



Standard Specification for Laminated Architectural Flat Glass¹

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1. Scope

1.1 This specification covers the quality requirements for cut sizes of flat laminated glass consisting of two or more lites of glass bonded with an interlayer material for use in building glazing.

1.2 Depending on the number, thickness and treatment of plies, and the number and thickness of interlayers, the glass shall be laminated for applications including but not limited to safety security, detention, hurricane/cyclic-wind resistance, blast resistant, bullet resistant and sound reduction glazing applications.

1.3 Optical distortion and the evaluation thereof is not currently within the scope of the standard. Mockups are recommended as a method to evaluate glass. (See Appendix X1.)

1.4 The dimensional values, except thickness designations, stated in inch-pound units are to be regarded as the standard. The values given in parenthesis are for information only.

1.5 The following safety hazards caveat pertains only to the test method portion, Section 7, 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 Reference to these documents shall be the latest revision unless otherwise specified by the authority applying this specification.

2.2 ASTM Standards:

C 162 Terminology of Glass and Glass Products²

C 1036 Specification for Flat Glass²

C 1048 Specification for Heat-Treated Flat Glass—Kind HS, Kind FT Coated and Uncoated Glass²

C 1376 Specification for Pyrolytic and Vacuum Deposition Coatings on Flat Glass²

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² *Annual Book of ASTM Standards*, Vol 15.02.

C 1422 Specification for Chemically Strengthened Flat Glass²

C 1503 Specification for Silvered Flat Glass Mirror²

E 308 Practice for Computing the Colors of Objects by Using the CIE System³

E 1886 Test Methods for Performance of Exterior Windows, Curtain Walls, Doors and Storm Shutters Impacted by Missile(s) and Exposed to Cyclic Pressure Differentials⁴

E 1996 Specification for Performance of Exterior Windows, Curtain Walls, Doors and Storm Shutters Impacted by Windborne Debris in Hurricanes⁴

F 1233 Test Method for Security Glazing Materials and Systems⁵

F 1642 Test Method for Glazing and Glazing Systems subject to Airblast Loading⁵

F 1915 Test Method for Glazing for Detention Facilities⁵

2.3 ANSI Standard:

Z97.1 Safety Glazing Materials Used in Buildings—Safety Performance Specifications and Methods of Tests⁶

2.4 Federal Document:⁷

CPSC 16CFR1201 Consumer Product Safety Commission Safety Standard for Architectural Glazing Materials

2.5 UL Standards:⁸

UL 752 Standard for Bullet Resisting Materials

UL 972 Standard for Burglary Resisting Glazing Materials

3. Terminology

3.1 *Definitions*—Refer to Terminology C 162, Specifications C 1036 or C 1048, as appropriate.

3.1.1 *blemishes in flat glass*—Refer to Specifications C 1036 or C 1048, as appropriate.

3.2 Definitions of Terms Specific to This Standard:

3.2.1 *adhesion chips*—See *fuse*.

³ *Annual Book of ASTM Standards*, Vol 06.01.

⁴ *Annual Book of ASTM Standards*, Vol 04.12.

⁵ *Annual Book of ASTM Standards*, Vol 15.08.

⁶ Available from American National Standards Institute, 11 W. 42nd St., 13th Floor, New York, NY 10036.

⁷ Available from Superintendent of Documents, U.S. Government Printing Office, Washington, DC 20402.

⁸ Available from Underwriters Laboratory, 333 Pfingsten Road, Northbrook, IL 60062.

3.2.2 *blow-in*—a separation of glass and interlayer at or close to the laminate edge caused by penetration of the autoclaving medium into the edge during manufacturing.

3.2.3 *boil (bubble)*—a gas pocket in the interlayer material or between the glass and interlayer.

3.2.4 *covered edge*—the perimetric area of the laminate covered by the channel or sash when installed.

3.2.5 *decorative glass*—glass with an ornamental appearance created by a textured glass surface (patterned glass), design printed interlayer, application of decal(s) to the glass or interlayer, or other embellishments performed on or to the glass or interlayer material to give the glass an ornamental appearance.

3.2.6 *delamination*—a condition in which one or two of the lites of glass loses the bond between the glass lite and the interlayer.

3.2.7 *discoloration*—a visibly noticeable color change (from original) in the appearance of a material.

3.2.8 *distortion*—the inability to see an image clearly; the image is twisted out of natural shape.

3.2.9 *edge boil*—See *boil (bubble)*.

3.2.10 *edge cover*—See *covered edge*.

3.2.11 *exposed edge*—the perimetric area of the laminate exposed to the environment after installation.

