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Standard Practice for Determining Load Resistance of Glass in Buildings[1]

This standard is issued under the fixed designation E 1300; 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.

ε1 NOTE—Editorially corrected figure references in October 2007

1. Scope

1.1 This practice describes procedures to determine the load resistance (LR) of specified glass types, including combinations of glass types used in a sealed insulating glass (IG) unit, exposed to a uniform lateral load of short or long duration, for a specified probability of breakage.

1.2 This practice applies to vertical and sloped glazing in buildings for which the specified design loads consist of wind load, snow load and self-weight with a total combined magnitude less than or equal to 10 kPa (210 psf). This practice shall not apply to other applications including, but not limited to, balustrades, glass floor panels, aquariums, structural glass members, and glass shelves.

1.3 This practice applies only to monolithic, laminated, or insulating glass constructions of rectangular shape with continuous lateral support along one, two, three, or four edges. This practice assumes that (*1*) the supported glass edges for two, three, and four-sided support conditions are simply supported and free to slip in plane; (*2*) glass supported on two sides acts as a simply supported beam,beam; and (*3*) glass supported on one side acts as a cantilever.

1.4 This practice does not apply to any form of wired, patterned, etched, sandblasted, drilled, notched, or grooved glass with surface and edge treatments that alter the glass strength.

1.5 This practice addresses only the determination of the resistance of glass to uniform lateral loads. The final thickness and type of glass selected also depends upon a variety of other factors (see 5.3).

1.6 Charts in this practice provide a means to determine approximate maximum lateral glass deflection. Appendix X1 and Appendix X2 provide additional procedures to determine maximum lateral deflection for glass simply supported on four sides. Appendix X3 presents a procedure to compute approximate probability of breakage for annealed (AN) monolithic glass lites simply supported on four sides.

1.7 The values stated in SI units are to be regarded as the standard. The values given in parentheses are for information only. For conversion of quantities in various systems of measurements to SI units, refer to SI 10.

1.8 Appendix X4 lists the key variables used in calculating the mandatory type factors in Tables 1-3 and comments on their conservative values.

1.9 *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.*

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2. Referenced Documents

2.1 *ASTM Standards:*[2]

C 1036 Specification for Flat Glass
C 1048 Specification for Heat-Treated Flat GlassKind HS, Kind FT Coated and Uncoated Glass
C 1172 Specification for Laminated Architectural Flat Glass
D 4065 Practice for Plastics: Dynamic Mechanical Properties: Determination and Report of Procedures
E 631 Terminology of Building Constructions
SI 10 Practice for Use of the International System of Units (SI) (the Modernized Metric System)

[1] This practice is under the jurisdiction of ASTM Committee E06 on Performance of Buildings and is the direct responsibility of Subcommittee E06.51 on Performance of Windows, Doors, Skylights and Curtain Walls.

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[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.

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TABLE 1 Glass Type Factors (GTF) for a Single Lite of Monolithic or Laminated Glass (LG)

Glass Type	GTF	
	Short Duration Load (3 sec)	Long Duration Load (30 day)
AN	1.0	0.43
HS	2.0	1.3
FT	4.0	3.0

TABLE 2 Glass Type Factors (GTF) for Insulating Glass (IG), Short Duration Load

Lite No. 1 Monolithic Glass or Laminated Glass Type	Lite No. 2 Monolithic Glass or Laminated Glass Type					
	AN		HS		FT	
	GTF1	GTF2	GTF1	GTF2	GTF1	GTF2
AN	0.9	0.9	1.0	1.9	1.0	3.8
HS	1.9	1.0	1.8	1.8	1.9	3.8
FT	3.8	1.0	3.8	1.9	3.6	3.6

TABLE 3 Glass Type Factors (GTF) for Insulating Glass (IG), Long Duration Load (30 day)

Lite No. 1 Monolithic Glass or Laminated Glass Type	Lite No. 2 Monolithic Glass or Laminated Glass Type					
	AN		HS		FT	
	GTF1	GTF2	GTF1	GTF2	GTF1	GTF2
AN	0.39	0.39	0.43	1.25	0.43	2.85
HS	1.25	0.43	1.25	1.25	1.25	2.85
FT	2.85	0.43	2.85	1.25	2.85	2.85

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3. Terminology

3.1 *Definitions:*

3.1.1 Refer to Terminology E 631for additional terms used in this practice.

3.2 *Definitions of Terms Specific to This Standard:*

3.2.1 *aspect ratio (AR)*, *n*—for glass simply supported on four sides, the ratio of the long dimension of the glass to the short dimension of the glass is always equal to or greater than 1.0. For glass simply supported on three sides, the ratio of the length of one of the supported edges perpendicular to the free edge, to the length of the free edge, is equal to or greater than 0.5.

3.2.2 *etched glass*, *n*—glass surface that has been attacked with hydrofluoric acid or other agent, generally for marking or decoration.

