Designation: C1048 – 18

Standard Specification for Heat-Strengthened and Fully Tempered Flat Glass[1]

This standard is issued under the fixed designation C1048; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

This standard has been approved for use by agencies of the U.S. Department of Defense.

1. Scope

1.1 This specification covers the requirements for monolithic flat heat-strengthened and fully tempered coated and uncoated glass produced on a horizontal tempering system used in general building construction and other applications.

1.2 This specification does not address bent glass, or heat-strengthened or fully tempered glass manufactured on a vertical tempering system.

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

1.4 The following safety hazards caveat pertains only to the test method portion, Section 10, of this specification: *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, health, and environmental practices and determine the applicability of regulatory limitations prior to use.*

1.5 *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:*[2,3]

C162 Terminology of Glass and Glass Products

C346 Test Method for 45-deg Specular Gloss of Ceramic Materials

C724 Test Method for Acid Resistance of Ceramic Decorations on Architectural-Type Glass

C978 Test Method for Photoelastic Determination of Residual Stress in a Transparent Glass Matrix Using a Polarizing Microscope and Optical Retardation Compensation Procedures

C1036 Specification for Flat Glass

C1203 Test Method for Quantitative Determination of Alkali Resistance of a Ceramic-Glass Enamel

C1279 Test Method for Non-Destructive Photoelastic Measurement of Edge and Surface Stresses in Annealed, Heat-Strengthened, and Fully Tempered Flat Glass

C1376 Specification for Pyrolytic and Vacuum Deposition Coatings on Flat Glass

E1300 Practice for Determining Load Resistance of Glass in Buildings

2.2 *ANSI Standard:*

Z97.1 Safety Performance Specifications and Methods of Test for Safety Glazing Materials Used in Buildings[4]

2.3 *Other Documents:*

CPSC 16 CFR 1201 Safety Standard for Architectural Glazing Materials[5]

GANA 01-0116 Proper Procedures for Cleaning Architectural Glass Products

3. Terminology

3.1 *Definitions*—For definitions of terms used in this specification, refer to Terminology C162 and Specification C1036.

3.2 *Definitions of Terms Specific to This Standard:*

3.2.1 *bow*—the deviation in flatness of a lite of glass, expressed over the entire width or length dimension of the glass or over a smaller, local area (see 10.7 for measurement technique).

3.2.2 *coating voids, condition B*—uncoated areas forming unintentional discernable irregularities in the intended flood coat, pattern, or image.

[1] This specification is under the jurisdiction of ASTM Committee C14 on Glass and Glass Products and is the direct responsibility of Subcommittee C14.08 on Flat Glass.

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

[3] 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.

[4] Available from American National Standards Institute, 25 W. 43rd St., 4th Floor, New York, NY 10036, and the Accredited Standards Committee Z97 website in electronic format at www.ansiz97.com.

[5] Available from Superintendent of Documents, U.S. Government Printing Office, Washington, DC 20402.

3.2.3 *edge curl (also edge lift, edge kink)*—an out-of-plane deformation near the physical leading and/or trailing edges of flat glass processed in a horizontal roller hearth furnace, observed as being concave or convex in nature.

3.2.4 *heat-treated glass*—a term used to reference both heat-strengthened and fully tempered glass.

3.2.5 *heat-treating*—the process of heating and cooling annealed glass in a tempering system to produce either heat-strengthened or fully tempered glass.

3.2.6 *opaque particle*—undispersed debris trapped in the coated surface.

3.2.7 *relief cut*—the removal of a narrow section of glass-from the glass edge to the rim of a glass hole intended to reduce breakage and stress concentrations during the fabrication and heat-treating process.

3.2.8 *scattered pinholes*—small light transmitting voids in applied ceramic frit coatings, requiring backlighting for visibility.

3.2.9 *screen mark (mesh mark)*—a mesh pattern left by a silk screen process in the applied ceramic glass enamel before or after firing.

3.2.10 *thermal stress*—stress caused by thermal gradients across the glass surface.

4. Classification

4.1 *Kinds*—Flat glass furnished under this specification shall be of the following kinds, as specified (see Section 6):

4.1.1 *Kind HS*—Heat-strengthened glass shall be flat glass, either transparent or patterned, in accordance with the applicable requirements of Specification C1036 as further processed to conform with the requirements hereinafter specified for heat-strengthened glass.

4.1.2 *Kind FT*—Fully tempered glass shall be flat glass, either transparent or patterned in accordance with the applicable requirements of Specification C1036 as further processed to conform with the requirements hereinafter specified for fully tempered glass.

4.2 *Conditions*—Glass furnished under this specification shall be of the following conditions, as specified (see Section 6):

4.2.1 *Condition A*—Uncoated surfaces.

4.2.2 *Condition B*—Fully or partially ceramic coated glass having a ceramic coating of a specified color, pattern, or image which has been fused onto and made an integral part of the surface of the glass as a result of the heat treating process.

4.2.3 *Condition C*—Other coated glass with a pyrolytic or vacuum deposition coating typically applied to affect characteristics such as solar heat gain, energy performance, comfort level, condensation, and the aesthetics of the building.