3.2.12 *fuse*—a glass particle or crystalline material that is permanently bonded to a surface of a lite.

3.2.13 *glass edge bite*—See *covered edge*.

3.2.14 *hair*—a slender, pigmented filament from human or animal epidermis or other thread-like filament.

3.2.15 *inside dirt*—foreign material trapped inside the laminate.

3.2.16 *interlayer*—a layer or multiple layers of material acting as an adhesive between plies of glass which adds additional performance to the finished product, for example, impact resistance, solar control, acoustical insulation.

3.2.17 *laminate*—See *laminated glass*.

3.2.18 *laminated bullet resistant glass*—multiple lites of flat glass, bonded by interlayer material, that resist penetration from medium- to super-power arms and high-power rifles.

3.2.19 *laminated glass*—an assembly consisting of two or more lites of glass, conforming to Specification C 1036 or C 1048 that are bonded together by interlayer material.

3.2.20 *laminated safety glass*—two or more lites of flat glass, bonded by interlayer material. In the case of breakage, the interlayer serves to retain the glass fragments, limit the size of the opening and reduce the risk of cutting or piercing injuries.

3.2.21 *laminated security glass*—two or more lites of flat glass, bonded by interlayer material, that resist manual penetration, including physical attack from hand-held or hand-thrown objects.

3.2.22 *lint*—short fibers of yarn or fabric trapped within the laminate.

3.2.23 *lite or light*—a panel or sheet of glass or a panel or sheet of laminated glass.

3.2.24 *mismatch*—misalignment of the edges of two lites of glass, when laminated.

3.2.25 *nonsymmetrical*—a term used to describe the construction of a laminate comprised of different glass types or thickness, or both.

3.2.26 *offset*—intentional mismatch (see *mismatch*).

3.2.27 *ply*—one sheet or panel of glass in a laminate.

3.2.28 *scuff*—See *streak*.

3.2.29 *separation*—an area of the laminate that has become delaminated (see *delamination*).

3.2.30 *shiner*—an area on a glass edge that has not been ground or polished.

3.2.31 *short interlayer*—a condition of the laminate in which the interlayer does not extend to the edge.

3.2.32 *slippage*—See *mismatch*.

3.2.33 *streak*—a noticeably visible deviation on or in the laminating unit.

3.2.34 *surfaces*—surfaces of glass faces are counted as Nos. 1, 2, 3, and 4, respectively. The No. 1 surface is the surface that is to the exterior; the Nos. 2 and 3 surfaces are those separated by and bonded to the interlayer material; the No. 4 surface is the surface that is to the interior.

3.2.35 *symmetrical*—a term used to describe the construction of a laminate comprised of only one glass type and thickness.

3.2.36 *template*—a pattern used as a guide to define the overall size and shape of a cut lite.

3.2.37 *two-ply flat glass (laminates)*—See *laminated glass*.

3.2.38 *unlaminated area*—an area of the laminate that failed to laminate during the laminating process. This blemish is discernible due to the textured appearance of the interlayer material.

4. Classification

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

4.1.1 *Kind LA*—Two or more lites of flat annealed transparent glass conforming to the applicable requirements of Specification C 1036 and bonded by an interlayer material.

4.1.2 *Kind LC*—Two or more lites of flat glass, one or more of which are chemically strengthened glass bonded by an interlayer material.

4.1.3 *Kind LD*—Two or more lites of flat glass, bonded by an interlayer material yielding a decorative laminate.

4.1.4 *Kind LHS*—Two or more lites of flat glass, all of which are heat-strengthened glass conforming to the applicable requirements of Specification C 1048 and bonded by an interlayer material.

4.1.5 *Kind LM*—Two or more lites of flat glass, one or more of which are mirror glass conforming to the applicable requirements of Specifications C 1036, C 1048 (if one or more of the lites are tempered or heat-strengthened glass), and C 1503 and bonded by an interlayer material.

4.1.6 *Kind LP*—Two or more lites of flat glass, one or more of which are pattern glass conforming to the applicable requirements of Specifications C 1036 and C 1048 (if one or more of the lites are tempered or heat-strengthened glass) and bonded by an interlayer material.

4.1.7 *Kind LR*—Two or more lites of flat glass, one or more of which are reflective glass, conforming to the applicable requirements of Specifications C 1036 and C 1048 (if one or

more of the lites are tempered or heat-strengthened glass) and bonded by an interlayer material.

4.1.8 *Kind LSP*—Two or more lites of flat glass, one or more of which are spandrel glass, conforming to the applicable requirements of Specifications C 1036 and C 1048 (if one or more of the lites are tempered or heat-strengthened glass) and bonded by an interlayer material.