3.2.3 *glass breakage*, *n*—the fracture of any lite or ply in monolithic, laminated, or insulating glass.

~~3.2.3~~

3.2.4 *Glass Thickness*:

~~3.2.3.1~~

3.2.4.1 *thickness designation for monolithic glass, n*—a term that defines a designated thickness for monolithic glass as specified in Table 4 and Specification C 1036.

~~3.2.3.2~~

3.2.4.2 *thickness designation for laminated glass (LG), n*—a term used to specify a LG construction based on the combined thicknesses of component plies.

~~*(a)*~~ (1) Add the minimum thicknesses of the individual glass plies and the interlayer thickness. If the sum of all interlayer thicknesses is greater than 1.52 mm (0.060 in.) use 1.52 mm (0.060 in.) in the calculation.

~~*(b)*~~ (2) Select the monolithic thickness designation in Table 4 having the closest minimum thickness that is equal to or less than the value obtained in ~~3.2.3.2~~3.2.4.2 (~~*a*~~1).

~~*(c)* Exception: The construction of two 6 mm (¼ in.) glass plies plus 0.76 mm (0.030 in.) interlayer shall be defined as 12 mm (½~~ (3) Exception: The construction of two 6-mm (¼-n.) glass plies plus 0.76-m (0.030-n.) interlayer shall be defined as 12 mm (½ in.).

~~3.2.4~~

3.2.5 *Glass Types*:

~~3.2.4.1~~

3.2.5.1 *annealed (AN) glass, n*—a flat, monolithic, glass lite of uniform thickness where the residual surface stresses are nearly zero as defined in Specification C 1036.

TABLE 4 Minimum Glass Thicknesses

Nominal Thickness or Designation, mm (in.)	Minimum Thickness, mm (in.)
2.5 (3⁄32)	2.16 (0.085)
2.7 (lami)	2.59 (0.102)
3.0 (1⁄8)	2.92 (0.115)
4.0 (5⁄32)	3.78 (0.149)
5.0 (3⁄16)	4.57 (0.180)
6.0 (1⁄4)	5.56 (0.219)
8.0 (5⁄16)	7.42 (0.292)
10.0 (3⁄8)	9.02 (0.355)
12.0 (1⁄2)	11.91 (0.469)
16.0 (5⁄8)	15.09 (0.595)
19.0 (3⁄4)	18.26 (0.719)
22.0 (7⁄8)	21.44 (0.844)

~~3.2.4.2~~

3.2.5.2 *fully tempered (FT) glass, n*—a flat, monolithic, glass lite of uniform thickness that has been subjected to a special heat treatment process where the residual surface compression is not less than 69 MPa (10 000 psi) or the edge compression not less than 67 MPa (9700 psi) as defined in Specification C 1048.

~~3.2.4.3~~

3.2.5.3 *heat strengthened (HS) glass, n*—a flat, monolithic, glass lite of uniform thickness that has been subjected to a special heat treatment process where the residual surface compression is not less than 24 MPa (3500 psi) or greater than 52 MPa (7500 psi) as defined in Specification C 1048.

~~3.2.4.4~~

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

~~3.2.4.5~~

3.2.5.5 *laminated glass (LG), n*—a flat lite of uniform thickness consisting of two or more monolithic glass plies bonded together with an interlayer material as defined in Specification C 1172~~–~~.

(1) Discussion—Many different interlayer materials are used in ~~laminated glass.~~ LG. The information in this practice applies only to polyvinyl butyral (PVB) interlayer or those interlayers that demonstrate equivalency according to Appendix X10.

~~3.2.5*glass type (GT) factor*~~

3.2.6 *glass type factor (GTF)*, *n*~~—a multiplying factor for adjusting the load resistance of different glass types, that is, annealed, heat-strengthened, or fully tempered in monolithic, LG or IG constructions.~~

~~3.2.6~~—*a multiplying factor for adjusting the LR of different glass types, that is, AN, HS, or FT in monolithic glass, LG, or IG constructions.*

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

~~3.2.7~~

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

~~3.2.7.1~~

3.2.8.1 *specified design load, n*—the magnitude in kPa (psf), type (for example, wind or snow) and duration of the load given by the specifying authority.

~~3.2.7.2~~

3.2.8.2 *load resistance (LR), n*—the uniform lateral load that a glass construction can sustain based upon a given probability of breakage and load duration.

~~*(a)*~~

(1) Discussion—Multiplying the non-factored load (NFL) from figures in Annex A1 by the relevant GTF and load share (LS) factors gives the ~~load resistance~~ LR associated with a breakage probability less than or equal to 8 lites per 1000.

~~3.2.7.3~~3.2.8.3 *long duration load, n*—any load lasting approximately 30 days.

(1) Discussion—For loads having durations other than 3 s or 30 days, refer to Table X6.1.

