ab.

6.4.3.3 For edge to edge, banding, mottling, or picture framing nonuniformity within a unit, readings shall be taken in locations within the lite representing areas of visual color difference. The ΔE*ab calculated between these measurements shall be less than 4.5.

6.4.4 Units may have a perceived color difference due to off-angle (non-normal incidence) viewing. This is particularly true with highly selective solar control coatings which are engineered to maximize visible light transmission and minimize infrared transmission. This angular color variation is not reason for rejection if the glass in question does not exceed the ΔE*ab of 4.5 using the normal incidence measurement procedure outlined above.

7. Keywords

7.1 coated glass; flat glass; glazing; nonuniformity; overhead glass; pyrolytic coating; spandrel glass; sputtered coatings; vacuum deposition coating; vision glass

APPENDIX

X1. SOURCES OF COLOR VARIATION

X1.1 Visual observation of color differences on the exterior of a building are subjective and vary from person to person. The perceived color variation in a building façade is affected by the following:

X1.1.1 Lighting conditions (overcast sky may increase color differences which are not visible in direct sunlight).

X1.1.2 Distance and angle of observation. Some coatings may show enhanced color variation when viewed at higher incidence angles.

X1.1.3 Internal conditions of the building. While under construction, the absence of lighting, blinds, and finished dry wall leads to a dark background and may enhance color variation.

X1.1.4 Surrounding area (shading or reflection of adjacent buildings).

X1.1.5 The standard only applies when comparing glass products of like construction utilizing the same coating. When using glass products of different construction utilizing the same coating type on a glass façade, there is the possibility to have color non-uniformity between the varying product types even though the coating is the same. These products include, but are not limited to:

X1.1.5.1 Insulating glass construction where various insulating makeups can introduce multiple glass panes (in other words, double vs. triple), various glass thicknesses, coating orientation (in other words, #2 surface vs. #3 surface), and air spacer thickness.

X1.1.5.2 Spandrel glass where materials may be used in direct contact with the coating or on the opposite surface (in other words, ceramic frits, opacifier film) or have materials placed behind the glass (in other words, shadow box) that will influence observed color and may enhance color variation.

X1.1.5.3 Laminated glass construction where various laminated constructions can introduce multiple glass plies, glass thicknesses, coating surface orientation, and interlayer material and thickness.