4.3 *Types, Classes, Forms, Qualities, and Finishes*—these are described in Specification C1036.

5. Intended Use

5.1 *Kind HS*—Heat-strengthened glass is used as architectural glazing when additional resistance to wind pressure and/or thermal stress is desired, but the strength or safety break pattern of fully tempered glass is not required. When broken, heat-strengthened glass fragments are more similar in size and shape to annealed glass fragments than to fully tempered glass particles, and thus tend to stay in the opening longer than fully tempered glass particles.

NOTE 1—**Caution:** Monolithic heat-strengthened glass is not suitable for safety glazing as defined by ANSI Z97.1 or CPSC 16 CFR 1201.

5.2 *Kind FT*—Fully tempered glass is used in architectural glazing applications when significant additional strength is needed to resist wind pressure, a mechanical load and/or thermal stress. When broken, fully tempered glass fractures (dices) into relatively small particles. Fully tempered glass with sufficient surface compression to meet the requirements of safety glazing standard such as CPSC 16, CFR 1201, or ANSI Z97.1 is considered a safety glass because it fractures into relatively small pieces thereby greatly reducing the likelihood of serious cutting or piercing injuries in comparison to ordinary annealed glass. For some applications, such as doors used for passage, tub and shower enclosures and fixed glass in close proximity to a walking surface, fully tempered safety glass is required by building codes and ordinances. Fully tempered safety glass is often used for other applications where its strength or safety characteristics, or both, are desirable such as table tops, counter tops, show case enclosures, refrigeration and food service equipment, furniture, and similar applications.

6. Ordering Information

6.1 Purchasers should select the preferred options permitted in this specification and include the following information in procurement documents:

6.1.1 Number, date, and title of this specification.

6.1.2 Kind, condition, type, class, style, form, quality, finish, and pattern of glass as applicable (see Section 4).

6.1.3 Fabrication requirements (see 7.7).

6.1.4 Requirements for fittings and hardware (see 7.1).

6.1.5 Glass thickness (see 9.1).

6.1.6 Non-rectangular shapes must be within the tolerances specified (see 9.3).

6.1.7 When surface or edge compression test is required for heat–strengthened or fully tempered glass (see 8.1.1).

6.1.8 When break safe characteristics are required for fully tempered glass (see 8.1.2).

6.1.9 Color or tint of glass (see 8.2).

6.1.10 When either permanent or temporary identification marking is required (see Section 11).

6.1.11 Coatings, color, pattern, percent coverage, or image for Condition B and Condition C glass (see 8.3 and 8.4).

6.1.12 When addition of fallout resistance capability is required for Condition A, Condition B, or Condition C glasses used as spandrels. (Normally achieved by adhering a reinforcing material to the glass surface.) (See 10.3.)

7. Properties and Fabrication of Heat-Treated Glass

NOTE 2—The stress distribution and fracture characteristics of heat-treated glass result in some unique properties and fabrication considerations for heat-strengthened and fully tempered glass. The information and guidelines in this section are meant to provide understanding and guidance to heat-treated glass users including, but not limited to, architects, owners, specifiers, consultants, and contractors.

7.1 *Distortion:*

7.1.1 Heat-strengthened and fully tempered glass is made by heating annealed glass in a tempering system to a temperature at which the glass becomes slightly plastic. Immediately after heating, the glass surfaces are rapidly cooled by quenching with air. The original flatness of the glass is slightly modified by the process, causing reflected images to be distorted. When viewing images through the glass, the distortion, in most glazing applications, is less than that of reflected images.

7.1.2 Heat-strengthened and fully tempered glass that has been produced in a horizontal tempering system may contain surface distortion (for example, picture framing, heat distortion or roller wave distortion). Distortion may be detected when viewing images in reflection or transmission and may be more noticeable at viewing angles other than perpendicular.

7.1.3 Pressures exerted around the periphery of glass by the glazing system can also alter glass flatness, thereby distorting reflected images. This is true regardless of whether the glass is annealed, heat-strengthened, or fully tempered.

7.1.4 Sealed insulating glass units also exhibit distortion regardless of glass type. Air or other gas, sealed in the gap between the lites of glass, expands or contracts with temperature and barometric changes, creating a pressure differential between the sealed gap and the atmosphere. The glass reacts to the pressure differential by being deflected inward or outward.

7.1.5 Regardless of glass flatness, the degree of reflected distortion perceived is largely due to the characteristics or symmetry of the object being reflected. Linear objects (such as building curtain walls and telephone poles) and moving objects (such as cars) may appear distorted. Irregular and free-form objects such as trees and clouds may appear to have less perceived distortion.

7.1.6 Specified bow limits may not adequately define, or control, the distortion that may become apparent after glazing. The factors, noted above, may have a larger influence on the perceived reflected distortion than that which is caused by bow from the heat-treating process. Consultation with suppliers and the viewing of full-size mock-ups, under typical job conditions and surroundings, is highly recommended for evaluation of reflective distortion.