~~3.2.7.4~~

3.2.8.4 *non-factored load (NFL), n*—three second duration uniform load associated with a probability of breakage less than or equal to 8 lites per 1000 for monolithic ~~annealed~~AN glass as determined from the figures in Annex A1.

~~3.2.7.5~~

3.2.8.5 *glass weight load, n*—the dead load component of the glass weight.

~~3.2.7.6~~

3.2.8.6 *short duration load, n*—any load lasting 3 s or less.

~~3.2.8~~

3.2.9 *load share (LS) factor*, *n*—a multiplying factor derived from the load sharing between the ~~two lites,~~double glazing, of

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equal or different thicknesses and types (including the layered behavior of laminated glass LG under long duration loads), in a sealed IG unit.

3.2.8.13.2.9.1 *Discussion*—The LS factor is used along with the glass type factor (GTF) and the non-factored load (NFL) value from the non-factored load charts to give the load resistance of the IG unit, based on the resistance to breakage of one specific lite only.

3.2.9—*The LS factor is used along with the GTF and the NFL value from the NFL charts to give the LR of the IG unit, based on the resistance to breakage of one specific lite only.*

3.2.10 *patterned glass*, *n*—rolled flat glass having a pattern on one or both surfaces.

3.2.11 *probability of breakage* (P_b), *n*—the fraction of glass lites or plies that would break at the first occurrence of a specified load and duration, typically expressed in lites per 1000.

3.2.10

3.2.12 *sandblasted glass*, *n*—glass surface that has been sprayed by sand at high velocities to produce a translucent effect.

3.2.13 *specifying authority*, *n*—the design professional responsible for interpreting applicable regulations of authorities having jurisdiction and considering appropriate site specific factors to determine the appropriate values used to calculate the specified design load, and furnishing other information required to perform this practice.

3.2.14 *wired glass*, *n*—flat glass with a layer of wire mesh completely embedded in the glass.

4. Summary of Practice

4.1 The specifying authority shall provide the design load, the rectangular glass dimensions, the type of glass required, and a statement, or details, showing that the glass edge support system meets the stiffness requirement in 5.2.4.

4.2 The procedure specified in this practice shall be used to determine the uniform lateral load resistance LR of glass in buildings. If the load resistance LR is less than the specified load, then other glass types and thicknesses may be evaluated to find a suitable assembly having load resistanceLR equal to or exceeding the specified design load.

4.3 The charts presented in this practice shall be used to determine the approximate maximum lateral glass deflection. Appendix X1 and Appendix X2 present two additional procedures to determine the approximate maximum lateral deflection for a specified load on glass simply supported on four sides.

4.4 An optional procedure for determining the probability of breakage at a given load is presented in Appendix X3.

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5. Significance and Use

5.1 This practice is used to determine the load resistanceLR of specified glass types and constructions exposed to uniform lateral loads.

5.2 Use of this practice assumes:

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

5.2.2 The glass has not been subjected to abuse,

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

5.2.4 The glass edge support system is sufficiently stiff to limit the lateral deflections of the supported glass edges to no more than 1⁄175 of their lengths. The specified design load shall be used for this calculation.

5.2.5 The center of glass deflection will not result in loss of edge support.

NOTE 1—This practice does not address aesthetic issues caused by glass deflection.

5.3 Many other factors shall be considered in glass type and thickness selection. These factors include but are not limited to: thermal stresses, spontaneous breakage of tempered glass, 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 building codes along with criteria presented in safety glazing standards and site specific concerns may control the ultimate glass type and thickness selection.

5.4 For situations not specifically addressed in this standard, the design professional shall use engineering analysis and judgment to determine the load resistanceLR of glass in buildings.

6. Procedure

6.1 Select a glass type, thickness, and construction for load-resistance evaluation.

6.2 *For Monolithic Single Glazing Simply Supported Continuously Along Four Sides*:

6.2.1 Determine the non-factored load (NFL)NFL from the appropriate chart in Annex A1 (the upper charts of Figs A1.1–A1.12) for the glass thickness and size.

6.2.2 Determine the glass type factor (GTF)GTF for the appropriate glass type and load duration (short or long) from Table 1.

6.2.3 Multiply NFL by GTF to get the load resistance (LR)LR of the lite.

6.2.4 Determine the approximate maximum lateral (center of glass) deflection from the appropriate chart in Annex A1 (the lower charts of Figs. A1.1–A1.12) for the designated glass thickness, size, and design load. If the maximum lateral deflection falls outside the charts in Annex A1, then use the procedures outlined in Appendix X1 and Appendix X2.

6.3 *For Monolithic Single Glazing Simply Supported Continuously Along Three Sides*:

6.3.1 Determine the ~~non-factored load (NFL)~~NFL from the appropriate chart in Annex A1 (the upper charts of Figs. A1.13–A1.24) for the designated glass thickness and size.

