Designation: E2461 − 12 (Reapproved 2017)

Standard Practice for Determining the Thickness of Glass in Airport Traffic Control Tower Cabs[1]

This standard is issued under the fixed designation E2461; 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.

1. Scope

1.1 This practice covers the determination of the thickness of glass installed in airport traffic control towers (ATCT) to resist a specified design loading with a selected probability of breakage less than or equal to either 1 lite per 1000 or 4 lites per 1000 at the first occurrence of the design wind loading.

1.2 The procedures apply to common outward sloping cab glass designs for which the specified loads do not exceed 10 kPa (210 psf).

1.3 The procedures assume control tower cab glass has an aspect ratio no greater than 2.

1.4 The procedures assume control tower cab glass has an area no less than 1.86 square metres (20 square feet).

1.5 The procedures apply only to annealed monolithic, annealed laminated, or annealed insulating glass having a rectangular or trapezoidal shape.

1.6 The use of the procedures assumes the following:

1.6.1 Annealed monolithic and annealed laminated glass installed in ATCTs shall have continuous lateral support along two parallel edges, along any three edges, or along all four edges;

1.6.2 Insulating glass shall have continuous lateral support along all four edges; and

1.6.3 Supported glass edges are simply supported and free to slip in plane.

1.7 The procedures do not apply to any form of wired, patterned, etched, sandblasted, or glass types with surface treatments that reduce the glass strength.

1.8 The procedures do not apply to any form of heat treated glass, chemically strengthened glass, or any type of glass with surface treatments intended to increase the glass strength.

1.9 The procedures address the determination of thickness and construction type to resist a specified design wind load at a selected probability of breakage. The final glass thickness and construction determined also depends upon a variety of other factors (see 5.3).

1.10 These procedures do not address blast loading on glass.

1.11 The values stated in SI units are to be regarded as standard. The values given in parentheses are mathematical conversions to inch-pound units that are provided for information only and are not considered standard.

1.12 *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 to determine the applicability of regulatory limitations prior to use.*

1.13 *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]

C162 Terminology of Glass and Glass Products
C1036 Specification for Flat Glass
E631 Terminology of Building Constructions
E1300 Practice for Determining Load Resistance of Glass in Buildings

2.2 *American Society of Civil Engineers Standard:*[3]

ASCE 7 Minimum Design Loads for Buildings and Other Structures

3. Terminology

3.1 *Definitions:*

3.1.1 For definitions of general terms related to building construction used in this practice refer to Terminology E631,

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[1] This practice is under the jurisdiction of ASTM Committee E06 on Performance of Buildings and is the direct responsibility of Subcommittee E06.52 on Glass Use in Buildings.

Current edition approved April 1, 2017. Published April 2017. Originally approved in 2005. Last previous edition in 2012 as E2461-12. DOI: 10.1520/E2461-12R17.

[2] For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

[3] Available from American Society of Civil Engineers (ASCE), 1801 Alexander Bell Dr., Reston, VA 20191, http://www.asce.org.

and for general terms related to glass and glass products, refer to Terminology C162.

3.2 *Definitions of Terms Specific to This Standard:*

3.2.1 *annealed (AN) glass, n*—a flat, monolithic, glass lite of uniform thickness; it is formed by a process whereby the magnitudes of the residual stresses are nearly zero.

3.2.2 *aspect ratio (AR), n*—the ratio of the long dimension to the short dimension for rectangular glass or the ratio of the long dimension to the short dimension of the rectangle that completely encloses trapezoidal glass. In these procedures, AR is always equal to or greater than 1.0.

NOTE 1—The rectangle that completely encloses the trapezoid has two sides parallel to the horizontal edges of the trapezoid and the other two sides perpendicular to the horizontal edges of the trapezoid. All dimensions shall be measured from edge to edge of glass.

3.2.3 *equivalent rectangular area (ERA), n*—the product of the longest horizontal glass dimension and the length of the edge perpendicular to the horizontal dimension in the plane of the glass. All dimensions shall be measured from edge to edge of glass.

3.2.4 *designated thickness for laminated glass (LG), n*—the designated thickness for LG as Table 1 specifies.

3.2.5 *designated thickness for monolithic glass, n*—the designated or nominal thickness commonly used in specifying a particular glass product, based on the minimum thicknesses presented in Table 2 and Specification C1036.

3.2.6 *glass breakage, n*—the fracture of any lite or ply in monolithic, laminated, or insulating glass resulting from stress that an applied uniform lateral load induces.

3.2.7 *insulating glass (IG) unit, n*—consists of any combination of two glass lites, as defined herein, that enclose a sealed space filled with air or other gas.

3.2.8 *laminated glass (LG), n*—a flat-lite of uniform thickness that is fabricated by bonding two or more monolithic glass lites or plies of equal thickness, as defined herein, together with polyvinyl butyral (PVB) interlayer(s).

TABLE 2 Thickness Designations, Minimum Glass Thickness, and Unit Self-Weight

Nominal thickness or designation, mm (in.)	Minimum thickness, mm (in.)	Glass weight Pa (psf)
2.7 (lami)	2.59 (0.102)	67.0 (1.40)
3.0 (⅛)	2.92 (0.115)	74.2 (1.55)
4.0 (5⁄32)	3.78 (0.149)	99.1 (2.07)
5.0 (3⁄16)	4.57 (0.180)	124 (2.59)
6.0 (¼)	5.56 (0.219)	149 (3.11)
8.0 (5⁄16)	7.42 (0.292)	199 (4.15)
10.0 (⅜)	9.02 (0.355)	248 (5.18)
12.0 (½)	11.91 (0.469)	298 (6.22)
16.0 (⅝)	15.09 (0.595)	397 (8.29)
19.0 (¾)	18.26 (0.719)	472 (9.85)
22.0 (⅞)	21.44 (0.844)	546 (11.4)
25.0 (1)*	24.4 (0.969)	622 (13.0)
32 (1 – ¼)[A]	27.38 (1.22)	795 (16.6)
38 (1 – ½)[A]	31.6 (1.47)	943 (19.7)

[A] Not a glazing industry standard thickness designation.

3.2.9 *lateral, adj*—perpendicular to the glass surface.

3.2.10 *load, n*—a uniformly distributed lateral pressure.

3.2.10.1 *design load, n*—the magnitude of the 3-second duration load used to design glass for ATCT cabs. Equations used herein for computing magnitudes for design loads adjust glass self weight to a magnitude consistent with a 3-second duration.

3.2.10.2 *specified design load, n*—the magnitude in kPa (psf), type (for example, wind or self-weight) and duration of the load. The wind load has a duration of approximately 3 seconds. Glass self-weight (Table 2) has a long duration, typically equal to the in-service life of the window glass lite. Earth facing cab glass is only subjected to wind load and its self-weight.

3.2.10.3 *long duration load, n*—any load lasting approximately 30 days or longer.

3.2.10.4 *short duration load, n*—any load lasting approximately 3 seconds, such as, wind load.

TABLE 1 Thickness Designations for Laminated Glass

Laminated glass designation, t, mm (in.)	Laminated glass construction nominal thickness, mm (in.) [glass/PVB/glass]	Laminated glass thickness designation for use in these procedures mm (in.)
6 (¼)	2.7/0.76/2.7 {(lami)/0.030/(lami)} 3/0.76/3 {(⅛)/0.030/(⅛)} 3/1.52/3 {(⅛)/0.060/(⅛)}	6 (¼)
8 (5⁄16)	4/0.76/4 {(5⁄32)/0.030/(5⁄32)}	8 (5⁄16)
10 (⅜) 11 (7⁄16)	5/0.76/5 {(3⁄16)/0.030/(3⁄16)} 5/1.52/5 {(3⁄16)/0.060/(3⁄16)}	10 (⅜)
12 (½) 13 (9⁄16)	6/0.76/6 {(¼)/0.030/(¼)} 6/1.52/6 {(¼)/0.060/(¼)}	12 (½)
16 (⅝)	8/0.76/8 {(5⁄16)/0.030/(5⁄16)} 8/1.52/8 {(5⁄16)/0.060/(5⁄16)} 8/2.28/8 {(5⁄16)/0.090/(5⁄16)}	16 (⅝)
19 (¾)	10/0.76/10 {(⅜)/0.030/(⅜)} 10/1.52/10 {(⅜)/0.060/(⅜)} 10/2.28/10 {(⅜)/0.090/(⅜)}	19 (¾)
25 (1)	12/1.52/12 {(½)/0.060/(½)} 12/2.28/12 {(½)/0.090/(½)}	25 (1)
32 (1¼)	16/1.52/16 {(⅝)/0.060/(⅝)} 16/2.28/16 {(⅝)/0.090/(⅝)}	32 (1¼)
38 (1½)	19/1.52/19 {(¾)/0.060/(¾)} 19/2.28/19 {(¾)/0.090/(¾)}	38 (1½)

3.2.11 *minimum thickness of monolithic glass, n*—the minimum allowable thickness associated with a nominal or designated glass thickness as given in Table 2 and Specification C1036.

3.2.12 *probability of breakage (P_b), n*—the theoretical fraction of glass lites or plies that would break at the first occurrence of the resistance load, typically expressed in lites per thousand.