7.2 *Strain Pattern*—A strain pattern, also known as iridescence, is inherent in all heat-strengthened and fully tempered glass. This strain pattern may become visible under certain polarized lighting conditions. It is a characteristic of heat-treated glass and should not be mistaken as discoloration, non-uniform tint or color, or a defect in the glass. The strain pattern does not affect any physical properties or performance values of the glass.

7.3 *Edge Curl (also edge lift, edge kink)*—Glass which is heat treated in a horizontal furnace may show some level of edge curl.

7.4 *Surface Particles*—The production of heat-strengthened and fully tempered glass involves the transport of very hot glass on conveyor rollers. As a result of this soft glass-to-roller contact, some glass surface changes will occur. Minute particles (fines), typically invisible to the naked eye, may adhere to one or both glass surfaces. These surface particles may occur from a variety of sources including, but not limited to, the glass cutting and edging process, typical manufacturing plant airborne debris or dust, refractory particles from the furnace roof, and external airborne dirt and grit carried into the plant by the large volumes of quench air used in the process. Particles on the furnace rollers may be picked up by the hot bottom surface of the glass as it travels over the particles. Surface particles invisible to the naked eye are inherent in the heat-treating process and are not a cause for rejection.

7.5 *Glass Cleaning*—Scrapers and/or razor blades shall not be used as part of a routine glass cleaning process because such use may result in scratches from dragging surface particles across the glass surface. In some cases the resulting scratches may only be visible under certain lighting conditions. It is important to use proper cleaning procedures when cleaning architectural glass products to avoid causing scratches; see GANA/IWCA 01-0116 Proper Procedures for Cleaning Architectural Glass Products.

7.6 *Resistance to Wind Load*—The structural performance and load-induced deflections of the glass under uniform load conditions shall be properly considered in relationship to the requirements of the application, and consistent with Practice E1300 as applicable.

7.7 *Fabrication*—Heat-strengthened and fully tempered glass can be furnished with holes, notches, cutouts, and bevels. Fabrication involving other methods of modification shall be discussed with the fabricator/manufacturer.

7.7.1 *Fabrication Guidelines*—Heat-strengthened and fully tempered flat glass cannot be cut after the heat-treating process. Fabrication altering the glass surface, thickness, or edges shall be performed before heat-treating to avoid a reduction of glass strength.

7.7.2 *Fittings and Hardware*—Requirements for fittings and hardware shall be as specified (see Section 6) or as shown on plans or drawings. Fittings and hardware specified shall be compatible with glass fabrication guidelines.

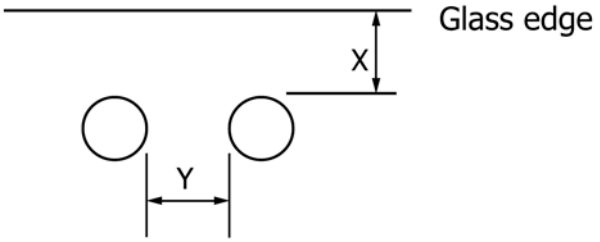
7.7.3 *Placement of Holes:*

7.7.3.1 The minimum distance from any edge of the glass to the nearest point on the rim of a hole shall be 6 mm (¼ in.) or two times the thickness of the glass, whichever is greater (see Fig. 1).

7.7.3.2 The minimum distance between the rims of adjoining holes shall be 10 mm (⅜ in.) or two times the thickness of glass, whichever is greater (see Fig. 1).

7.7.3.3 Holes near corners shall be located so that the nearest edge of the hole is a minimum of 6.5 times the thickness of the glass from the tip of the corner when the corner is 90° or more (see Fig. 2). When the corner is less than 90 or rounded, the minimum distance between the hole and the edge shall be maintained at minimum 6 mm (¼ in.) or two times the glass thickness, whichever is greater. Also may require the hole be located asymmetric with respect to the corner.

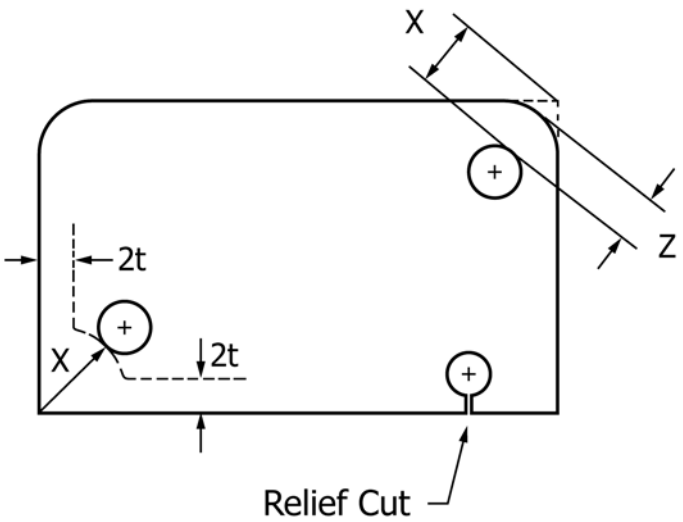
7.7.3.4 If a hole is placed closer to the edge than recommended, the risk of glass breakage increases substantially. This may be reduced by making a relief cut from the rim of the hole to the nearest edge prior to the heat treating process. Consult the glass fabricator and hardware supplier.