6.3.2 Determine the GTF for the appropriate glass type and load duration (short or long) from Table 1.

6.3.3 Multiply NFL by GTF to get the LR of the lite.

6.3.4 Determine the approximate maximum lateral (center of unsupported edge) deflection from the appropriate chart in Annex A1 (the lower charts in Figs A1.13–A1.24) for the designated glass thickness, size, and design load.

6.4 *For Monolithic Single Glazing Simply Supported Continuously Along Two Opposite Sides*:

6.4.1 Determine the NFL from the upper chart of Fig. A1.25 for the designated glass thickness and length of unsupported edges.

6.4.2 Determine the GTF for the appropriate glass type and load duration (short or long) from Table 1.

6.4.3 Multiply NFL by GTF to get the LR of the lite.

6.4.4 Determine the approximate maximum lateral (center of an unsupported edge) deflection from the lower chart of Fig. A1.25 for the designated glass thickness, length of unsupported edge, and design load.

6.5 *For Monolithic Single Glazing Continuously Supported Along One Edge (Cantilever)*:

6.5.1 Determine the NFL from the upper chart of Fig. A1.26 for the designated glass thickness and length of unsupported edges that are perpendicular to the supported edge.

6.5.2 Determine the GTF for the appropriate glass type and load duration (short or long) from Table 1.

6.5.3 Multiply NFL by GTF to get the LR of the lite.

6.5.4 Determine the approximate maximum lateral (free edge opposite the supported edge) deflection from the lower chart of Fig. A1.26 for the designated glass thickness, length of unsupported edges, and design load.

6.6 ~~*For Single-glazed Laminated Glass Constructed with a PVB Interlayer Simply Supported Continuously Along Four Sides where In-Service LG Temperatures do not exceed 50°C (122°F)*~~For Single-Glazed Laminated Glass (LG) Constructed With a PVB Interlayer Simply Supported Continuously Along Four Sides Where In-Service Laminated Glass (LG) Temperatures Do Not Exceed 50°C (122°F):

6.6.1 Determine the NFL from the appropriate chart (the upper charts of Figs A1.27–A1.33) for the designated glass thickness.

6.6.2 Determine the GTF for the appropriate glass type, load duration (short or long) from Table 1.

6.6.3 Multiply NFL by GTF to get the LR of the laminated lite.

6.6.4 Determine the approximate maximum lateral (center of glass) deflection from the appropriate chart (the lower charts of Figs. A1.27–A1.33) for the designated glass thickness, size, and design load. If the maximum lateral deflection falls outside the charts in Annex A1, then use the procedures outlined in Appendix X1 and Appendix X2.

6.7 ~~*For Laminated Single Glazing Simply Supported Continuously Along Three Sides where In-Service LG Temperatures do not exceed 50°C (122°F)*~~For Laminated Single Glazing Simply Supported Continuously Along Three Sides Where In-Service Laminated Glass (LG) Temperatures Do Not Exceed 50°C (122°F):

6.7.1 Determine the NFL from the appropriate chart (the upper charts of Figs. A1.34–A1.40) for the designated glass thickness and size equal to the ~~laminated glass~~LG thickness.

6.7.2 Determine the GTF for the appropriate glass type and load duration (short or long) from Table 1.

6.7.3 Multiply NFL by GTF to get the LR of the laminated lite.

6.7.4 Determine the approximate maximum lateral (center of unsupported edge) deflection from the appropriate chart (the lower charts of Figs. A1.34–A1.40) for the designated glass thickness, size, and design load.

6.8 ~~*For Laminated Single Glazing Simply Supported Continuously Along Two Opposite Sides where In-Service LG Temperatures do not exceed 50°C (122°F)*~~For Laminated Single Glazing Simply Supported Continuously Along Two Opposite Sides Where In-Service Laminated Glass (LG) Temperatures Do Not Exceed 50°C (122°F):

6.8.1 Determine the NFL from the upper chart of Fig. A1.41 for the designated glass thickness and length of unsupported edges.

6.8.2 Determine the GTF for the appropriate glass type and load duration (short or long) from Table 1.

6.8.3 Multiply NFL by GTF to get the LR of the laminated lite.

6.8.4 Determine the approximate maximum lateral (center of an unsupported edge) deflection from the lower chart of Fig. A1.41 for the designated glass thickness, length of unsupported edge, and design load.

6.9 ~~*For Laminated Single Glazing Continuously Supported Along One Edge (Cantilever) where In-Service LG Temperatures do not exceed 50°C (122°F)*~~For Laminated Single Glazing Continuously Supported Along One Edge (Cantilever) Where In-Service Laminated Glass (LG) Temperatures Do Not Exceed 50°C (122°F):

6.9.1 Determine the NFL from the upper chart of Fig. A1.42 for the designated glass thickness and length of unsupported edges that are perpendicular to the supported edge.

