INTERNATIONAL

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Standard Specification for Heat-Treated Flat Glass—Kind HS, Kind FT Coated and Uncoated GlassHeat-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 Department of Defense.

1. Scope

1.1This specification covers the requirements for flat heat-strengthened and flat fully tempered coated and uncoated glass used in general building construction.

1.2The dimensional values stated in SI units are to be regarded as the standard. The units given in parentheses are for information only.

1.3

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 1110, 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 and health practices and determine the applicability of regulatory limitations prior to use.*

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 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]

[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.

2.3 *Other Documents:*

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

3. Terminology

3.1 *Definitions*~~Definitions: *For*~~ *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*, *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 *heat-treated glass*, *n*—a term used to reference both heat-strengthened and fully tempered glass.

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

3.2.4 *thermal 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*~~—Spandrel glass, one surface ceramic coated.~~ —Fully or partially ceramic coated glass. (See 8.3.)

4.2.3 *Condition C*~~—Other coated glass.~~ —Other coated glass. (See 8.4.)

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 generally twice as strong as annealed glass of the same thickness and configuration. When broken, the fragments are generally similar to that of annealed glass. Intended for general glazing when additional strength is desired but not requiring the strength of fully tempered glass.~~ —Heat-strengthened glass is used as architectural glazing when additional resistance to wind pressure or thermal stress, or both, 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 approximately four times as strong as annealed glass of the same thickness and configuration. When broken, by impact, fully tempered glass fractures into relatively small pieces meeting safety glazing requirements thereby greatly reducing the likelihood of serious cutting or piercing injuries in comparison with ordinary annealed glass. Fully tempered glass is intended for use in applications where its strength or safety characteristics may be required. 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 glass is required by building codes and ordinances. It is often used for other applications where the properties of fully tempered glass are desirable such as table tops, counter tops, show case enclosures and similar applications.~~ —Fully tempered glass is used in architectural glazing applications when significant additional strength is needed to resist wind pressure or thermal stress, or both. 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 CPSC 16 CFR 1201 or ANSI Z97.1, or both, 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:

[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.

6.1.1Title, number, and date of this specification.
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).
6.1.4 Requirements for fittings and hardware (see 7.2).
6.1.5Specific location of tong marks, when required (see 7.3).
6.1.6
6.1.5 Custom design or texture required (see 7.87.7).
6.1.7Glass thickness (see
6.1.6 Glass thickness (see 9.1).
6.1.8
6.1.7 Pattern-cut glass must be within the tolerances specified (see 9.3).
6.1.96.1.8 When surface or edge compression test is required for Kind HS heat–strengthened or Kind FTfully tempered glass (see 8.1.1).
6.1.10When6.1.9 When break safe characteristics are required for fully tempered (Kind FT) glass (see 8.1.2).
6.1.11
6.1.10 Color or tint of glass (see 8.2).
6.1.121 When either permanent or temporary identification marking is required (see Section 1211).
6.1.13
6.1.12 Surface treatment or coatings for Condition B and Condition C glass (see 8.3 and 8.4).
6.1.14
6.1.13 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 11.310.3.)

7. Fabrication

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 7.97.8). 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 specification. standard.

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.

7.3*Tong Marks*—The center of tong marks, when present, shall be located a maximum of 12.7 mm (½ in.) from one edge of the glass on thicknesses up to and including 9.5 mm (⅜ in.). On thicknesses over 9.5 mm, the center of tong marks, when present, shall be located a maximum of 19 mm (¾ in.) from one edge of the glass. Tong marks shall be located on a specific edge when specified (see Section 6). For location of tong marks on glass with special fabrication or irregular patterns, consult fabricators.
7.4
7.3 *Distortion*:
7.4.1Thermally tempered 7.3.1 Heat-strengthened and heat-strengthened fully tempered glass is made by heating annealed glass in a furnace 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 from a series of nozzles. air. The original flatness of the glass is slightly modified by the heat treatment, 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 and is not as noticeable. images.
7.4.2Fully tempered 7.3.2 Heat-strengthened and heat-strengthened glass that has been made in a vertical furnace contains small surface depressions along one edge resembling dimples (tong marks) (see 7.3). Distortion will be observed in the areas surrounding the tong marks. Fully fully tempered and heat-strengthened glass that has been madeproduced in a horizontal furnace tempering system may contain surface distortion (for example, picture framing, heat distortion or roller wave distortion). Distortion willmay be detected when viewing images reflected from the glass surface.
7.4.3Pressures,7.3.3 Pressures exerted around the periphery of glass by the glazing system,system can also alter glass flatness, thereby distorting reflected images. This is true regardless of whether or not the glass is annealed, heat-streangthened, or fully tempered.
7.43.4 Sealed insulating glass units also exhibit distortion regardless of glass type. Air or other gas, trappedsealed in the sealed airspace gap between the panes, lites of glass, expands or contracts with temperature and barometric changes, creating a pressure differential between the airspace sealed gap and the atmosphere. The glass reacts to the pressure differential by being deflected inward or outward.
7.43.5 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 willmay appear to have littleless perceived distortion.