4. Summary of Practice

4.1 The use of these procedures requires a specified design load that shall consist of the wind load and the factored lateral component of glass weight. The total design load shall not exceed 10 kPa (210 psf).

4.2 The procedures specified herein facilitate determination of the thickness of an annealed window glass construction required to resist the specified design loading for the selected probability of breakage.

4.3 This standard procedure uses methods in Practice E1300 to determine the approximate lateral deflection of the geometric center of the window glass construction. Annex A2 provides deflection charts for laminated glass thicknesses larger than those contained in Practice E1300.

5. Significance and Use

5.1 This standard procedure facilitates determination of the thickness of a glass construction required to resist a specified design load with a selected probability of breakage.

5.2 This standard procedure addresses the following glass constructions: annealed monolithic, annealed laminated, and insulating glass fabricated with annealed monolithic or annealed laminated glass, or both.

5.3 Use of these procedures assume:

5.3.1 The glass is free of edge damage and is properly glazed,

5.3.2 The glass has not been subjected to abuse,

5.3.3 The surface condition of the glass is typical of glass that has been in service for several years, and is significantly weaker than freshly manufactured glass due to minor abrasions on exposed surfaces,

5.3.4 The glass edge support system is sufficiently stiff to limit the lateral deflections of the supported glass edges to less than 1⁄175 of their lengths. The specified design load shall be used for this calculation, and

5.3.5 The center of glass deflection shall not result in loss of edge support. Typically maintaining center of glass deflection at or below the magnitude of three times the nominal glass thickness assures that no loss of edge support will occur.

5.4 Many other factors affect the selection of glass type and thickness. These factors include but are not limited to: thermal stresses, the effects of windborne debris, excessive deflections, behavior of glass fragments after breakage, seismic effects, heat flow, edge bite, noise abatement, potential post-breakage consequences, and so forth. In addition, considerations set forth in federal, state, and local building codes along with criteria presented in safety glazing standards and site specific concerns may control the ultimate glass type and thickness selection.

6. Procedure

6.1 Select a probability of breakage, glass type or construction, and glass thickness(es).

6.2 Compute the design load for monolithic or single laminated glass according to:

$$L_D = L_W + 2L_G\cos\theta \quad (1)$$

where:

L_D = denotes the design load,
L_W = denotes the wind load,
L_G = denotes the weight of the glass, and
θ = denotes the acute angle the glass makes with the horizontal. For monolithic or single laminated glazing, the user shall obtain L_G from Table 2 for the nominal glass thickness. For insulating glass, L_G shall consist of the weights of both glass lites as determined from Table 2.

6.3 *Monolithic Single Glazing Continuously Supported Along all Four Edges:*

6.3.1 Determine the ERA.

6.3.2 Determine the AR.

6.3.3 Determine the required glass thickness from Fig. A1.1 (P_B = 0.001) or Fig. A1.2 P_B = 0.004) for the design load, ERA, and AR.

6.3.4 Determine the approximate maximum center of glass deflection using procedures from Practice E1300.

6.4 *Single Laminated Glazing Continuously Supported Along all Four Edges:*

6.4.1 Determine the ERA.

6.4.2 Determine the AR.

6.4.3 Determine the required glass thickness from Fig. A1.3 (P_B = 0.001) or Fig. A1.4 (P_B = 0.004) for the design load, ERA, and AR.

6.4.4 Determine the approximate maximum center of glass deflection using procedures from Practice E1300.

6.5 *Monolithic Single Glazing Simply Supported Continuously Along Two Opposite Sides or any Three Sides:*

6.5.1 Determine the Unsupported Glass Length.

6.5.2 Determine the required glass thickness from Fig. A1.5 (P_B = 0.001) or Fig. A1.6 (P_B = 0.004) for the design load, ERA, and AR.

6.5.3 Determine the approximate maximum center of glass deflection using procedures from Practice E1300.

6.6 *Single Laminated Glazing Simply Supported Continuously Along Two Opposite Sides or any Three Sides:*

6.6.1 Determine the unsupported glass length.

6.6.2 Determine the required glass thickness from Fig. A1.7 (P_B = 0.001) or Fig. A1.8 (P_B = 0.004) for the design load, ERA, and AR.

6.6.3 Determine the approximate maximum center of glass deflection using procedures from Practice E1300.

6.7 *Insulating Glass (IG) with Monolithic Glass Lites of Equal (Symmetric) Glass Type and Thickness.*

6.7.1 Compute the design load for IG as $L_{DIG}=5(L_W+2L_G\cos\theta)/9$ in which all terms are previously defined. The weigh of the glass, L_G, consists of the weight of both glass lites.

6.7.2 Determine the ERA.

6.7.3 Determine the AR.

6.7.4 Determine the required glass thickness for a single lite in the IG unit from Fig. A1.1 (P_B = 0.001) or Fig. A1.2 (P_B = 0.004) for the design load, ERA, and AR.

6.7.5 Determine the approximate maximum center of glass deflection as the deflection of one lite in the IG unit under the design load $0.9L_{DIG}$ using procedures from Practice E1300.

6.8 *Insulating Glass (IG) with Laminated Glass Lites of Equal (Symmetric) Glass Type and Thickness.*

6.8.1 Compute the design load for IG as $L_{DIG}=5(L_W+2L_G\cos\theta)/9$ in which all terms are previously defined. The weigh of the glass, L_G, consists of the weight of both glass lites.

6.8.2 Determine the ERA.

6.8.3 Determine the AR.

6.8.4 Determine the required glass thickness for a single lite in the IG unit from Fig. A1.1 (P_B = 0.001) or Fig. A1.4 (P_B = 0.004) for the design load, ERA, and AR.

6.9 Determine the approximate maximum center of glass deflection as the deflection of one lite in the IG unit under the design load $0.9L_{DIG}$ using procedures from Practice E1300.

7. Report

7.1 Report the following information:

7.1.1 Date of calculation;

7.1.2 The probability of breakage, design wind load, drawing of the glass shape with dimensions, glass edge support conditions, longest horizontal dimension of the glass, the length of the edge perpendicular to the horizontal dimension in the plane of the glass, aspect ratio, equivalent rectangular area, glass type(s) and thickness(es), weight of the glass, glass type factor(s), approximate lateral deflection; and

7.1.3 A statement that the procedure followed was in accordance with this practice or a full description of any deviations.

8. Precision and Bias

8.1 The non-factored load charts (the upper charts of Figs. A1.1-A1.8) are based upon a theoretical glass breakage model that relates the strength of glass to the surface condition. Complete discussions of the formulation of the model are presented elsewhere.[4, 5]

8.1.1 A conservative estimate of the surface condition for glass design was used in generation of the charts. This surface condition estimate is based upon the best available glass strength data and engineering judgment. It is possible that the information presented in the non-factored load charts may change as further data becomes available.

9. Keywords

9.1 annealed glass; deflection; flat glass; glass; insulating glass; laminated glass; load resistance; monolithic glass; probability of breakage; strength; wind load

[4] Norville, H.S., El-Shami, M.M., Jackson, R., and Johnson G., "Design Methodology for Large Trapezoidal Window Glass Lites," *The Use of Glass in Buildings*, ASTM STP 1434.

[5] Norville, H.S., and Minor J. E., "Simplified Window Glass Design Procedure," *Journal of Architectural Engineering*, Vol 105, No. 6, December 2000.

ANNEXES

(Mandatory Information)

A1. DESIGN CHARTS

A1.1 Figs. A1.1-A1.8 present design charts in both SI and inch-pound units. The design charts were developed using failure prediction models for glass. Practice E1300 discusses the failure prediction models for glass. The design charts presented herein are predicated on the same surface flaw parameters as the non-factored load charts in Practice E1300. The design charts are based on minimum glass thicknesses referenced in Specification C1036.

A1.2 In Design charts for glass simply supported continuously along four sides (Figs. A1.1-A1.4), solid lines represent glass with AR = 1.0 and dashed lines represent glass with AR = 2.0. For aspect ratios falling between 1.0 and 2.0, interpolation is acceptable.

A1.3 Design charts for laminated glass assume an interlayer temperature of 50°C (122°F).