6.9.2 Determine the GTF for the appropriate glass type and load duration (short or long) from Table 1.

6.9.3 Multiply NFL by GTF to get the LR of the laminated lite.

6.9.4 Determine the approximate maximum lateral (free edge opposite the supported edge) deflection from the lower chart of Fig. A1.42 for the designated glass thickness, length of unsupported edges, and design load.

6.10 *For Insulating Glass (IG) with Monolithic Glass Lites of Equal (Symmetric) or Different (Asymmetric) Glass Type and Thickness Simply Supported Continuously Along Four Sides*:

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6.10.1 Determine the NFL1 for lite No. 1 and NFL2 for lite No. 2 from the the upper charts of Figs. A1.1–A1.12. (See Annex A2 for examples.)

NOTE 2—Lite Nos. 1 or 2 can represent either the outward or inward facing lite of the IG unit.

6.10.2 Determine the GTF1 for lite No. 1 and GTF2 for lite No. 2 from Table 2 or Table 3, for the relevant glass type and load duration.

6.10.3 Determine the LSF1 for lite No. 1 and LSF2 for lite No. 2 from Table 5, for the relevant lite thickness.

6.10.4 Multiply NFL by GTF and by ~~LSF~~ LS factors for each lite to determine LR1 for lite No. 1 and LR2 for lite No. 2 of the ~~insulating glass~~IG unit as follows:

$$LR1 = NFL1 \times GTF1 \times LS1 \text{ and } LR2 = NFL2 \times GTF2 \times LS2$$

6.10.5 The ~~load resistance~~ LR of the IG unit is the lower of the two values, LR1 and LR2.

6.11 *For Insulating Glass (IG) with One Monolithic Lite and One Laminated Lite Under Short Duration Load Simply Supported Continuously Along Four Sides*:

6.11.1 Determine the NFL for each lite from the upper charts of Figs. A1.1–A1.12 and A1.27–A1.33.

6.11.2 Determine the GTF1 for lite No. 1 and GTF2 for lite No. 2 from Table 2.

6.11.3 Determine LS1 for lite No. 1 and LS2 for lite No. 2, from Table 5.

6.11.4 Multiply NFL by GTF and by LS for each lite to determine LR1 for lite No. 1 and LR2 for lite No. 2 of the ~~insulating glass~~IG unit as follows:

$$LR1 = NFL1 \times GTF1 \times LS1 \text{ and } LR2 = NFL2 \times GTF2 \times LS2$$

6.11.5 The ~~load resistance~~ LR of the IG unit is the lower of the two calculated LR values.

6.12 *For Insulating Glass with Laminated Glass (LG) over Laminated Glass (LG) Under Short Duration Load Simply Supported Continuously Along Four Sides*:

6.12.1 Determine the NFL1 for lite No. 1 and NFL2 for lite No. 2 from the upper charts of Figs. A1.27–A1.33. (See Annex A2 for examples.)

6.12.2 For each lite, determine GTF1 for lite No. 1 and GTF2 for lite No. 2 from Table 2.

6.12.3 For each lite, determine the LSF1 for lite No. 1 and LSF2 for lite No. 2 from Table 5.

6.12.4 Multiply NFL by GTF and by LS for each lite to determine LR1 for lite No. 1 and LR2 for lite No. 2 of the ~~insulating glass~~IG unit as follows:

~~LR1=NFL1×GTF1×LS1andLR2=NFL2×<usb>GTF2×<usb>LS2~~

$$LR1 = NFL1 \times GTF1 \times LS1 \text{ and } LR2 = NFL2 \times GTF2 \times LS2$$

6.12.5 The ~~load resistance~~LR of the IG unit is the lower of the two calculated LR values.

6.13 *For Insulating Glass (IG) with One Monolithic Lite and One Laminated Lite, Under Long Duration Load Simply Supported Continuously Along Four Sides*:

6.13.1 The ~~load resistance~~ LR of each lite must first be calculated for that load acting for a short duration as in 6.11, and then for the same load acting for a long duration as given in 6.13.2-6.13.5.

NOTE 3—There are some combinations of IG with ~~laminated glass~~ LG where its monolithic-like behavior under a short duration load gives the IG a lesser ~~load resistance~~ LR than under the layered behavior of long duration loads.

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TABLE 5 Load Share (LS) Factors for Insulating Glass (IG) Units

NOTE 1—Lite No. 1 Monolithic glass, Lite No. 2 Monolithic glass, short or long duration load, or Lite No. 1 Monolithic glass, Lite No. 2 Laminated glass, short duration load only, or Lite No. 1 Laminated Glass, Lite No. 2 Laminated Glass, short or long duration load.