7.43.6 Specified bow ~~and warp~~ 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 ~~and warp~~ 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 ~~user or architectural~~ evaluation of ~~the~~ reflective distortion.

~~7.5~~7.4 *Strain Pattern*~~—In heat-strengthened and fully tempered glass, a strain pattern, which is not normally visible, may become visible under certain light conditions. It is characteristic of these kinds of glasses and should not be mistaken as discoloration or nonuniform tint or color.~~

~~7.6~~*—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 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.*

7.5 *Surface Particles*~~—The heat-treating process typically 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 glass particles (fines) from the glass cutting and edging process, typical manufacturing plant airborne debris or dust, refractory particles from the tempering oven roof, as well as external airborne dirt and grit carried into the plant by the large volumes of quench air used in the process, may adhere to one or both glass surfaces.~~

~~7.7~~*—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.*

7.6 *Resistance to Wind Load*—The support system and the amount of glass deflection for a given set of wind-load conditions ~~must~~shall be considered for design purposes. Consult the manufacturer to determine the appropriate thickness of heat-strengthened ~~(Kind HS)~~ or fully tempered ~~(Kind FT)~~ glass needed to satisfy the design wind load and probability of breakage design factor for the required glass in accordance with Practice E1300.

~~7.8~~7.7 *Special Surfaces, Types I or II*—Custom designs or textures shall be as specified (see ~~6.1.6~~6.1.5) or as shown on plans or drawings.

~~7.9~~

7.8 *Fabrication Guidelines*~~—Heat-treated flat glass cannot be cut after tempering. Fabrication altering the stress distribution, surface or edge shape, or dimension must be performed before being heat treated. Consult suppliers for special edges or irregular patterns or, when required, on a specific type of edge. The following guidelines may be used for normal fabrication requirements.~~

~~7.9.1~~Heat-treated glass can be furnished with holes, notches, cutouts, and bevels.

~~7.9.2~~*—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.*

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

7.8.2 *Placement of Holes*:

7.98.2.1 The minimum distance from any edge of the glass to the nearest point on the rim of a hole ~~must~~shall be 6 mm (¼ in.) or 2 times the thickness of the glass, whichever is greater (see Fig. 1).

7.98.2.2 The minimum distance between the rims of adjoining holes ~~must~~shall be 10 mm (⅜ in.) or 2 times the thickness of glass, whichever is greater (see Fig. 1).

7.98.2.3 Holes near corners ~~must~~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).

~~7.9.3~~

7.8.3 *Minimum Dimension of Holes*—Circular holes ~~must~~shall have a minimum diameter of ~~6.4~~6 mm (¼ in.) or the thickness of the glass, whichever is greater. In other than circular holes, any corners ~~must~~shall have fillets, the radius of which ~~must~~shall be equal to or greater than the thickness of the glass (see Fig. 3).

~~7.9.4~~

7.8.4 *Dimensional Tolerances of Holes*:

7.98.4.1 Tolerance of hole diameter shall be ±1.6 mm (1/16 in.).

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

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

7.98.5 Chips and flakes at hole edges ~~must~~shall not exceed 1.6 mm (1/16 in.).

~~7.9.6~~

7.8.6 *Notches and Cutouts*:

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

7.98.6.2 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.