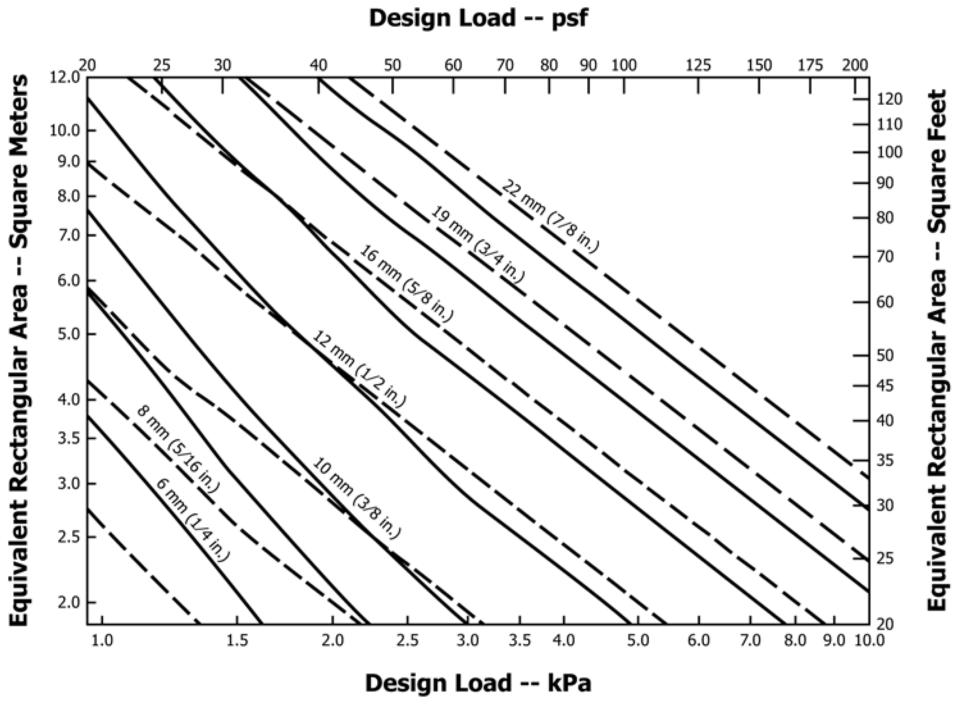

FIG. A1.1 Design Chart for Annealed Glass with Four Sides Simply Supported (P_b = 0.001)

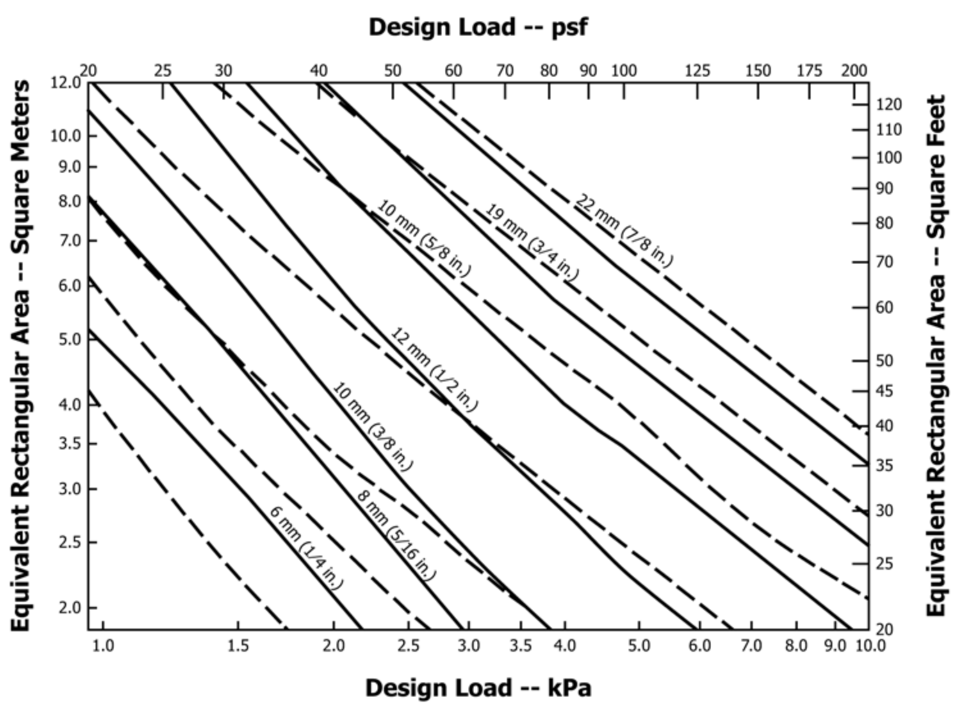

FIG. A1.2 Design Chart for Annealed Glass with Four Sides Simply Supported (P_b = 0.004)

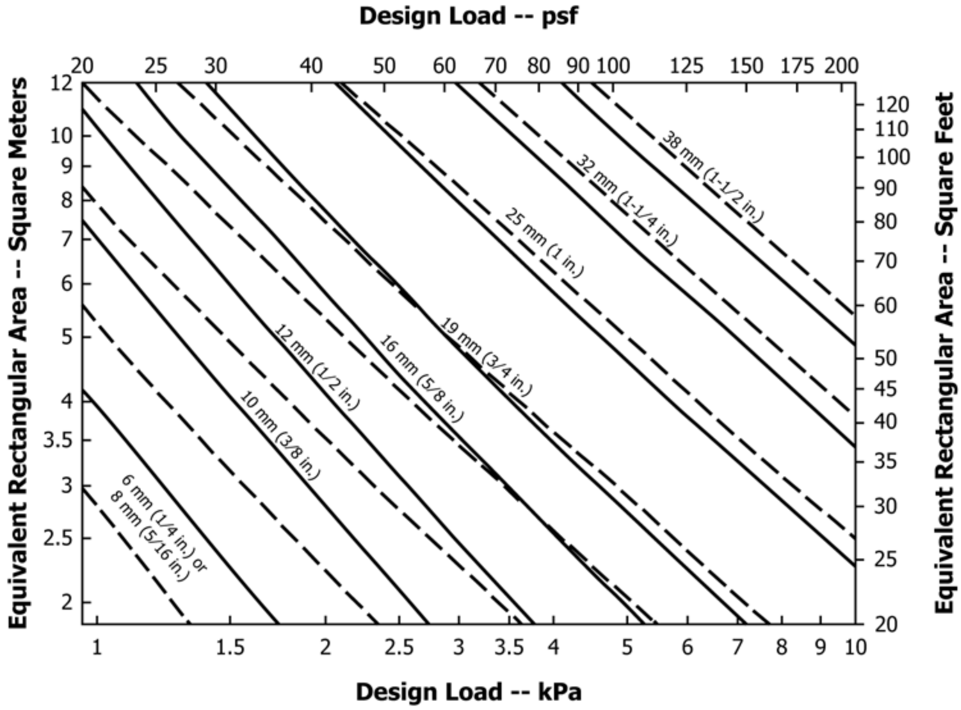

FIG. A1.3 Design Chart for Annealed Laminated Glass with Four Sides Simply Supported (P_b=0.001)

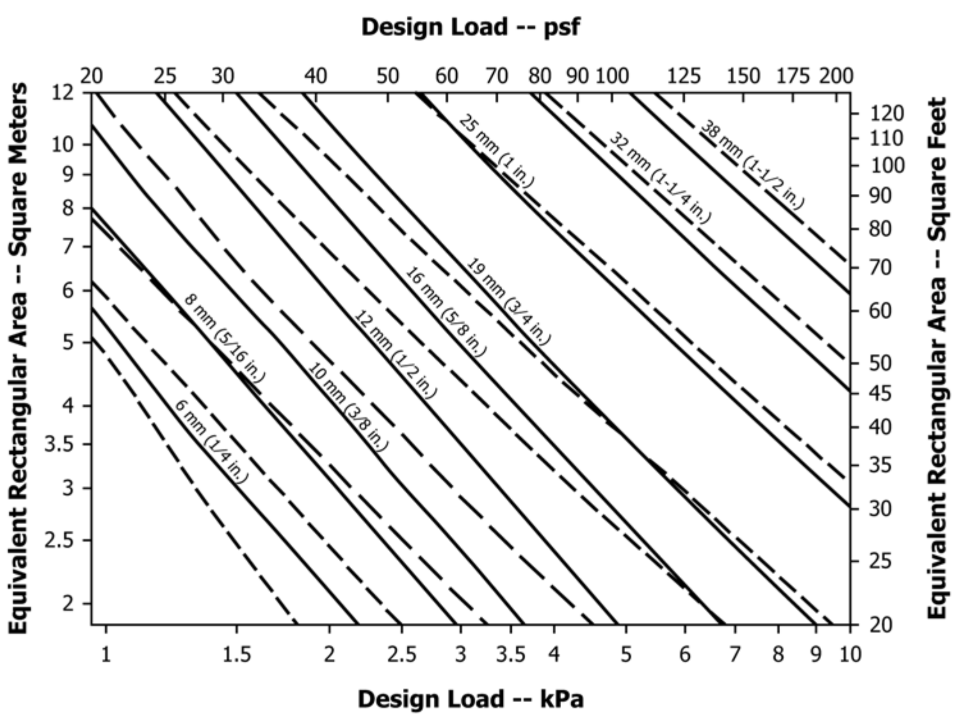

FIG. A1.4 Design Chart for Annealed Laminated Glass with Four Sides Simply Supported (P_b = 0.004)