4.1.9 *Kind LT*—Two or more lites of flat glass, all of which are fully tempered glass conforming to the applicable requirements of Specification C 1048 and bonded by an interlayer material.

4.1.10 *Kind LW*—Two or more lites of flat glass, one or more of which are wired glass, conforming to the applicable requirements of Specification C 1036 and bonded by an interlayer material.

4.1.11 *Kind LX*—Laminated glass with combinations not previously defined.

5. Ordering Information

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

5.1.1 Title, number, and date of this specification.

5.1.2 Kind of laminated flat glass as referred to in this specification (see Section 4).

5.1.3 Edgework requirements (see 8.2).

5.1.4 Thickness requirements:

5.1.4.1 Thickness designation of each individual ply of glass to be used in the laminate,

5.1.4.2 Interlayer type and thickness designation, and

5.1.4.3 Overall nominal thickness of the laminate.

5.1.5 Nominal length and width of the laminate.

5.1.5.1 Blueprint, drawing, template, configuration specification, or other forms of information which detail overall size, configuration, and orientation.

5.1.6 Classification of each individual lite of glass to be used in the laminate, in accordance with the Classification and Intended Use section of Specification C 1036.

5.1.6.1 Color, tint, decorative effect and strength of each individual lite of glass.

5.1.7 Color, tint and decorative effect of the interlayer.

5.1.8 The luminous transmittance of the laminate (see 7.11).

5.1.9 Safety standards or regulations to which the laminate must conform (see 6.8).

5.1.10 All other standards to which the laminate must conform.

5.2 *Packaging Requirements*—Glass packaging and protection will be standard manufacturer practice unless otherwise specified. Consult manufacturer before specifying.

6. Other Requirements

6.1 Heat strengthened or fully tempered glass plies shall conform to the requirements of Specification C 1048 for the incorporated glass type.

6.2 Annealed glass plies shall conform to the requirements of Specification C 1036 for the incorporated glass type.

6.3 Chemically strengthened glass plies shall conform to the requirements of Specification C 1422.

6.4 Pyrolytic and vacuum deposition coated glass plies shall conform to the requirements of Specification C 1376.

6.5 Mirror glass plies shall conform to the requirements of Specification C 1503.

6.6 Spandrel glass plies shall conform to the requirements of Specification C 1048 for the incorporated glass type.

6.7 Luminous transmittance shall be as specified.

6.8 Laminates specified for safety glazing shall meet the requirements of the specified safety glazing standards (see 7.1).

7. Test Methods

7.1 *Impact Test for Safety Glazing*—Test and interpret in accordance with ANSI Z97.1 or CPSC 16CFR1201, or both, as applicable.

7.2 *Test for Missile Impact and Cyclic Pressure*—Test and interpret in accordance with Test Method E 1886 and Specification E 1996.

7.3 *Test for Security Glazing*—Test and interpret in accordance with Test Method F 1233.

7.4 *Test for Glazing Subject to Airblast Loading*—Test and interpret in accordance with Test Method F 1642.

7.5 *Test for Detention Glazing*—Test and interpret in accordance with Test Method F 1915.

7.6 *Test for Bullet Resisting Glazing*—Test and interpret in accordance with Standard UL 752.

7.7 *Test for Burglary Resisting Glazing*—Test and interpret in accordance with Standard UL 972.

7.8 *Overall Bow and Warp*—Place sample glass in a free-standing vertical position, with the longest edge resting on blocks at the quarter points. With the laminate in this position, place a straightedge across the concave surface, parallel to and within 1 in. (25.4 mm) of the edge, and measure the maximum deviation with a taper or feeler gage. A dial indicator may also be used.

7.9 *Size*—Measure length and width from edge to edge, including flares, mismatch, or offset (see 8.5).

7.10 *Visual Inspection*—Place the specimen in a vertical position. The viewer shall look through the specimen, using daylight without direct sunlight, or using a background light suitable for observing the blemishes. View at 36 in. (914 mm) except where otherwise specified in Table 1.

7.11 *Transmittance*—Using Practice E 308, measure transmittance by illuminating each laminated specimen at normal incidence with light having the spectral composition of International Commission on Illumination (CIE) illuminate C. Measure the ratio of transmittance to incident luminous flux by calculating from the spectral distribution of illuminate C as defined by Practice E 308.