Lite No. 1		Lite No. 2																					
Monolithic Glass		Monolithic Glass, Short or Long Duration Load or Laminated Glass, Short Duration Load Only																					
Nominal Thickness		2.5 (3⁄32)		2.7 (lami)		3 (1⁄8)		4 (5⁄32)		5 (3⁄16)		6 (1⁄4)		8 (5⁄16)		10 (3⁄8)		12 (1⁄2)		16 (5⁄8)		19 (3⁄4)	
mm	(in.)	LS1	LS2	LS1	LS2	LS1	LS2	LS1	LS2	LS1	LS2	LS1	LS2	LS1	LS2	LS1	LS2	LS1	LS2	LS1	LS2	LS1	LS2
2.5	(3⁄32)	2.00	2.00	2.73	1.58	3.48	1.40	6.39	1.19	10.5	1.11	18.1	1.06	41.5	1.02	73.8	1.01	169.	1.01	344.	1.00	606.	1.00
2.7	(lami)	1.58	2.73	2.00	2.00	2.43	1.70	4.12	1.32	6.50	1.18	10.9	1.10	24.5	1.04	43.2	1.02	98.2	1.01	199.	1.01	351.	1.00
3	(1⁄8)	1.40	3.48	1.70	2.43	2.00	2.00	3.18	1.46	4.83	1.26	7.91	1.14	17.4	1.06	30.4	1.03	68.8	1.01	140.	1.01	245.	1.00
4	(5⁄32)	1.19	6.39	1.32	4.12	1.46	3.18	2.00	2.00	2.76	1.57	4.18	1.31	8.53	1.13	14.5	1.07	32.2	1.03	64.7	1.02	113.	1.01
5	(3⁄16)	1.11	10.5	1.18	6.50	1.26	4.83	1.57	2.76	2.00	2.00	2.80	1.56	5.27	1.23	8.67	1.13	18.7	1.06	37.1	1.03	64.7	1.02
6	(1⁄4)	1.06	18.1	1.10	10.9	1.14	7.91	1.31	4.18	1.56	2.80	2.00	2.00	3.37	1.42	5.26	1.23	10.8	1.10	21.1	1.05	36.4	1.03
8	(5⁄16)	1.02	41.5	1.04	24.5	1.06	17.4	1.13	8.53	1.23	5.27	1.42	3.37	2.00	2.00	2.80	1.56	5.14	1.24	9.46	1.12	15.9	1.07
10	(3⁄8)	1.01	73.8	1.02	43.2	1.03	30.4	1.07	14.5	1.13	8.67	1.23	5.26	1.56	2.80	2.00	2.00	3.31	1.43	5.71	1.21	9.31	1.12
12	(1⁄2)	1.01	169.	1.01	98.2	1.01	68.8	1.03	32.2	1.06	18.7	1.10	10.8	1.24	5.14	1.43	3.31	2.00	2.00	3.04	1.49	4.60	1.28
16	(5⁄8)	1.00	344.	1.01	199.	1.01	140.	1.02	64.7	1.03	37.1	1.05	21.1	1.12	9.46	1.21	5.71	1.49	3.04	2.00	2.00	2.76	1.57
19	(3⁄4)	1.00	606.	1.00	351.	1.00	245.	1.01	113.	1.02	64.7	1.03	36.4	1.07	15.9	1.12	9.31	1.28	4.60	1.57	2.76	2.00	2.00

6.13.2 Determine the values for the NFL1 for ~~Lite No.1~~lite No. 1 and NFL2 for lite No. 2 from the upper charts of Figs. A1.1–A1.12 and A1.27–A1.33 (see Annex A2 for examples).

6.13.3 Determine GTF1 for lite No. 1 and GTF2 for lite No. 2) from Table 3 for the relevant glass type.

6.13.4 Determine LS1 for lite No. 1 and LS2 for lite No. 2 from Table 6 for the relevant lite thickness.

6.13.5 Multiply NFL by GTF and by LS for each lite to determine LR1 for lite No. 1 and LR2 for lite No. 2 of the ~~insulating glass~~ IG unit, based on the long duration ~~load resistance~~LR of each lite, as follows:

$$LR1 = NFL1 \times GTF1 \times LS1 \text{ and } LR2 = NFL2 \times GTF2 \times LS2$$

6.13.6 The ~~load resistance~~ LR of the IG unit is the lowest of the four calculated LR values LR1 and LR2 for short duration loads from 6.11.4 and LR1 and LR2 for long duration loads from 6.13.5.

6.14 *For Insulating Glass with Laminated Glass (LG) over Laminated Glass (LG) Under Long Duration Load*:

6.14.1 The ~~load resistance~~ LR of each lite must first be calculated for that load acting for a short duration as in 6.12, and then for the same load acting for a long duration as given in 6.14.2-6.14.5.

6.14.2 Determine NFL1 for lite No. 1 and NFL2 for lite No. 2 from the upper charts of Figs A1.1–A1.12 and A1.27–A1.33 (see Annex A2 for examples).