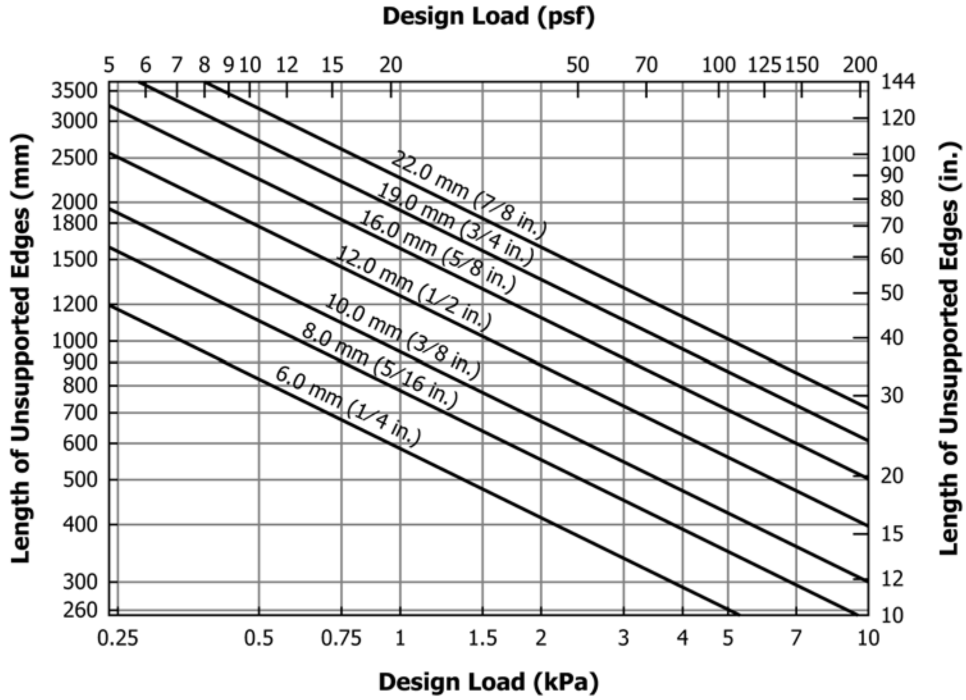

FIG. A1.5 Design Chart for Annealed Glass with Two and Three Sides Simply Supported (P_b = 0.001)

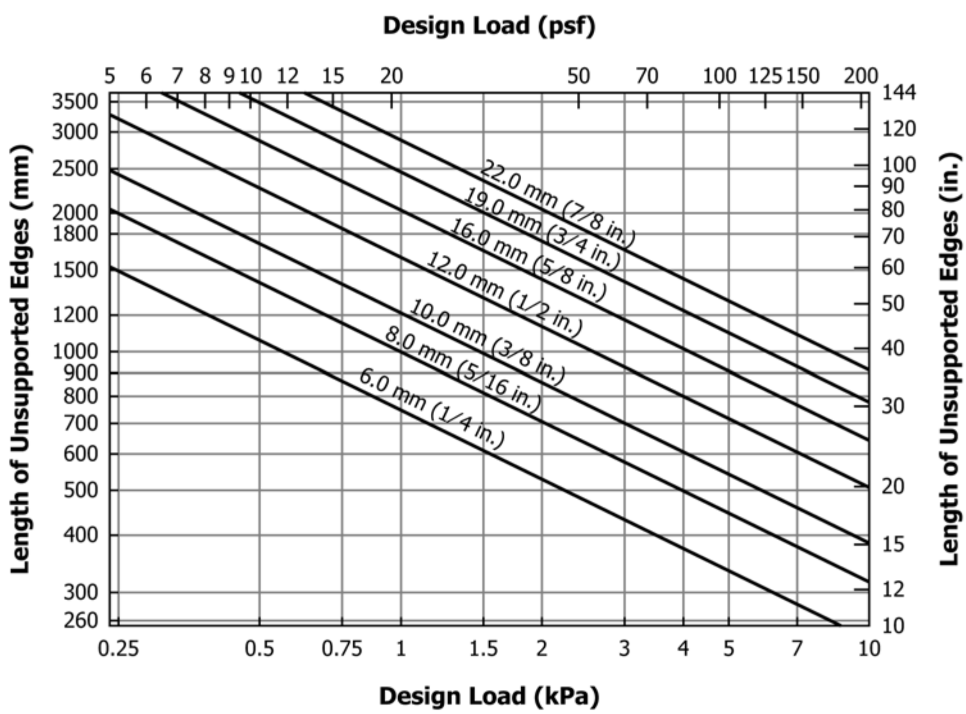

FIG. A1.6 Design Chart for Annealed Glass with Two and Three Sides Simply Supported (P_b=0.004)

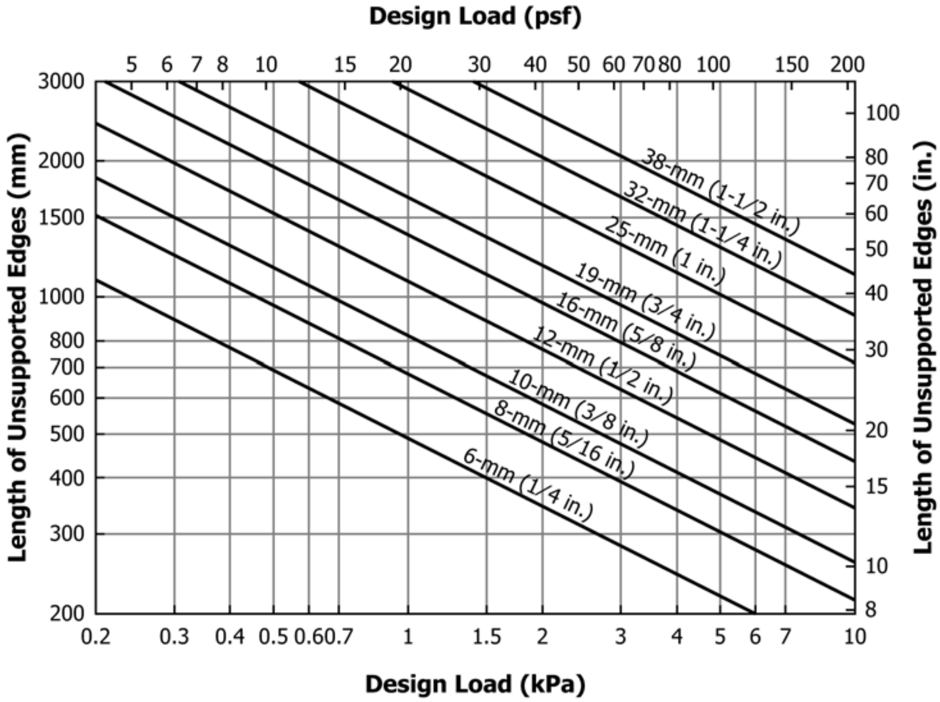

FIG. A1.7 Design Chart for Annealed Laminated Glass with Two and Three Sides Simply Supported (P_b = 0.001)

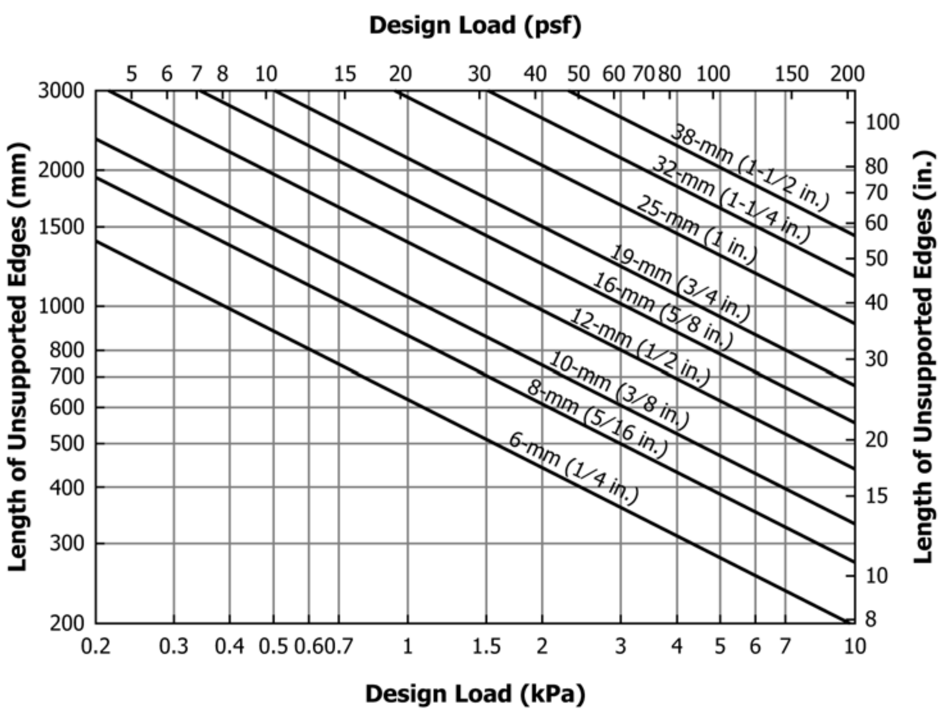

FIG. A1.8 Design Chart for Annealed Laminated Glass with Two and Three Sides Simply Supported (P_b = 0.004)

A2. ADDITIONAL DEFLECTION CHARTS

A2.1 Figs. A2.1-A2.3 present charts for determining approximate center of glass deflection for thick laminated glass simply supported continuously along four sides. Fig. A2.4 gives a deflection chart for laminated glass supported along two or three sides. Deflection lines for AR3, AR4, and AR5 are given for informational purposes only. Designers use these charts in the same manner as they would use the deflections charts in Practice E1300.