X = 6 mm (¼ in.) or 2t, whichever is greater
Y = 10 mm (⅜ in.) or 2t, whichever is greater

where:
X = Minimum distance between glass edge and rim of nearest hole,
Y = Minimum distance between rims of adjoining holes, and
t = Glass thickness.

FIG. 1 Location of Holes Near Edge



X = 6.5 * t
Z = 6 mm (¼ in.) or 2 * t, whichever is greater

where:
X = Minimum distance between glass corner and rim of nearest hole,
Z = Minimum distance between rim and hole and rounded corner, and
t = Glass thickness.

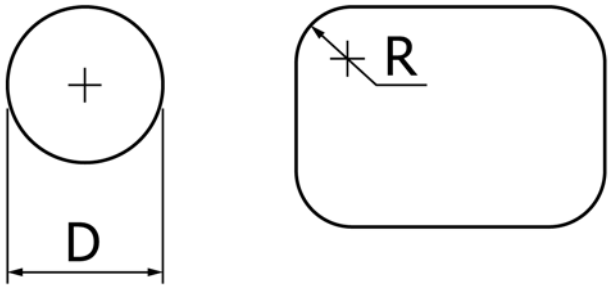
FIG. 2 Location of Holes Near Corners

7.7.4 *Minimum Dimension of Holes*—Circular holes shall have a minimum diameter of 6 mm (¼ in.) or the thickness of the glass, whichever is greater. In other than circular holes, any corners shall have fillets, the radius of which shall be equal to or greater than the thickness of the glass (see Fig. 3).

7.7.5 *Dimensional Tolerances of Holes:*

7.7.5.1 Tolerance of hole diameter shall be ±1.6 mm (1⁄16 in.).

7.7.5.2 Tolerance for dimensions of hole center from specified edges shall be ±1.6 mm (1⁄16 in.).



D = 6 mm (1/4 in.) or 1t, whichever is greater
R ≥ t

where:
D = Minimum diameter of a hole,
R = Radius, and
t = Glass thickness.

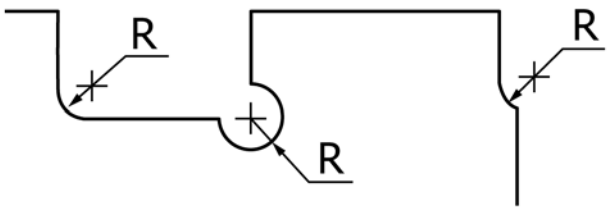
FIG. 3 Minimum Dimension of Holes

7.7.5.3 Tolerance for dimension between hole centers shall be ±1.6 mm (1⁄16 in.).

7.7.6 Chips and flakes at hole edges shall not exceed 3.2 mm (⅛ in.). Exception: chips and flakes at countersunk holes shall not exceed 0.8 mm (1⁄32 in.).

7.7.7 *Notches and Cutouts:*

7.7.7.1 Notches and cutouts shall have fillets, the radius of which shall be equal to or greater than the thickness of the glass (see Fig. 4).



R ≥ t

where:
t = thickness of glass, and
R = radius.

FIG. 4 Notch and Cutout Fillets

7.7.7.2 Dimensional tolerance of notches and cutouts shall be:

±1.6 mm (1⁄16 in.) for glass thickness less than 12 mm (½ in.)
±3 mm (⅛ in.) for glass thickness of 12 mm (½ in.) and greater

.

7.7.7.3 Inner surfaces of notches and cutouts shall be smooth, seamed, ground, or polished.

7.7.8 Consult manufacturer regarding heat-treatment of glass with irregular patterns, surface treatments, unusual edge work or any fabrication that falls outside these guidelines.

8. Other Requirements

8.1 *Strength Requirements:*

8.1.1 *Surface and Edge Compression Requirements* (see 10.8):

8.1.1.1 *Kind HS, Heat-Strengthened Glass*—Kind HS glass with thicknesses of 6 mm (¼ in.) and less shall have a surface compression between 24 to 52 MPa (3500 and 7500 psi). Surface compression testing, when required (see 6.1.7), shall be done in accordance with 10.8.

NOTE 3—Heat-strengthening of glass thicker than 6 mm (¼ in.) can be difficult. Consult the fabricator providing the heat-strengthened glass.

8.1.1.2 *Kind FT, Fully Tempered Glass*—Fully tempered glass shall have either a minimum surface compression of 69 MPa (10 000 psi) or an edge compression of not less than 67 MPa (9700 psi) or meet ANSI Z97.1 or CPSC 16 CFR 1201 in accordance with 10.9. Surface compression or edge compression testing, when required (see 6.1.7), shall be done in accordance with 10.8.

8.1.2 *Break Test Requirement for Fully Tempered Glass*—When specified (see Section 6), the break requirements of fully tempered glass shall be tested and interpreted in accordance with 10.9.