6.14.3 Determine the GTF1 for lite No. 1 and GTF2 for lite No. 2 from Table 3.

6.14.4 Determine LS1 for lite No. 1 and LS2 for lite No. 2 from Table 5.

6.14.5 Multiply NFL by GTF and by LS for each lite to determine the ~~load resistances~~ LRs (LR1 and LR2 for lites Nos. 1 and 2) of the ~~insulating glass~~ IG unit, based on the long duration ~~load resistance~~LR of each lite, as follows:

~~LR1 = NFL1 × GTF1 × LS1 and LR2 = NFL2 × GTF2 ×<usb> LS2~~

$$LR1 = NFL1 \times GTF1 \times LS1 \text{ and } LR2 = NFL2 \times GTF2 \times LS2$$

6.14.6 The ~~load resistance~~ LR of the IG unit is the lowest of the four calculated LR values LR1 and LR2 for short duration loads from 6.12.4 and LR1 and LR2 for long duration loads from 6.14.5.

6.15 If the ~~load resistance~~ LR thus determined is less than the specified design load and duration, the selected glass types and thicknesses are not acceptable. If the ~~load resistance~~LR is greater than or equal to the specified design load, then the glass types and thicknesses are acceptable for a breakage probability of less than, or equal to, 8 in 1000.

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7. Report

7.1 Report the following information:

7.1.1 Date of calculation,

7.1.2 The specified design load and duration, the short dimension of the glass, the long dimension of the glass, the glass type(s) and thickness(es), the ~~glass type factor(s),~~ GTF(s), the ~~load share~~ LS factors (for ~~insulating glass),~~ IG), the factored ~~load resistance~~LR and the approximate lateral deflection, the glass edge support conditions, 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~~NFL charts (the upper charts of Figs. A1.1–A1.42) are based upon a theoretical glass breakage model

TABLE 6 Load Share (LS) Factors for Insulating Glass (IG) Units

NOTE 1—Lite No. 1 Monolithic glass, Lite No. 2 Laminated glass, long duration load only.

Lite No. 1		Lite No. 2													
Monolithic Glass		Laminated Glass													
Nominal Thickness		5 (3⁄16)		6 (1⁄4)		8 (5⁄16)		10 (3⁄8)		12 (1⁄2)		16 (5⁄8)		19 (3⁄4)	
mm	(in.)	LS1	LS2	LS1	LS2	LS1	LS2	LS1	LS2	LS1	LS2	LS1	LS2	LS1	LS2
2.5	(3⁄32)	3.00	1.50	4.45	1.29	11.8	1.09	20.0	1.05	35.2	1.03	82.1	1.01	147	1.01
2.7	(lami)	2.16	1.86	3.00	1.50	7.24	1.16	12.0	1.09	20.8	1.05	48.0	1.02	85.5	1.01
3	(1⁄8)	1.81	2.24	2.39	1.72	5.35	1.23	8.68	1.13	14.8	1.07	33.8	1.03	60.0	1.02
4	(5⁄32)	1.37	3.69	1.64	2.56	3.00	1.50	4.53	1.28	7.34	1.16	16.1	1.07	28.1	1.04
5	(3⁄16)	1.21	5.75	1.36	3.75	2.13	1.88	3.00	1.50	4.60	1.28	9.54	1.12	16.4	1.07
6	(1⁄4)	1.12	9.55	1.20	5.96	1.63	2.59	2.11	1.90	3.00	1.50	5.74	1.21	9.54	1.12
8	(5⁄16)	1.05	21.3	1.09	12.8	1.27	4.76	1.47	3.13	1.84	2.19	3.00	1.50	4.60	1.28
10	(3⁄8)	1.03	37.4	1.05	22.1	1.15	7.76	1.26	4.83	1.47	3.13	2.11	1.90	3.00	1.50
12	(1⁄2)	1.01	85.0	1.02	49.7	1.06	16.6	1.11	9.84	1.20	5.92	1.48	3.07	1.87	2.15
16	(5⁄8)	1.01	172	1.01	100	1.03	32.8	1.06	19.0	1.10	11.0	1.24	5.23	1.43	3.35
19	(3⁄4)	1.00	304	1.01	176	1.02	57.2	1.03	32.8	1.06	18.7	1.13	8.46	1.24	5.15
22	(7⁄8)	1.00	440	1.00	256	1.01	82.5	1.02	47.2	1.04	26.7	1.09	11.8	1.17	7.02

that relates the strength of glass to the surface condition. Complete discussions of the formulation of the model are presented elsewhere.[3,4]

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~~NFL charts may change as further data becomes available.