8. Fabrication Requirements

8.1 All dimensional fabrication, such as cutting to overall dimensions, edgework, drilling, notching, grinding, sandblasting and etching, on laminates incorporating heat-strengthened, chemically strengthened, or fully tempered glass shall be performed prior to strengthening or tempering. After the glass has been strengthened or tempered, it shall not be modified except as recommended by the fabricator.

TABLE 1 Maximum Allowable Laminating Process Blemishes, in. (mm)

NOTE 1— All imperfections noted should be separated by a minimum of 12 in. (305 mm).

NOTE 2—See 7.10 for method of inspection.

NOTE 3—Refer to Specification C 1036 for the quality specification for the individual glass plies.

Blemish	Up to 25 ft ² (2.5 m ²)		25 to 75 ft ² (2.5 to 7.0 m ²)		Over 75 ft ² (7.0 m ²)	
	Central ^A	Outer ^A	Central ^A	Outer ^A	Central ^A	Outer ^A
Boil (Bubbles)	1/16 (1.6)	3/32 (2.4)	1/8 (3.2)	3/16 (4.8)	1/4 (6.4)	1/4 (6.4)
Blow-in; edge boil	^B	CE 1/4 (6.4) EE 1/32 (0.8) ^C	^B	CE 1/4 (6.4) EE 1/16 (1.6) ^C	^B	CE 5/16 (8.0) EE 3/32 (2.3) ^C
Fuse	1/32 (0.8)	1/16 (1.6)	1/16 (1.6)	3/32 (2.4)	3/32 (2.4)	5/32 (4.0)
Hair, lint (single strand)	light intensity ^D	medium intensity ^E	light intensity ^D	medium intensity ^E	medium intensity ^E	medium intensity ^E
Inside dirt (dirt spot)	1/16 (1.6)	3/32 (2.4)	3/32 (2.4)	5/32 (4.0)	1/8 (3.2)	3/16 (4.8)
Lint-areas of concentrated lint	light intensity ^D	light intensity ^D	light intensity ^D	light intensity ^D	light intensity ^D	light intensity ^D
Separation, discoloration	none	none	none	none	none	none
Short interlayer; unlaminated area chip	^B	CE 1/4 (6.4) EE 1/16 (1.6) ^C	^B	CE 1/4 (6.4) EE 3/32 (2.4) ^C	^B	CE 1/4 (6.4) EE 1/8 (3.2) ^C
Scuff; streak	light intensity ^D	light intensity ^D	light intensity ^D	light intensity ^D	light intensity ^D	light intensity ^D

^A The *central area* is an area formed by an oval or circle whose axes or diameters, when centered, do not exceed 80 % of the overall dimension. The *outer area* is the area outside of the *central area*.

^B Not applicable.

^C CE = covered edge of glass edge bite and

EE = exposed edge. (If CE or EE is unknown use CE tolerance.)

^D *Light Intensity*—Barely noticeable at 36 in. (914.4 mm).

^E *Medium Intensity*—Noticeable at 36 in. (914.4 mm) but not at 11 ft (3352.8 mm).

8.2 *Edge*—An edge shall be cut, sawed, ground, sanded to remove sharp edges only, seamed, ground and polished, beveled, or mitered as specified.

8.3 Marking:

8.3.1 Each laminate, as supplied by the manufacturer, shall bear the manufacturer's name, or trademark, or both, unless otherwise specified.

8.3.2 Laminated glass intended for safety glazing applications specified by building codes, shall be permanently marked as required by the applicable safety glazing standard.

8.4 *Thickness*—For thickness tolerances consult the laminator. Nominal thickness tolerance computation guidelines are as follows:

8.4.1 *Minimum Thickness Tolerance*—Minimum thickness tolerance shall be the summation of the values for the minimum thickness of each glass ply obtained from Specification C 1036 and the minimum interlayer thickness obtained from the laminator.

8.4.2 Maximum Thickness Tolerance:

8.4.2.1 *Annealed Glasses*—The summation of the values for the maximum thickness of each glass ply obtained from Specification C 1036 and the maximum interlayer thickness obtained from the laminator.

8.4.2.2 *Heat Treated Glasses*—Add 0.031 in. (0.79 mm) to the overall maximum thickness of the laminate.

8.5 Length and Width:

8.5.1 Length and width tolerances of symmetrically laminated glass shall be in accordance with Table 2 when measured in accordance with 7.9.

