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Designation: ~~C1048 – 12ε1~~ 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.

~~ε[1] NOTE—Section 9 was updated editorially in November 2012.~~

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~~ safety, health, and ~~health~~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.*

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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

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[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.

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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,*~~ *bow—n*—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). ~~Also known as warp.~~

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

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,*~~ *glass—n*—a term used to reference both heat-strengthened and fully tempered glass.

3.2.5 ~~*heat-treating,*~~ *heat-treating—v*—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 glassfrom 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—n*—~~edge~~ 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. (See~~glass having ~~8.3.)~~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. (See~~glass with ~~8.4.)~~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 ~~or thermal stress, or both,~~ 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 or thermal stress, or both.~~ 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, or both,~~ 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.

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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 ~~7.1~~7.7).

6.1.4 Requirements for fittings and hardware (see ~~7.2~~7.1).

~~6.1.5 Custom design or texture required (see 7.7).~~

6.1.5 Glass thickness (see 9.1).

6.1.6 ~~Pattern-cut glass~~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 ~~Surface treatment or coatings~~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. ~~Fabrication~~ Properties and Fabrication of Heat-Treated Glass

~~7.1 *Fabrication*—All fabrication, such as cutting to overall dimensions, edgework, drilled holes, notching, grinding, sandblasting, and etching, shall be performed before heat-strengthening or tempering and shall be as specified (see Section 6 and 7.8). After the glass has been heat-strengthened or tempered, it shall not be modified except as recommended by the fabricator; for example, some Condition C coatings. No modification shall be made that will affect its structural characteristics or integrity as specified in this standard.~~

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.

~~7.2 *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 limitations.~~

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 ~~reflected from the glass surface.~~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 ~~and other~~ 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 ~~support system and the amount of glass deflection for a given set of wind load~~ structural performance and load-induced deflections of the glass under uniform load conditions shall be ~~considered for design purposes. Consult the manufacturer to determine the appropriate thickness of heat-strengthened or fully tempered glass needed to satisfy the design wind load and probability of breakage design factor for the required glass in accordance~~ properly considered in relationship to the requirements of the application, and consistent with Practice E1300~~.~~ as applicable.

~~7.7 *Special Surfaces, Types I or II*—Custom designs or textures shall be as specified (see 6.1.5) or as shown on plans or drawings.~~

7.7 ~~*Fabrication Guidelines*—~~*Fabrication*—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.~~ 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 ~~can be furnished with holes, notches, cutouts, and bevels. Fabrication involving other methods of modification should be discussed with the fabricator/manufacturer.~~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 ~~2~~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 ~~2~~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.

7.7.4 *Minimum Dimension of Holes*—Circular holes shall have a minimum diameter of 6 mm (¼ ~~in.)~~ 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.).~~ in.).

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

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

7.7.6 Chips and flakes at hole edges shall not exceed ~~1.6 mm~~ 3.2 mm (⅛ ~~in.).~~ 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).

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
~~± 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.~~

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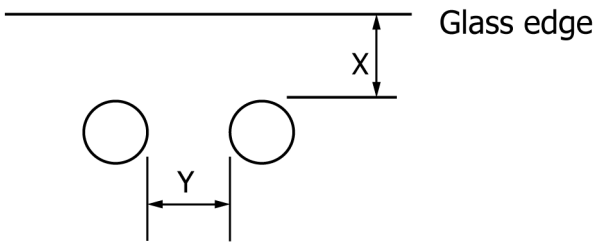

~~X = 6 mm (¼ in.) or 2t, whichever is greater~~
~~Y = 10 mm (⅜ in.) or 2t, whichever is greater~~
~~Where:~~
~~X = Minimum distance between glass edge and rim of nearest hole~~
~~Y = Minimum distance between rims of adjoining holes~~
~~t = Glass thickness~~

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 ~~Placement~~ Location of Holes Near Edge

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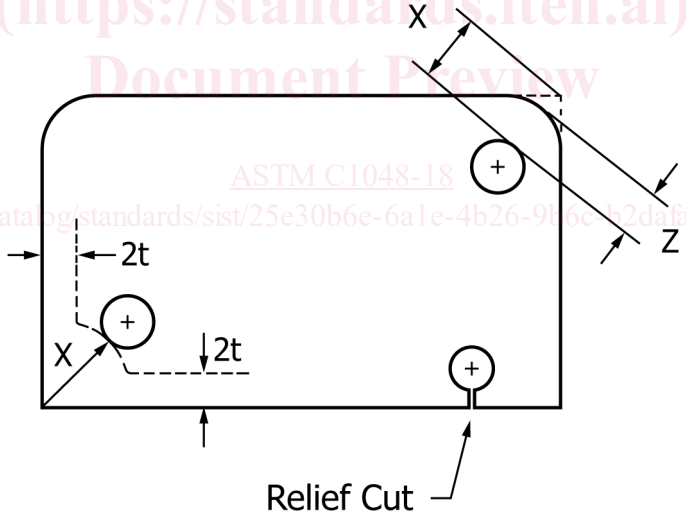
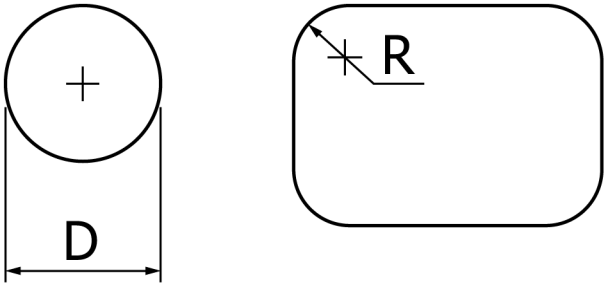


~~X = 6.5t~~
~~Where:~~
~~X = Minimum distance between glass corner and rim of nearest hole~~
~~t = Glass thickness~~

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

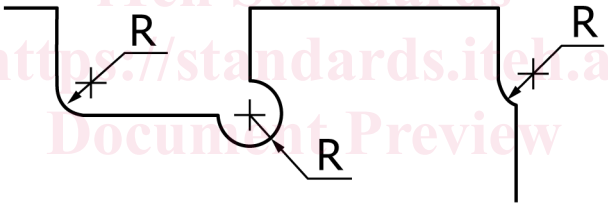


~~D = 6 mm (1/4 in.) or 1t, whichever is greater~~
~~R ≥ t~~
~~Where:~~
~~D = Minimum diameter of a hole~~
~~R = Radius~~
~~t = Glass thickness~~

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



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~~R ≥ t~~
~~t = thickness of glass~~
~~R = radius~~
~~See paragraph 7.8.6.~~

R ≥ t

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

FIG. 4 Notch and Cutout Fillets

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 ~~6.1.8~~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 ~~manufacturer.~~the fabricator providing the heat-strengthened glass.