8.2 *Color or Tint*—The color or tint for each kind, type, class, style, finish, or pattern shall be as specified in 6.1.9 and as follows:

8.2.1 *Tint*—Heat-absorbing glass and light-reducing glass are available in a variety of tints. These types of glass vary in tint between different manufacturers and from melt to melt so some variation in tint may occur.

8.2.2 *Color or Tint Samples*—The request and particular purpose of any color or tint sample shall be stated in the invitation for bid. Glass samples are often supplied as annealed glass. Heat-treating may alter the color of certain glass products. Color variation may exist between annealed and heat-treated versions of the same glass product.

8.3 *Condition B*—Fully or partially ceramic coated glass, shall be heat-strengthened or fully tempered glass having a ceramic coating of a specified color, pattern, or image which has been fused onto and made an integral part of the surface of the glass as a result of the heat-strengthening or tempering process.

8.3.1 *Appearance*—When viewed in accordance with 10.10, scattered pinholes, voids, screen marks, and small opaque particles in the ceramic coating are not permissible. Alternative quality requirements may be established between the purchaser and fabricator when ordering.

8.4 *Condition C*—Other coated glass shall be heat-strengthened or fully tempered glass with a pyrolytic or vacuum deposition coating typically applied to affect characteristics such as solar heat gain, energy performance, comfort level, condensation, and the aesthetics of the building (see Specification C1376).

9. Dimension Requirements

9.1 *Thickness*—Substrates for heat-strengthened and fully tempered glass shall be in accordance with the thickness requirements of Specification C1036 and as specified therein (see Section 6). Available sizes and thicknesses of heat-strengthened and fully tempered glass are subject to the processing limitations of each tempering system. All thicknesses are not available in all conditions, types, and classes. Consult manufacturers or fabricators.

9.2 *Tolerance, Length, and Width for Rectangular Shapes for Conditions A, B, and C Glass*—See requirements in Table 1.

9.3 *Non-rectangular Shapes*—Unless otherwise specified (see Section 6), dimensional tolerances for non-rectangular shaped glass shall be specified and negotiated with the supplier. Consult the manufacturer or fabricator for tolerances.

9.4 *Flatness*—Because of the nature of the processes used in manufacturing heat-strengthened and fully tempered glass, these products are not as flat as annealed glass. The deviation from flatness depends on thickness, width, length, and other factors (see 7.1). Usually greater thicknesses yield flatter products (see 10.7).

9.4.1 *Localized Bow*—Localized bow for rectangular glass shall not exceed 1.6 mm (1/16 in.) over any 300 mm (12 in.) span when measured in accordance with 10.7.1.

9.4.2 *Overall Bow*—Overall bow shall not exceed the values shown in Table 2 when measured in accordance with 10.7.2.

10. Test Methods

10.1 *Expansion Fit Test for Ceramic Coating—Condition B, Fully or Partially Ceramic Coated Glass:*

10.1.1 *Test Specimens*—Prepare and test in accordance with Test Method C978.

10.1.2 *Test Results:*

10.1.2.1 The expansion match between the glass and ceramic coatings can influence the strength characteristics of the glass. Proper match is essential to help ensure that significant reduction in strength does not result due to the thermal expansion coefficient of the ceramic coating.

10.1.2.2 When coated, cured, and well-annealed glass strips are tested in accordance with Test Method C978, the stress

TABLE 1 Length and Width Tolerances

Nominal Thickness Designation mm (in.)	Plus or Minus mm, (in.)
3 (⅛)	1.6 (1/16)
4 (5/32)	1.6 (1/16)
5 (3/16)	1.6 (1/16)
6 (¼)	1.6 (1/16)
8 (5/16)	2.0 (5/64)
10 (⅜)	2.4 (3/32)
12 (½)	3.2 (⅛)
16 (⅝)	4.0 (5/32)
19 (¾)	4.8 (3/16)