8.5.2 For length and width of nonsymmetrical laminated glass contact the supplier for size tolerances.

8.6 Flatness:

TABLE 2 Length and Width Tolerances for Rectangular Shapes of Symmetrically Laminated Glass,^A in. (mm)

Laminate Thickness Designation, <i>t</i>	Transparent Glass	Patterned and Wired Glass	Heat Strengthened and Tempered Glass
$t \leq 1/4$ ($t \leq 6.4$)	+ 5/32, - 1/16 (+ 4.0, - 1.6)	+ 5/16, - 1/8 (+ 7.9, - 3.2)	+ 7/32, - 3/32 (+ 5.6, - 2.4)
$1/4 < t \leq 1/2$ ($6.4 < t \leq 12.7$)	+ 1/4, - 1/16 (+ 6.4, - 1.6)	+ 5/16, - 1/8 (+ 7.9, - 3.2)	+ 1/4, - 1/8 (+ 6.4, - 3.2)
$1/2 < t \leq 1$ ($12.7 < t \leq 25.4$)	+ 1/4, - 1/8 (+ 6.4, - 3.2)	+ 5/16, - 1/8 (+ 7.9, - 3.2)	+ 5/16, - 1/8 (+ 7.9, - 3.2)

^A For nonsymmetrical laminated glass contact the laminator for size tolerances.

8.6.1 For annealed transparent glasses the overall bow and warp shall not exceed 1/16 in. (1.6 mm) per foot (300 mm) of length when measured in accordance with 7.8.

8.6.2 Because of the nature of the processes used in manufacturing heat-strengthened, rolled, tempered, or wired glass, these glasses may not be as flat as annealed transparent glass. The deviation from flatness of laminated glass depends on glass type, thickness, width, length, laminating process, and other factors. For other than annealed transparent glasses the overall bow and warp shall not exceed the values shown in Table 3 when measured in accordance with 7.8.

8.6.3 Localized warp for rectangular laminated glass shall not exceed 1/16 in. (1.6 mm) in any 12 in. (300 mm) span of edge.

8.7 *Blemishes*—Maximum allowable laminating process blemishes shall not be greater than those listed in Table 1.

9. Keywords

9.1 annealed; blast resistant; bullet resistant; hurricane resistant; glass; heat-treated; interlayer; laminated; safety; security

TABLE 3 Maximum Allowable Overall Bow and Warp for Laminated other than Annealed Transparent Glasses^A

Edge Dimension, in. (mm)	Laminate Make-up Two Glass Plies of, in. (mm):				
	1/8 to 3/16 (3 to 5)	1/4 (6)	5/16 (8)	3/8 (10)	1/2 to 7/8 (12 to 22)
0 to 18 (0 to 460)	1/8 (3.2)	1/16 (1.6)	1/16 (1.6)	1/16 (1.6)	1/16 (1.6)
over 18 to 36 (460 to 910)	3/16 (4.8)	1/8 (3.2)	3/32 (2.4)	3/32 (2.4)	1/16 (1.6)
over 36 to 48 (910 to 1220)	9/32 (7.1)	3/16 (4.8)	5/32 (4.0)	1/8 (3.2)	3/32 (2.4)
over 48 to 60 (1220 to 1520)	3/8 (9.5)	9/32 (7.1)	7/32 (5.6)	3/16 (4.8)	1/8 (3.2)
over 60 to 72 (1520 to 1830)	1/2 (12.5)	3/8 (9.5)	9/32 (7.1)	1/4 (6.4)	3/16 (4.8)
over 72 to 84 (1830 to 2130)	5/8 (15.9)	1/2 (12.7)	11/32 (8.7)	5/16 (7.9)	1/4 (6.4)
over 84 to 96 (2130 to 2440)	3/4 (19.0)	5/8 (15.9)	7/16 (11.1)	3/8 (9.5)	9/32 (7.1)
over 96 to 108 (2440 to 2740)	7/8 (22.2)	3/4 (19.0)	9/16 (14.3)	1/2 (12.7)	3/8 (9.5)
over 108 to 120 (2740 to 3050)	1 (25.4)	7/8 (22.2)	11/16 (17.5)	5/8 (15.9)	1/2 (12.7)
over 120 to 132 (3050 to 3350)	...	1 (25.4)	13/16 (20.6)	3/4 (19.0)	5/8 (15.9)
over 132 to 144 (3350 to 3660)	...	1 1/8 (28.6)	15/16 (23.8)	7/8 (22.2)	3/4 (19.0)
over 144 to 156 (3660 to 3960)	...	1 1/4 (31.8)	1 1/16 (27.0)	1 (25.4)	7/8 (22.2)

^A See 7.8 for measurement method.

APPENDIX

(Nonmandatory Information)

X1. GLASS SELECTION

X1.1 *Visual Mockups*—Viewing full-size mockups under typical site conditions and surrounding landscape is highly recommended for evaluation of reflected and optical distortion.

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