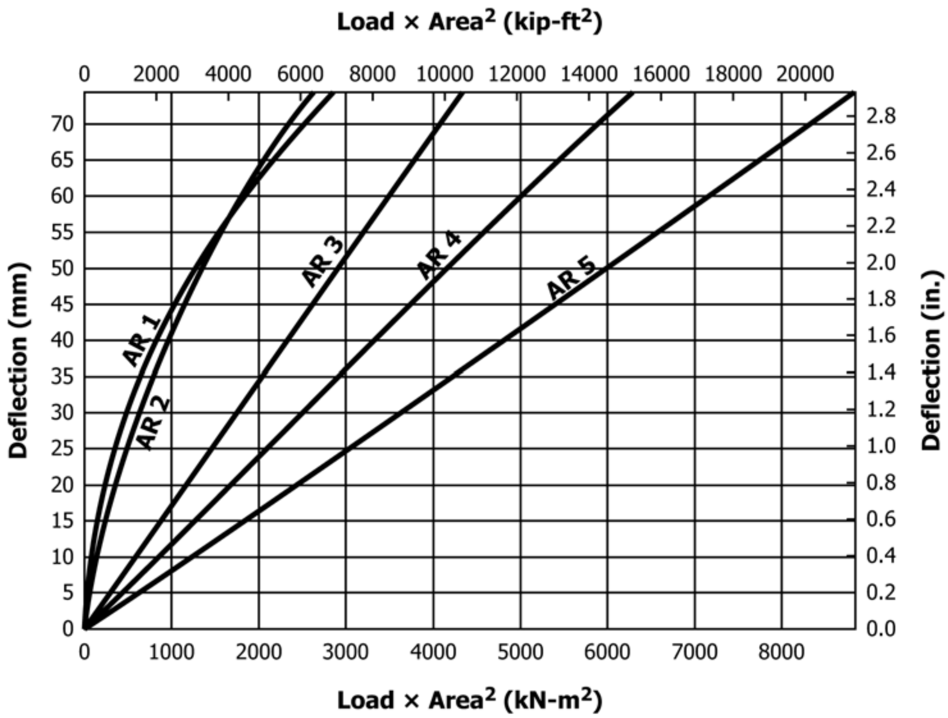

FIG. A2.1 Deflection Chart for 25 mm (1 in.) Annealed Laminated Glass with Four Sides Simply Supported

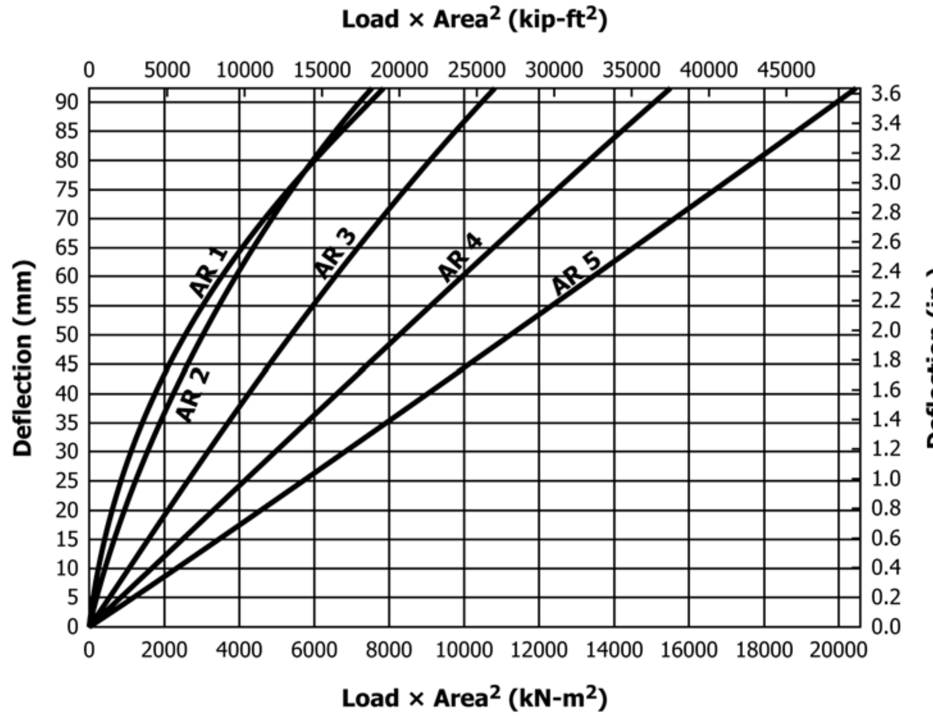

FIG. A2.2 Deflection Chart for 32 mm (1¼ in.) Annealed Laminated Glass with Four Sides Simply Supported

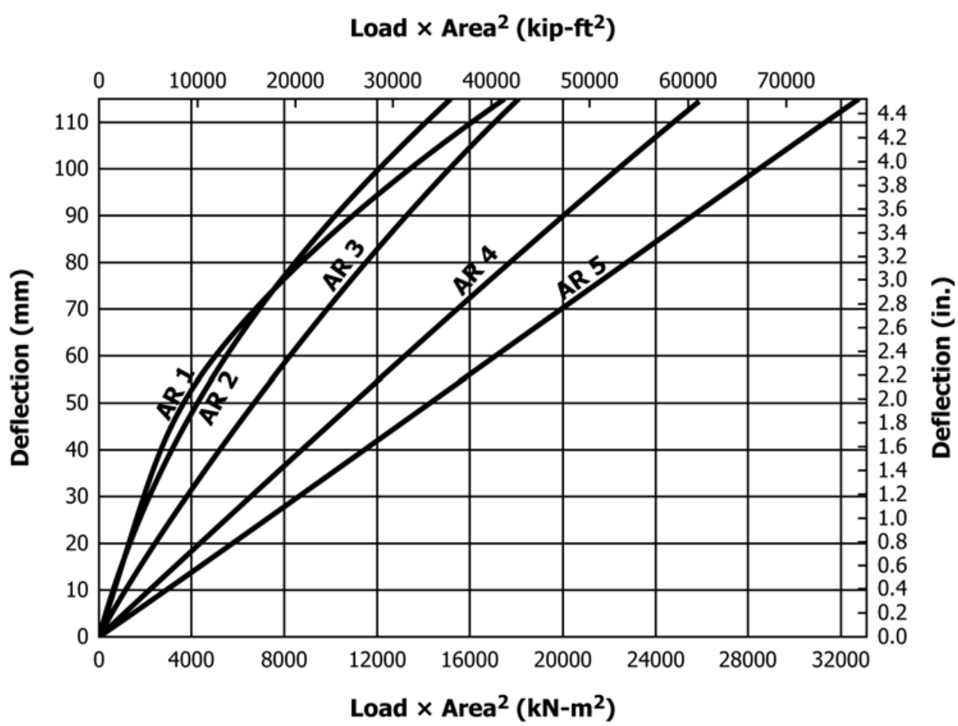

FIG. A2.3 Deflection Chart for 38 mm (1½ in.) Annealed Laminated Glass with Four Sides Simply Supported

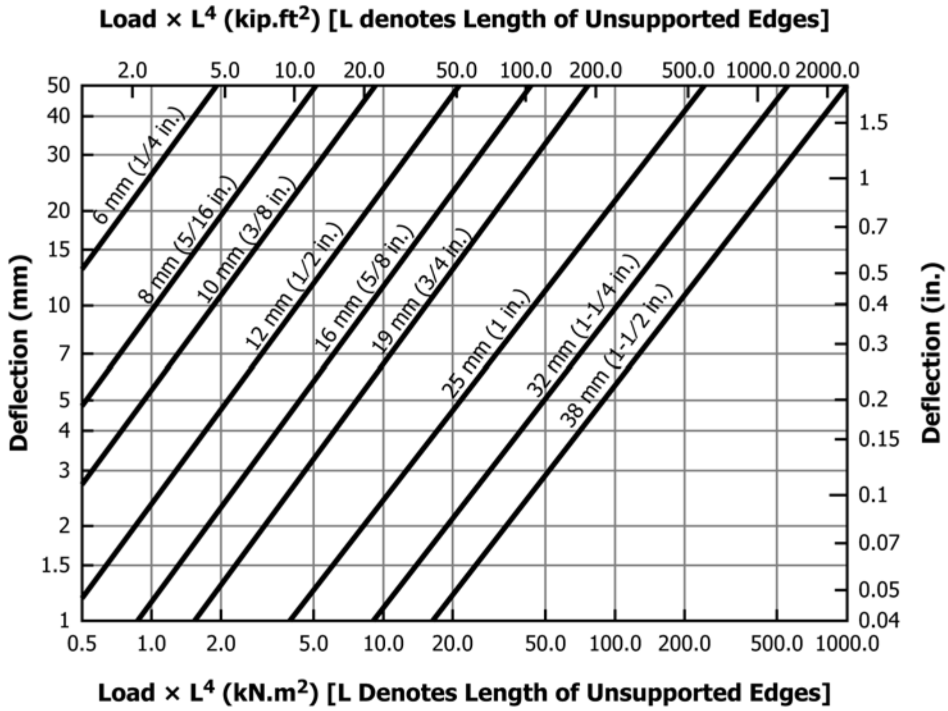

FIG. A2.4 Deflection Chart for Laminated Glass Simply Supported Along Two or Three Sides