TABLE 2 Overall Bow, Maximum

Nominal Thickness Desig., mm (in.)	Edge Dimension, cm (in.)											
	0–50 (0–20)	>50–90 (>20–35)	>90–120 (>35–47)	>120–150 (>47–59)	>150–180 (>59–71)	>180–210 (>71–83)	>210–240 (>83–94)	>240–270 (>94–106)	>270–300 (>106–118)	>300–330 (>118–130)	>330–370 (>130–146)	>370–400 (>146–158)
	Maximum Bow, mm (in.)											
3 (⅛)	3.0 (0.12)	4.0 (0.16)	5.0 (0.20)	7.0 (0.28)	9.0 (0.35)	12.0 (0.47)	14.0 (0.55)	17.0 (0.67)	19.0 (0.75)	. . .	. . .	. . .
3 (⅛) Alternate Method[A]	2.0 (0.08)	2.0 (0.08)	2.0 (0.08)	3.0 (0.12)	5.0 (0.20)	6.0 (0.24)	7.0 (0.28)	8.0 (0.31)	10.0 (0.39)	. . .	. . .	. . .
4 (5⁄32)	3.0 (0.12)	4.0 (0.16)	5.0 (0.20)	7.0 (0.28)	9.0 (0.35)	12.0 (0.47)	14.0 (0.55)	17.0 (0.67)	19.0 (0.75)	. . .	. . .	. . .
5 (3⁄16)	3.0 (0.12)	4.0 (0.16)	5.0 (0.20)	7.0 (0.28)	9.0 (0.35)	12.0 (0.47)	14.0 (0.55)	17.0 (0.67)	19.0 (0.75)	. . .	. . .	. . .
6 (¼)	2.0 (0.08)	3.0 (0.12)	4.0 (0.16)	5.0 (0.20)	7.0 (0.28)	9.0 (0.35)	12.0 (0.47)	14.0 (0.55)	17.0 (0.67)	19.0 (0.75)	21.0 (0.83)	24.0 (0.94)
8 (5⁄16)	2.0 (0.08)	2.0 (0.08)	3.0 (0.12)	4.0 (0.16)	5.0 (0.20)	6.0 (0.24)	8.0 (0.31)	10.0 (0.39)	13.0 (0.51)	15.0 (0.59)	18.0 (0.71)	20.0 (0.79)
10 (⅜)	2.0 (0.08)	2.0 (0.08)	2.0 (0.08)	4.0 (0.16)	5.0 (0.20)	6.0 (0.24)	7.0 (0.28)	9.0 (0.35)	12.0 (0.47)	14.0 (0.55)	17.0 (0.67)	19.0 (0.75)
12–22 (½ –⅞)	1.0 (0.04)	2.0 (0.08)	2.0 (0.08)	2.0 (0.08)	4.0 (0.16)	5.0 (0.20)	5.0 (0.20)	7.0 (0.28)	10.0 (0.39)	12.0 (0.47)	14.0 (0.55)	17.0 (0.67)

[A] Values apply to 3 mm (⅛ in.) thickness only when the alternative checking procedure in 10.7.2 is used.

measured in the glass at the ceramic-glass interface shall be a maximum of 1.52 MPa (220 psi) tension or compression.

10.2 *Durability Tests of Ceramic Coating:*

10.2.1 *Test Specimens:*

10.2.1.1 Specimens for durability tests shall have a representative thickness of ceramic coating of the same type and color as provided in specimens in 10.1.1. Specimens shall be fired in a normal manner with a production lot.

10.2.1.2 Specimens for tests in 10.2.2 and 10.2.4 may be of any convenient size.

10.2.2 *Test for Porosity*—Ceramic enamels must be adequately fused to ensure impermeability to liquids or vapors. Penetration of water through porous ceramic enamel coatings can cause separation of the ceramic coating from the base glass in freezing weather. Inadequate fusing may also cause discoloration, especially when the coating is in direct contact with laminating films. Adequate fusing of the enamel can be determined by one or more of the Test Methods A, B, C, or D.

10.2.2.1 *Test Method A—Gloss Test:*

(1) Procedure—Determine the gloss value according to C346 Standard Test Method for 45-deg Specular Gloss of Ceramic Materials.

(2) Test Results—When tested at the time of manufacture, the gloss value shall be a minimum of 35.

10.2.2.2 *Test Method B—India Ink Test:*

(1) Procedure—The specimen should be at ambient temperature. Lightly scrape an approximate 25 by 75 mm (1 by 3 in.) area of the ceramic coating with ten passes of a single-edge razor blade oriented toward the ten and four o'clock position at an angle of 45° to the surface of the specimen. Draw a line with India ink along the 75 mm (3 in.) dimension. After the ink has been on the specimen for 15 min, apply a fine abrasive paste over the line and scrub with an assay brush until the paste is removed from the line area. View the scrubbed area under a diffused light source with the unaided eye to determine if any residue remains in the ceramic coating.

(2) Test Results—Residual deposits of ink indicate a porosity of the ceramic coating that will allow water moisture penetration that may result in a discoloration of the ceramic coating and/or a separation of the coating and the glass substrate in freezing weather.

10.2.2.3 *Test Method C—Moisture Penetration Test:*

(1) Procedure—The specimen must be at ambient temperature. On the surface of the enamel, at points approximately 50 mm (2 in.) from each outer edge of the decoration and again at a point on the enamel near the geometric center of the part, apply a drop of water to the enamel or touch the enamel with a damp cloth, paper towel or cotton ball. Lightly rub the water into the surface with a finger or swab to ensure any possible absorption.

(2) Test Results—When viewed through the glass, none of the moistened areas should be visibly distinguishable from the area surrounding it.

10.2.2.4 *Test Method D—Permanent Marker Pen Test:*

(1) Procedure—The specimen must be at ambient temperature. The marker should be a fine point or thicker grade (such as a "Sharpie" brand or equivalent). On the surface of the enamel, at points approximately 50 mm (2 in.) from each outer edge of the decoration and again at a point on the enamel near the geometric center of the specimen, draw a line approximately 25 mm (1 in.) in length parallel to the edge of the specimen. In order to ensure an adequate deposit of ink, re-draw the same line over the original line twice. On white or light-colored enamels, yellow provides the best contrast between fully cured and inadequately cured conditions. Black or other color marker pens may also be used. The marker should

be fresh in order to ensure a full deposit of ink. This can be tested by printing a line of ink onto uncoated notebook paper. A fresh marker will leave a fully opaque, uniform deposit with clean edges, whereas an aged marker will leave a non-uniform and translucent deposit with rough edges.