~~7.9.6.3Inner surfaces of notches and cutouts must be smooth seamed or polished.~~

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

7.8.7 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

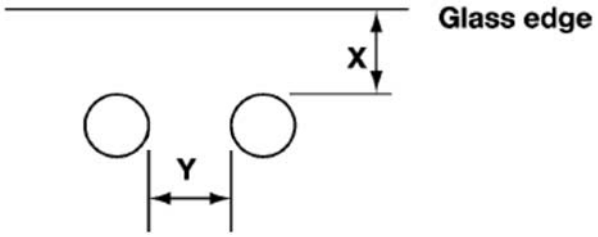
8.1 *Strength Requirements*:

8.1.1 *Surface and Edge Compression Requirements* (see ~~11.7~~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~~MPa (3500 and 7500 psi). Surface compression testing, when required (see ~~6.1.9~~6.1.8), shall be done in accordance with ~~11.7~~10.8.

NOTE~~2—Heat strengthening of glass thicker than 6 mm (¼ in.) within narrow limits of surface compression is difficult. Consult manufacturer.~~ 2—Heat-strengthening of glass thicker than 6 mm (¼ in.) can be difficult. Consult manufacturer.

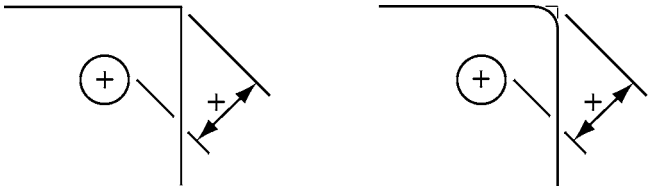
8.1.1.2 *Kind FT, Fully Tempered Glass*~~—Kind FT~~—Fully tempered glass shall have either a minimum surface compression of 69 MPa (10 000 psi) or an edge compression of not less than 67 MPa (9700 psi) or meet ANSI Z97.1 or CPSC ~~Standard16~~16 CFR 1201~~1201~~ in accordance with ~~11.8~~10.9. Surface compression or edge compression testing, when required (see ~~6.1.9~~6.1.8), shall be done in accordance with ~~11.7~~10.8.



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

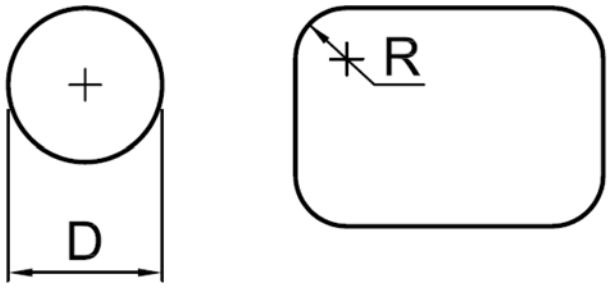
Where:
X = Minimum distance between glass edge and rim of nearest hole
Y = Minimum distance between rims of adjoining holes
t = Glass thickness

FIG. 1 Placement of Holes



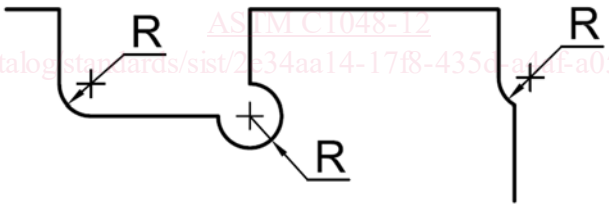
X = 6.5t
Where:
X = Minimum distance between glass corner and rim of nearest hole
t = Glass thickness.

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

FIG. 3 Minimum Dimension of Holes



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

FIG. 4 Notch and Cutout Fillets

8.1.2 *Break Test Requirement for ~~Kind FT~~Fully Tempered Glass*—When specified (see Section 6), the break requirements of ~~Kind FT~~fully tempered glass shall be tested and interpreted in accordance with ~~11.8~~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 ~~6.1.11~~ 6.1.10 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. Tint samples must be heat strengthened or fully tempered, as required, for the matching of tints as the heat-strengthened or fully tempered glasses may exhibit slight changes from the tint of annealed glass. Viewing of the color or tint samples should be performed with the glass in the eventual glazed position.~~ —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.