A3. DESIGN EXAMPLES

A3.1 Design Example 1—Design a trapezoidal IG unit supported along all four sides to resist a uniform wind loading (3-second duration assumed) of 2.4 kPa (50 psf) magnitude with a probability of breakage less than or equal to 0.001. The top and bottom sides of the lite are parallel and have 2540 mm (100 in.) and 2030 mm (80 in.) lengths, respectively. The side perpendicular to the top and bottom edges has 2540 mm (100 in.) length. The glass construction slopes outward 15° at the top from the vertical. The angle of the glass necessitates the addition of the component of glass weight normal to the plane of the glass and the wind load to determine the design load. Fig. A3.1 shows a view of the cab glass looking normal to its undeformed plane. The solid lines indicate the trapezoidal shape of the cab glass while the dashed lines indicate the

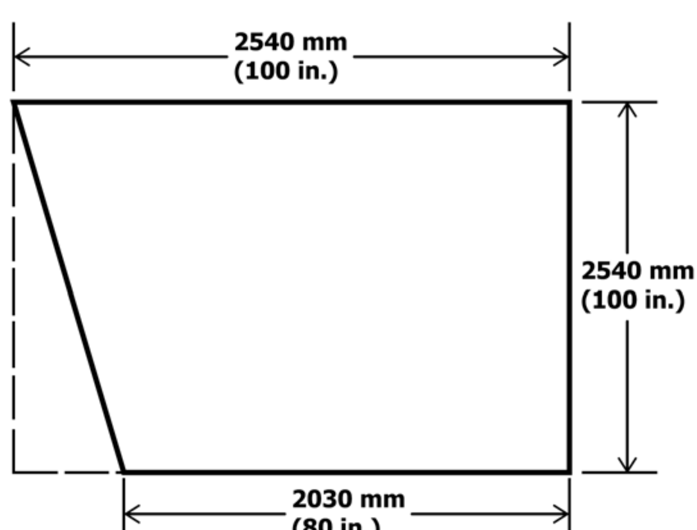

FIG. A3.1 Trapezoidal Cab Glass Outline with Encompassing Rectangle

encompassing rectangle with dimensions of 2540 mm (100 in.) by 2540 mm (100 in.), in this case, the encompassing rectangle.

A3.1.1 *Trial Glazing Design*—IG comprised of two monolithic lites, having 10 mm (3⁄8 in.) nominal thickness and a 12 mm (1⁄2 in.) airspace.

A3.1.2 *Design Load*—Compute the design load from Section 6.8.1, as

$$L_{DIG} = 5[2.4\text{ kPa} + 2(0.596\text{ kPa})(\cos 75°)]/9 = 1.50\text{ kPa }(31.4\text{ psf}) \tag{A3.1}$$

A3.1.3 *Equivalent Rectangular Area:*

$$ERA = (2.54\ m)^2 = 6.45\ m^2\ (69.4\ ft^2) \tag{A3.2}$$

A3.1.4 *Aspect Ratio:*

$$AR = 2540/2540 = 1.0 \tag{A3.3}$$

A3.1.5 *Required Glass Thickness*—Go to Fig. A1.1 (reproduced below for convenience as Fig. A3.2) and follow the steps listed.

A3.1.5.1 *Step 1*—Project a horizontal line from the vertical axes at points corresponding to 6.45 m^2 (69.4 ft^2).

A3.1.5.2 *Step 2*—Project a vertical line from the horizontal axes at points corresponding to 1.50 kPa (31.4 psf).

A3.1.5.3 *Step 3*—The thickness associated with the nearest sloping solid line (AR = 1) above the intersection of the horizontal and vertical lines drawn in Step 1 and Step 2 represents the required single lite glass thickness for the IG unit, that is, 16 mm (5⁄8 in.) for this example. The original trial design using a single glass lite thickness of 12 mm (1⁄2 in.) is not sufficient.

A3.1.6 At this point, we need to make sure that the additional weight associated with 16 mm (5⁄8 in.) glass does not require even thicker glass. Compute a revised design load based upon an IG comprised of two monolithic lites having nominal 16 mm (5⁄8 in.) nominal thickness and a 12 mm (1⁄2 in.) airspace.

A3.1.7 *Revised Design Load*—Compute the design load from 6.8.1, using the new glass thickness as

$$L_{DIG} = 5[2.4\text{ kPa} + 2(0.794\text{ kPa})(\cos 75°)]/9 = 1.56\text{ kPa }(32.6\text{ psf}) \tag{A3.4}$$

A3.1.8 *Check Required Glass Thickness*—Repeat A3.1.5.1 – A3.1.5.3 with revised design load to ensure that an IG with a single lite thickness of 16 mm (5⁄8 in.) will suffice.

A3.1.9 Since the intersection of the horizontal and vertical lines fall below the solid line (AR1) representing 16 mm (5⁄8 in.) glass, a symmetric IG unit comprised of two lites of 16 mm (5⁄8 in.) annealed glass with a 12 mm (1⁄2 in.) airspace will resist the design load with a probability of breakage less than or equal to 1 lite per thousand at the first occurrence of the design wind loading.

A3.1.10 *Determine the Approximate Center of Glass Deflection*—The approximate center of glass deflection is the deflection of one lite under a load of 0.9L_{DIG} = 1.40 kPa (29.4 psf). Using procedures shown in Practice E1300 indicates the approximate center of glass deflection is 10.6 mm (0.42 in.).

A3.2 Design Example 2—Design a single laminated glass lite with trapezoidal shape supported along all four sides to resist a uniform wind loading (3-second duration assumed) of 3.83 kPa (80 psf) magnitude with a probability of breakage less than or equal to 0.001. The top and bottom sides of the lite are

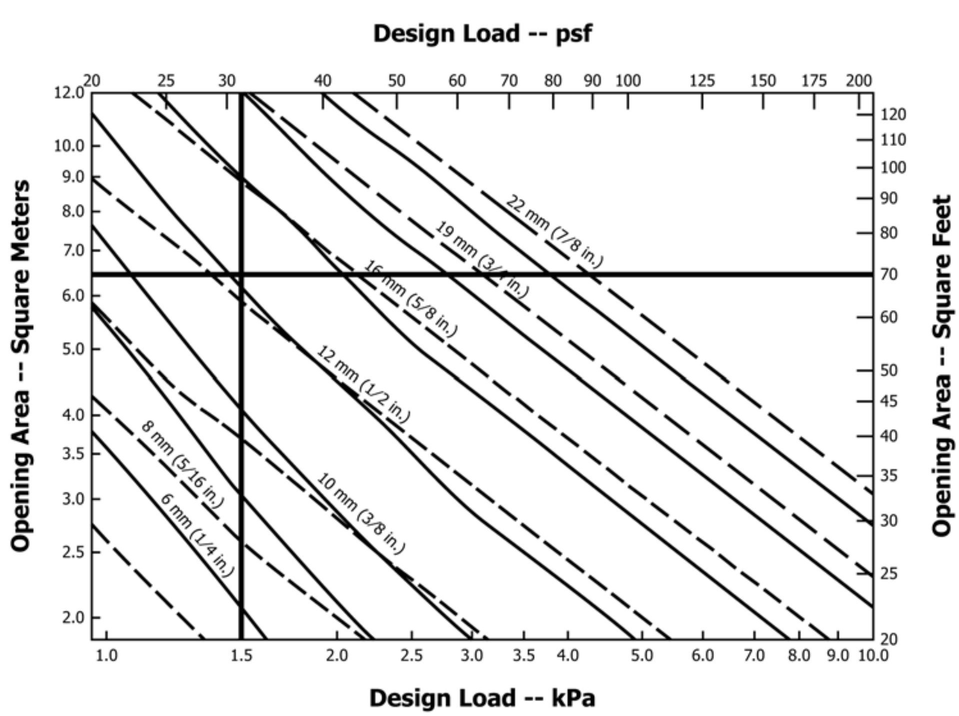

FIG. A3.2 Design Chart for Annealed Glass with Four Sides Simply Supported (P_b = 0.001), with Projected Lines for Design Load and Opening Area in Example

