



Designation: C1376 – 21

Standard Specification for Pyrolytic and Vacuum Deposition Coatings on Flat Glass¹

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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 to spandrel glass, and organic film opacifiers.

1.4 The *Nonuniformity for Coated Glass* requirements, given in 6.10, pertain to as installed in the building exterior glazing units of vertical and sloped orientations.

1.5 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.

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 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*:

3.1.1 Refer to Terminology C162 or Specification C1036 or C1048, as appropriate.

3.1.2 *blemishes in flat glass*—refer to Specification C1036 or C1048, as appropriate.

3.1.3 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/non-vision 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.

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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.

3.2.7 *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 *edge deletion*—the process of removing a portion of the vacuum deposition coating from the glass surface typically within 1 in (25 mm) or less of all edges before insulating or laminating the glass.

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

3.2.11 *nonuniformity*—obvious variation in reflected color of the coating within a lite of glass, or between two lites of coated glass of like construction that have been installed in the same plane and elevation in the same building, or both.

3.2.11.1 *banding*—wide or narrow area(s) of nonuniformity with demarcation that appears as a linear feature and may occur anywhere on a lite.

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

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

3.2.11.4 *mottling*—splotchy or patchy nonuniformity (not to be confused with strain pattern; see X1.1.5).

3.2.11.5 *picture framing*—perimeter nonuniformity within a lite of glass.

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

3.2.13 *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.

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

3.2.15 *stock size*—flat glass sheets cut to standard dimensions that will be cut to smaller sizes in a subsequent process.

3.2.16 *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.

3.2.17 *vacuum sputtering*—see *vacuum deposition*.

4. Significance and Use

4.1 This specification groups coated glass according to application. These groups are: vision, spandrel/non-vision, 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/non-vision glass.

6. Requirements

6.1 These specifications apply to cut size glass only. For specifications of stock size glass and blemishes not listed, contact the manufacturer.

6.2 All glass is to be inspected in transmission at a viewing angle of 90° to the specimen, using a bright uniform background with diffused daylight conditions, without direct sunlight. For factory inspection, the specimen shall be placed a minimum of 12 in. from the light source using uniform diffused background lighting with a minimum luminance of 1700 lux (160 foot-candles) and maximum of 2500 lux (230 foot-candles) measured at the center of the glass surface closest to the light source. If a blemish is readily apparent under these viewing conditions and detection distance as stated in 6.3, the criteria in Table 1, Table 2, or Table 3 applies for each kind of coated glass.

6.3 Defect detection distance for coated vision glass (*Kind CV*) is 10 ft. (3.0 m) and for coated overhead glass (*Kind CO*) and coated spandrel/non-vision glass (*Kind CS*) is 15 ft (4.6 m).

6.4 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.

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

Blemish	Central Area, in. (mm)	Outer Area, in. (mm)
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	length plus width not to exceed 2 in. (50) max	length plus width not to exceed 3 in. (75) max
Corrosion	none allowed	none allowed

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

Blemish	Central Area, in. (mm)	Outer Area, in. (mm)
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 1 (25)
Crazing	length plus width not to exceed 2 in. (50) max	length plus width not to exceed 3 in. (75) max
Corrosion	none allowed	none allowed

TABLE 3 Quality Specifications for Cut Size Coated Spandrel/Non-Vision Glass (Kind CS)

Blemish ^A	Range Number 1, in. (mm) ^B	Range Number 2, in. (mm) ^B
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	length plus width not to exceed 2 in. (50) max	length plus width not to exceed 5 in. (125) max
Corrosion	none allowed	none allowed

^A The glass shall be inspected, in reflection.

^B The specification 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).

6.5 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.

6.6 For coating edge deletion, the demarcation between where the coating was removed and where it still remains may be visible in the finished glazing unit and is not considered a defect. Any discoloration in the edge deleted area is also not considered a defect.

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

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

6.9 *Blemishes for Coated Spandrel/Non-vision Glass*—The type and number of blemishes shall be no greater than those specified in **Table 3** and only apply to the pyrolytic or vacuum deposition coating used in a spandrel/non-vision glass. See Specification **C1048** for inspection criteria and lighting conditions used in evaluating spandrel glass.

6.10 *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 begins. See **Appendix X1** for additional information.

6.10.1 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 visual differences in reflected color or intensity of light transmittance or reflectance, or both. Perceivable differences are not immediate cause for rejection.

6.10.2 Glass of the same kind and type should be viewed as installed on the same elevation and from the exterior of the building at a consistent angle in daylight for color uniformity comparison. Appearance nonuniformity may occur from lite to lite in a building. It may also occur within a lite in the form of edge-to-edge gradation, banding, mottling, haze, or picture framing.

6.10.3 *Color Survey*—Actual color of glazing can be measured with a hand held spectrophotometer and compared in order to remove the subjectivity of human eye evaluation. The color of glazing in question can be compared to the manufacturer's reference target (consult with the glass manufacturer) or to the onsite developed reference target (preferred method). The color difference equation ΔE^*_{ab} is defined in Test Method **D2244** for CIE 1976 $L^*a^*b^*$ Uniform Color Space. No glazing color measurement shall exceed a ΔE^*_{ab} of 4.0 when compared to the reference target color.

6.10.3.1 *Onsite Developed Reference Target*—Clean the exterior of the glazing in the area to be measured and take two color measurements about 12 in. apart in the central area or as close as reach will allow using a hand-held spectrophotometer (see **Note 1**). Avoid taking measurements within 2 in. of the daylight opening or sight line as this can affect the color measurement. Do this for a minimum of 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 there is uncertainty of acceptability, then more units shall be measured to obtain a better average of the units installed again adhering to like construction, in the same plane and elevation of the building. The average of all color measurements taken is used to determine the onsite developed reference target.

NOTE 1—Configured with built in sphere and $d/8^\circ$ measuring geometry, set the illuminant type to D65 and 10° observer with specular included turned on. Follow the spectrophotometer manufacturer's calibration procedure.

6.10.3.2 For lite to lite color nonuniformity, color measurements of glazing units in question shall be taken in the same way as described in **6.10.3.1**. The reference target color is used to calculate ΔE^*_{ab} for each individual measurement taken per unit.

6.10.3.3 For color nonuniformity within a unit, at least two color measurements in each area shall be taken from the exterior in locations within the unit representing areas of visual