(2) Test Results—When viewed through the glass, the ink must not be seen to have migrated through the enamel to the glass/enamel interface. Migration to the interface will result in a clear and easily seen mark that is the color and intensity of the ink of the marker itself. The line(s) may be somewhat visible, for enamel coatings that are not fully opaque, but this does not indicate a porous coating.

10.2.3 *Alkali Resistance Test*—Specimens for evaluation of resistance to alkali shall be prepared and tested in accordance with Test Method C1203. The measured weight loss shall not exceed 0.0028 g/cm^2 (0.000637 oz/in.^{2}).

10.2.4 *Acid-Resistance Test*—Specimens for evaluation of resistance to acid shall be tested in accordance with Test Method C724. The acid resistance of the test specimen shall be five or better to be considered acceptable, and no visible stain shall be observed when the undecorated side of the sample is viewed over an opaque background.

10.3 *Fallout Resistance Test for an Assembly of Glass and Adhered Reinforcing Material*—Applies to Condition A, Condition B, or Condition C glasses when used in spandrel glazing applications. (NOTE—Fallout resistance capability is optional and is intended to provide temporary retention of broken lites of glass in spandrel glazing applications.)

10.3.1 *Frequency of Tests*—Unless otherwise specified, the test for fallout resistance shall be performed with specimens taken from the initial production lot and thereafter only when changes are made in the assembly.

10.3.2 *Specimen Size*—Size of specimens shall be 863 by 1930 mm (34 by 76 in.) with a tolerance of ±1.6 mm (1⁄16 in.) on each dimension.

10.3.3 *Test Procedure*—Test for 100 cycles and repeat with no time delay between cycles. Perform each cycle in sequence as follows:

10.3.3.1 Hold for 1 h at −29°C (−20°F) and ambient humidity.

10.3.3.2 During the next 3 h, increase temperature from −29 to 82°C (−20°F to 180°F) with relative humidity at 95 to 100 % when above 5°C (41°F).

10.3.3.3 Then hold for 1 h at 82°C (180°F), 95 to 100 % relative humidity.

10.3.3.4 During the next 3 h, decrease temperature from 82 to −29°C (180 to −20°F) and ambient humidity.

10.3.4 *Sample Stabilization*—After completion of the test procedure of 10.3.3.4, the sample shall be allowed to rest for at least four h at temperatures between 20 and 30°C (68 and 86°F).

10.3.5 *Test Apparatus*—Each specimen shall be mounted in a test frame as specified in ANSI Z97.1 or CPSC 16 CFR 1201 as modified to conduct pressure test of 10.3.7.

10.3.6 *Fracturing Glass*—While the specimen is in the test frame, break the specimen using a spring-loaded prick punch at the midpoint of either vertical edge and 25 mm (1 in.) inboard of the edge. Cracks and fissures that may develop are permissible.

10.3.7 *Wind Load*—Subject each specimen after breakage to ten cycles of positive and negative pressure at 200 Pa (4 psf) to simulate the action of wind load against a building. Each positive and negative pressure shall be of 5-min duration.

10.3.8 *Interpretation of Tests*—Although cracks and fissures that may have developed are permissible, no opening shall occur through which a 76.2-mm (3-in.) diameter sphere may be freely passed, nor shall there be single or multiple areas with a cumulative total area of more than 58 cm^2 (9 in.^{2}) in which an attached film or other reinforcing material is detached from the glass.

10.4 *Blemish Detection for Point Blemishes (Knots, Dirt, Stone, Crush, Gaseous Inclusions and Other Similar Blemishes):*

10.4.1 *Condition A, B (Partially-Coated Only), and C*—See Specification C1036 test methods and evaluation criteria.

10.4.2 *Condition B (Fully-Coated)*—Glass shall be viewed by light reflected from the outside facing surface as installed. Place the glass sample against a uniformly opaque backup material in a vertical position. Refer to Specification C1036 for applicable point blemish evaluation criteria.

10.5 *Blemish Detection for Linear Blemishes (Scratches, Rubs, Digs, and Other Similar Blemishes):*

10.5.1 *Condition A, B (Partially-Coated Only) and C*—See Specification C1036 test methods and evaluation criteria.

10.5.2 *Condition B (Fully-Coated)*—glass shall be viewed by light reflected from the outside facing surface as installed. Place the glass sample against a uniformly opaque backup material in a vertical position. Refer to Specification C1036 for applicable linear blemish evaluation criteria.

10.6 *Ream, Strings, Lines, and Distortion:*

10.6.1 *Condition A, B (Partially-Coated Only)*—See Specification C1036 tables regarding allowable blemishes.

10.6.2 *Condition B (Fully-Coated)*—Not Applicable.