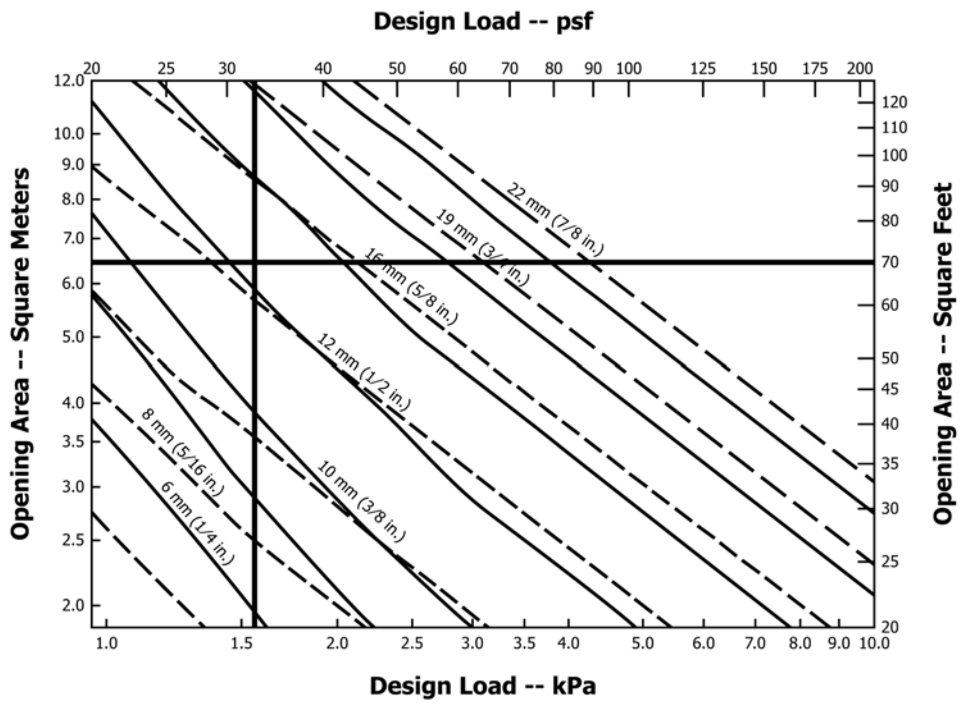

FIG. A3.3 Design Chart for Annealed Glass with Four Sides Simply Supported (P_b = 0.001), with Projected Lines for the Revised Design Load and Opening Area in Example

parallel and have 2210 mm (87 in.) and 2083 mm (82 in.) lengths, respectively. The side perpendicular to the top and bottom edges has a 2210 mm (87 in.) length. The glass construction slopes outward 15° at the top from the vertical. The angle of the glass necessitates the addition of the component of glass weight normal to the plane of the glass and the wind load to determine the design load. The encompassing square is 2210 mm (87 in.) on a side.

A3.2.1 *Trial Glazing Design*—Laminated glass with nominal 38 mm (1½ in.) thickness

A3.2.2 *Design Load*—Compute the design load from 6.2 as:

$$L_D = 3.83\ kPa + 2(0.943\ kPa)(\cos 75°) = 4.31\ kPa\ (90.1\ psf) \quad (A3.5)$$

A3.2.3 *Equivalent Rectangular Area:*

$$ERA = (2.21\ m)^2 = 4.88\ m^2\ (5.26\ ft^2) \quad (A3.6)$$

A3.2.4 *Aspect Ratio:*

$$AR = 2210/2210 = 1.0 \quad (A3.7)$$

A3.2.5 *Required Glass Thickness*—Go to Fig. A1.3 (reproduced below for convenience as Fig. A3.4) and follow the steps listed.

A3.2.5.1 *Step 1*—Project a horizontal line from the vertical axes at points corresponding to 4.88 m^2 (52.6 ft^2).

A3.2.5.2 *Step 2*—Project a vertical line from the horizontal axes at points corresponding to 3.46 kPa (72.2 psf).

A3.2.5.3 *Step 3*—The thickness associated with the nearest sloping line (AR = 1) above the intersection of the horizontal and vertical lines drawn in A3.2.5.1 and A3.2.5.2 is the required thickness of laminated glass required to resist the design loading. In this case, the required thickness of the single laminated glass is 25 mm (1 in.). Since the required thickness will impose a lower dead load with no change in the wind load, use nominal 25 mm (1 in.) laminated glass.

A3.2.6 To compute the approximate center of glass deflection, begin by computing the revised design load associated with the thinner glass.

A3.2.7 *Revised Design Load:*

$$L_D = 3.83\ kPa + 2(0.622\ kPa)(\cos 75°) = 4.15\ kPa\ (86.7\ psf) \quad (A3.8)$$

A3.2.8 *Determine the Approximate Center of Glass Deflection*—To find the approximate center deflection of the laminated glass, compute:

$$\text{Design Load} \times \text{Area}^2 = 4.15\ \text{kPa}(2.21\ \text{m})^4 \quad (A3.9)$$

$$= 99.0\ \text{kN} - \text{m}^2\ (240\ \text{kip} - \text{ft}^2)$$

A3.2.9 *Required Glass Thickness*—Go to Fig. A1.3 (reproduced below for convenience as Fig. A3.4) and follow the steps listed.

A3.2.9.1 *Step 1*—Project a horizontal line from the vertical axes at points corresponding to 4.88 m^2 (52.6 ft^2).

A3.2.9.2 *Step 2*—Project a vertical line from the horizontal axes at points corresponding to 3.46 kPa (72.2 psf).

A3.2.9.3 *Step 3*—The thickness associated with the nearest sloping line (AR = 1) above the intersection of the horizontal and vertical lines drawn in A3.2.9.1 and A3.2.9.2 is the required thickness of laminated glass to resist the design loading. In this case, the required thickness of the single laminated glass is 25 mm (1 in.). Since the required thickness will impose a lower dead load with no change in the wind load, use nominal 25 mm (1 in.) laminated glass.

A3.2.10 To determine approximate center of glass deflection, proceed as follows. In Fig. A2.1 (reproduced for

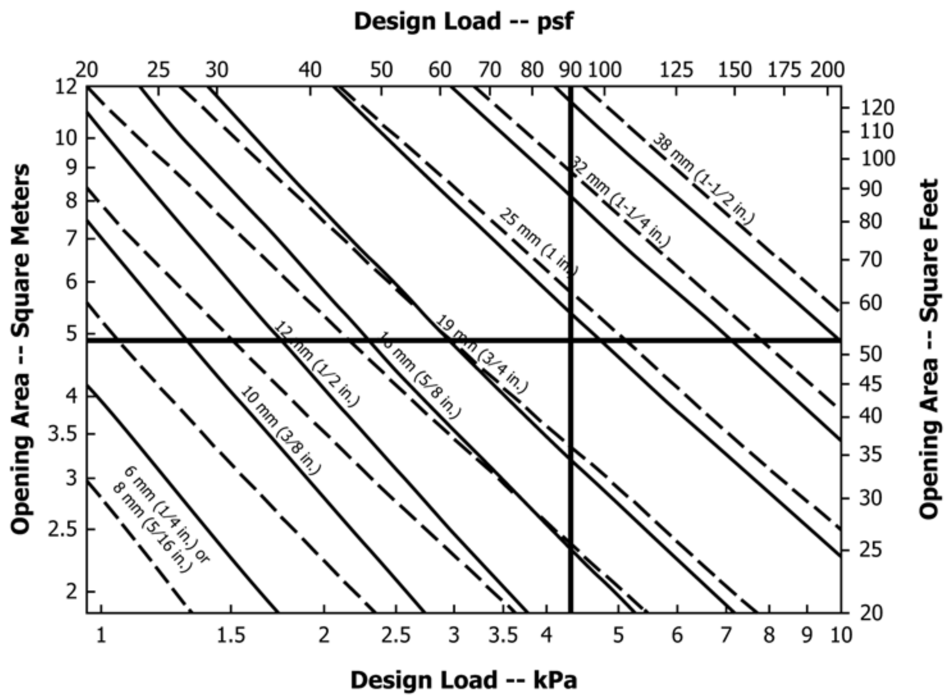

FIG. A3.4 Design Chart for Annealed Laminated Glass with Four Sides Simply Supported (P_b = 0.001)

convenience below as Fig. A3.5) project a vertical line from the points on the horizontal axes corresponding to 99.0 kN-m^2 (240 kip-ft^2). From the intersection of the vertical line with the sloping line corresponding to AR = 1, project a horizontal line to the vertical axes and read the approximate center of glass deflection as 7.0 mm (0.28 in.).

A3.3 *Design Example 3*—Design a single laminated glass lite with trapezoidal shape supported along its top and bottom sides. The uniform wind load acting on the glass has magnitude 1.92 kPa (40 psf). The top and bottom supported sides of the lite are parallel and have 2819 mm (111 in.) and 2565 mm (101 in.) lengths, respectively. The dimension perpendicular to

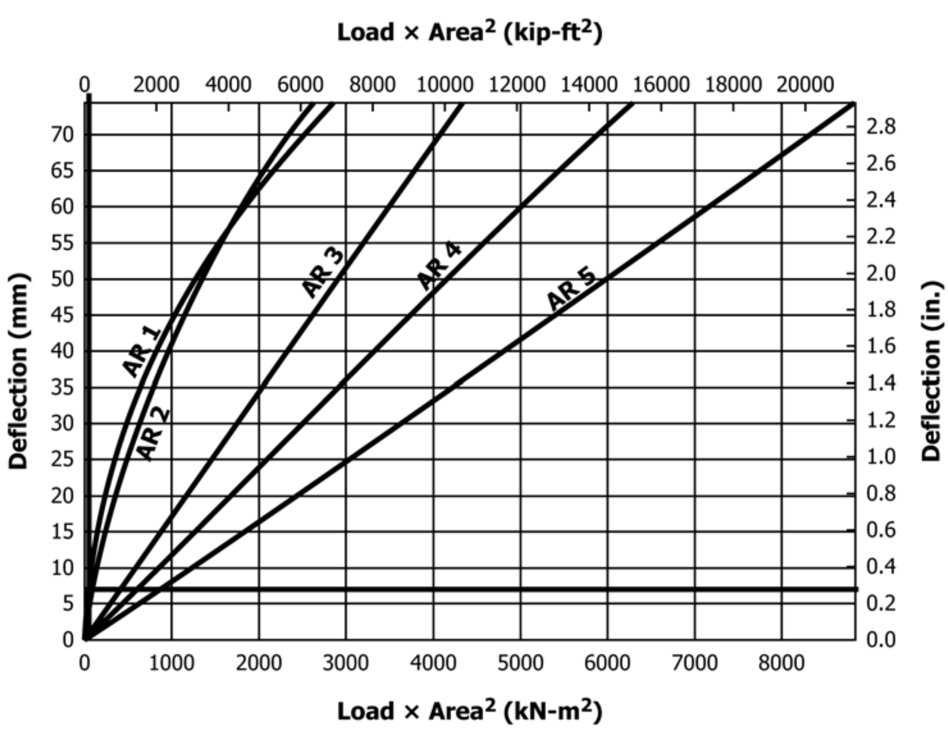

FIG. A3.5 Deflection Chart for 25 mm (1 in.) Annealed Laminated Glass with Four Sides Simply Supported Showing Lines for Second Design Example the top and bottom edges is 2794 mm (110 in.). The glass construction slopes outward 15° at the top from the vertical. The angle of the glass necessitates the addition of the component of glass weight normal to the plane of the glass and the wind load to determine the design load. Determine the smallest thickness of laminated glass that will resist the loading with a probability of breakage less than or equal to 0.004 at the first occurrence of the design wind loading.

A3.3.1 *Trial Glazing Design*—Laminated glass with nominal 38 mm (1½ in.) thickness

A3.3.2 *Design Load*—Compute the design load from 6.2, as:

$$L_D = 1.92 \text{ kPa} + 2(0.943 \text{ kPa})(\cos 75°) = 2.41 \text{ kPa } (50.3 \text{ psf}) \quad (A3.10)$$

A3.3.3 *Required Glass Thickness*—Go to Fig. A1.8 (reproduced for convenience as Fig. A3.6) and follow the steps listed.

A3.3.3.1 *Step 1*—Project a horizontal line from the vertical axes at points corresponding to 2794 mm (110 in.).

A3.3.3.2 *Step 2*—Project a vertical line from the horizontal axes at points corresponding to 2.41 kPa (50.3 psf).

A3.3.3.3 *Step 3*—The sloping line representing load resistance for 38 mm (1½ in.) laminated glass falls just above the intersection of the horizontal and vertical lines indicating that 38 mm (1½ in.) laminated glass will resist the design loading as desired.

A3.3.4 To determine approximate center of glass deflection, proceed as follows. In Fig. A2.4 (reproduced for convenience below as Fig. A3.7) project a vertical line from the points on the horizontal axes corresponding to 147.0 kN-m^2 (355 kip-ft^2). From the intersection of the vertical line with the sloping line corresponding to glass having 38 mm (1½ in.) thickness, project a horizontal line to the vertical axes and read the approximate center of glass deflection as 8.0 mm (0.31 in.).

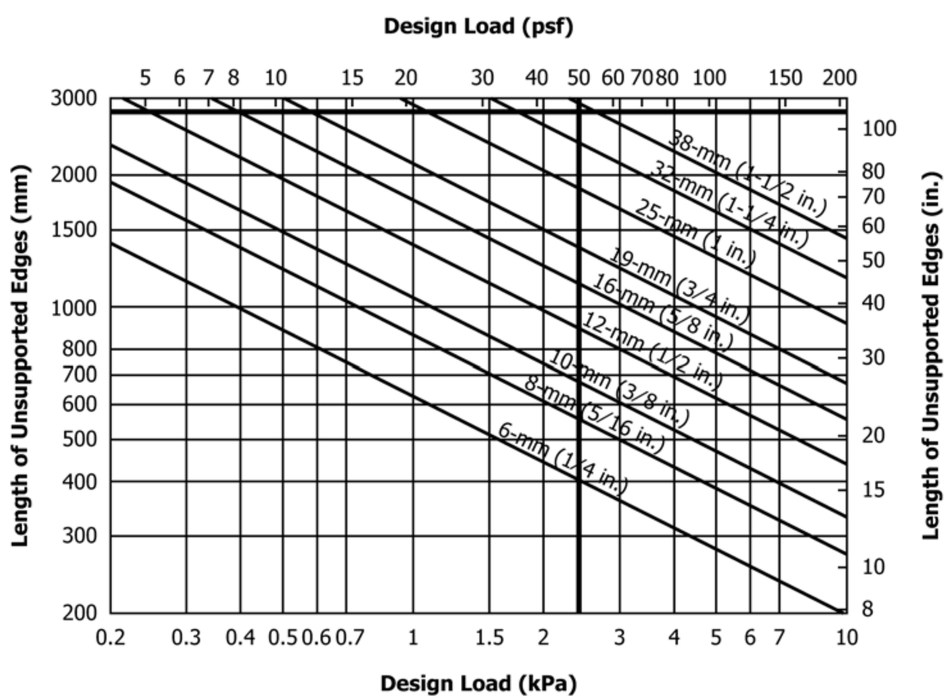

FIG. A3.6 Design Chart for Annealed Laminated Glass with Two and Three Sides Simply Supported (P_b = 0.004)

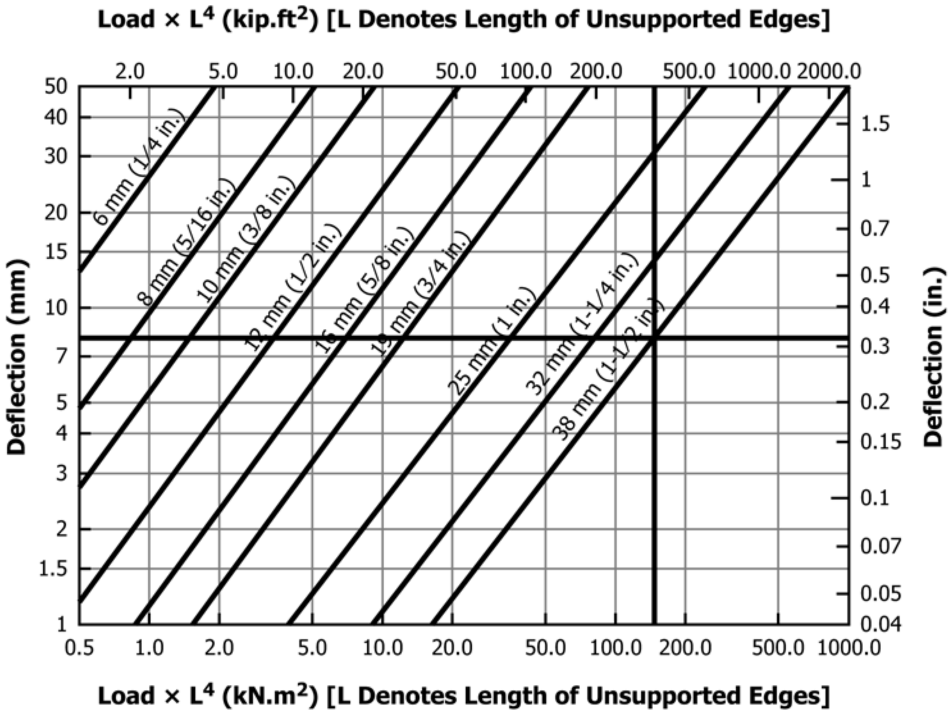

FIG. A3.7 Deflection Chart for Laminated Glass Simply Supported Along Two or Three Sides

APPENDIX

(Nonmandatory Information)

X1. COMMENTARY

X1.1 An ATCT is an airport terminal navigational facility, which, through the use of air/ground communications, visual signaling, and other devices, provides a working platform for air traffic control services. These services are primarily provided to airborne aircraft operating in the vicinity of an airport and aircraft or vehicles operating on the airport movement area. The ATCT consists of an elevated observation room with a 360-degree view of the airport area, supported by a shaft. The observation room is commonly referred to as the tower cab or cab. The cab is the primary operating space in the ATCT. Consequently it is situated at the desired elevation above ground level and physically oriented relative to the primary runways to obtain an unobstructed view of the aircraft primary movement areas (taxiways, runways, flight approaches, and departures). The cab glass slopes out on an angle between 15 and 30 degrees at the top for increased visibility.

X1.2 ATCTs are extremely important to the overall operation of the National Airspace System. (NAS); therefore, ATCTs are classified as Essential Facilities and the strength of the cab glass should use a lower probability of breakage than that of ordinary architectural glass (8 per 1000). However some ATCTs are more critical to the operation of the NAS than other ATCTs. For that reason this document provides two sets of charts for different probabilities of breakage. The user selects the appropriate charts depending on the criticality of the facility. The designer has to determine the ATCT's impact to the overall operation of the NAS in selecting the appropriate probability of breakage.