10.7 *Localized and Overall Bow:*

10.7.1 *Localized Bow*—Place sample glass in a freestanding vertical position, resting on blocks at the quarter points. With the glass in this position, place a 300 mm (12 in.) long straightedge anywhere on the concave surface. Measure the maximum deviation with a taper, or feeler gauge, dial indicator or fine scale ruler.

10.7.2 *Overall Bow*—Place sample glass in a freestanding vertical position, resting on blocks at the quarter points. With the glass in this position, place a straightedge or taut string across the concave surface, parallel to and within 25.4 mm (1 in.) of one edge, and spanning from one edge to the opposite other edge, and measure the maximum deviation with a taper, or feeler gauge, dial indicator or fine scale ruler. When the above procedure is impractical for larger sizes of 3 mm (⅛ in.) thickness, place the glass on a flat surface, concave side down, and use a taper, feeler gauge, dial indicator, or fine scale ruler,

reading in 0.02 mm (0.001 in.) increments, to determine overall bow. Overall bow values shown on the second line of Table 2 apply to 3 mm (⅛ in.) when the alternative (horizontal) procedure is used.

10.7.3 *Edge Curl*—There are several methods in use for measurement of edge curl in heat treated glass including bar and feeler gauges as well as non-contact optical instruments with such capabilities. Manual measurement method is similar to localized bow (see 10.7.1).

10.8 *Surface and Edge Compression, Heat-Strengthened and Fully Tempered Glass*—Examine specimens by the polariscopic or light refraction methods for surface or edge compression. When the range of the apparatus permits examination for edge compression only, obtain the averaged value for all midpoints of every edge. Accomplish this examination for Condition B glass by removing the ceramic coating with hydrofluoric acid or abrasive cloth. Index oil and a glass-slide cover plate may be necessary to eliminate the diffusing effect of the abraded surface and expose compression color bands.

10.8.1 *Surface Compression, Heat-Strengthened and Fully Tempered Glass* (see 8.1)—Surface compression to be measured by light refraction methods such as GASP, DSR, or similar methods in accordance with Test Method C1279. Surface compression measurements shall be made at each of five locations as indicated in Fig. 5. Failure of any single measurement to comply with the standards for surface compression specified in 8.1.1.1 for heat-strengthened glass and 8.1.1.2 for fully tempered glass shall be considered as cause for rejection. Note: Allow the glass to arrive at thermal equilibrium throughout before taking measurements.

10.9 *Break Test, Fully Tempered Glass*—Test and interpret in accordance with ANSI Z97.1 or CPSC 16 CFR 1201 as applicable (see 8.1.2).

10.10 *Coating Criteria, Condition B, Ceramic Coated*—Glass shall be viewed by light reflected from the outside facing surface as installed. Place the glass sample against a uniformly opaque backup material and in a vertical position. View the sample from a distance of approximately 3 m (10 ft). Determine acceptability in accordance with 8.3.1.

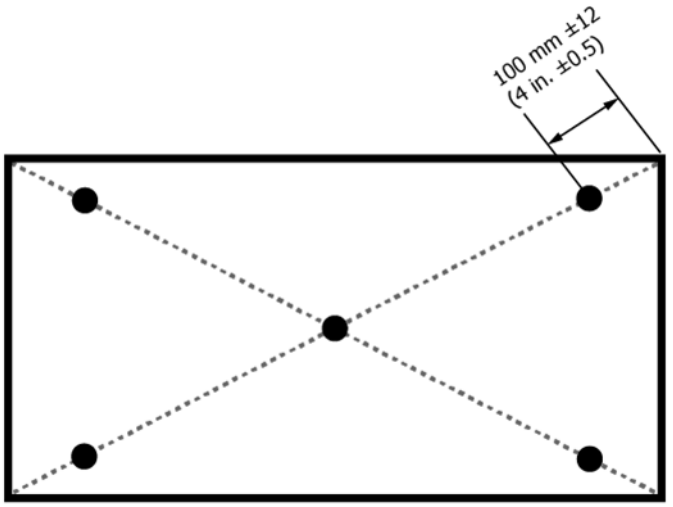


FIG. 5 Five Locations Examined

10.11 *Coating Criteria Condition C*—See Specification C1376.

11. Product Marking

11.1 The identification marking, when required, shall include the manufacturer's name or trademark, and the designation of heat-strengthened or fully tempered, or an abbreviation such as HS or Tempered. The identification marking shall be either permanent or temporary, as specified.

11.1.1 *Permanent Identification Marking*—Permanent identification marking may be accomplished by a variety of methods including, but not limited to, sandblasting, etching, fired-on ceramic decal or silk-screened imprint, or laser marking. The marking shall be located at one or more corners of the glass. Requirements for permanent identification markings on fully tempered glass may vary with application.

11.1.2 *Temporary Identification Marking*—Temporary identification marking shall consist of a label that is attached to the glass and can be removed after installation of the glass.

12. Keywords

12.1 edge compression; flat glass; heat-strengthened glass; heat-treated glass; surface compression; tempered glass