9. Keywords

9.1 annealed glass; deflection; flat glass; fully tempered glass; glass; heat-strengthened glass; insulating glass; laminated glass; load resistance; monolithic glass; probability of breakage; snow load; soda lime silicate; strength; wind load

ANNEXES

(Mandatory Information)

A1. NON-FACTORED LOAD (NFL) CHARTS

A1.1 ~~Non-factored load~~NFL charts are presented in the upper charts of Fig. A1.1 through Fig. A1.42 for both SI and inch-pound units. The ~~non-factored load~~NFL charts were developed using a failure prediction model for glass.[5,6] The model allows the probability of breakage of any lite or ply to be specified in terms of two surface flaw parameters, *m* and *k*.

A1.2 The values of the surface flaw parameters associated with a particular glass sample vary with the treatment and condition of the glass surface. In development of the ~~non-factored load~~NFL charts presented in upper charts of Fig. A1.1 through Fig. A1.42 it was assumed that m is equal to 7 and k is equal to 2.86×10^{-53} N^{-7} m^{12}(1.365×10^{-29} in.^{12} lb^{-7}). These flaw parameters represent the surface strength of weathered window glass that has undergone in-service conditions for approximately 20 years. The selection of the surface flaw parameters was based upon the best available data and engineering judgment. If the charts are used to predict the strength of freshly manufactured glass, the results may be conservative. This method does not apply to glass that has been subjected to severe surface degradation or abuse such as weld splatter or sand blasting.

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A1.3 The data presented in the ~~non-factored load~~NFL charts are based on the minimum glass thicknesses allowed by Specification C 1036. These minimum glass thicknesses are presented in Table 4. Glass may be manufactured thicker than those minimums. Not accounting for this fact in the ~~non-factored load~~NFL charts makes the charts conservative from a design standpoint.

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A1.4 The maximum center of glass lateral deflection of a lite is often a major consideration in the selection of glass. No recommendations are made in this practice regarding acceptable lateral deflections. The lower charts of Fig. A1.1 through Fig. A1.42 indicate the maximum lateral deflection of the glass.

A1.5 The following steps are used to determine the ~~non-factored load (NFL)~~NFL for a particular situation:

A1.5.1 Select the appropriate chart to be used based upon the nominal glass thickness.

A1.5.2 Enter the horizontal axis of the chart at the point corresponding to the long dimension of the glass and project a vertical line.

A1.5.3 Enter the vertical axis of the chart at the point corresponding to the short dimension of the glass and project a horizontal line until it intersects the vertical line of A1.5.2.

A1.5.4 Draw a line of constant ~~aspect ratio~~AR from the point of zero length and width through the intersection point in A1.5.3.

A1.5.5 Determine the NFL by interpolating between the load contours along the diagonal line of constant ~~aspect ratio~~AR drawn in A1.5.4.

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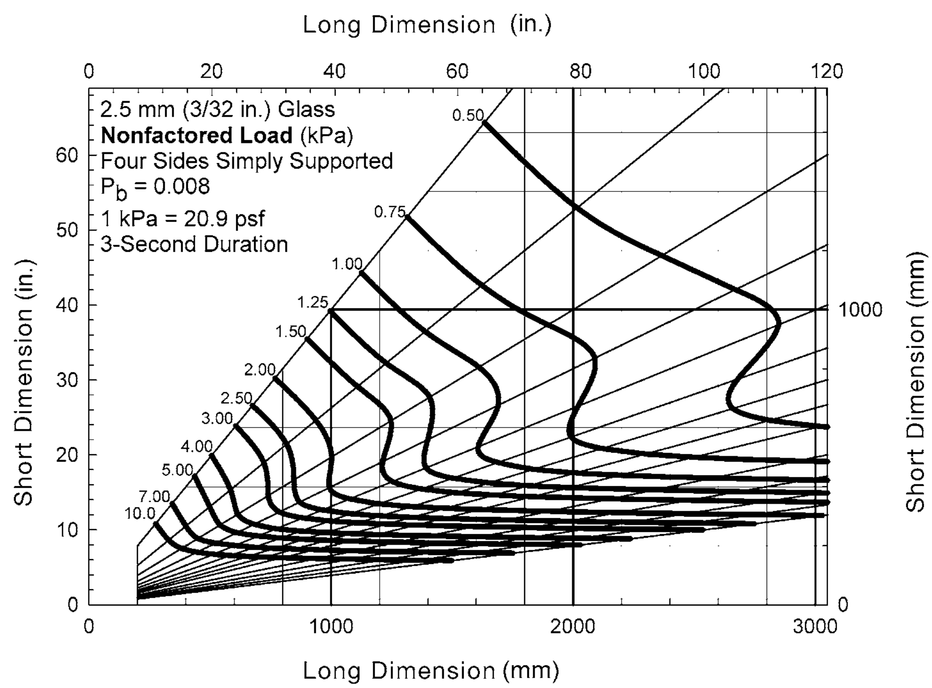
[3] Beason, W. L., Kohutek, T. L., and Bracci, J. M., "Basis for ASTM E1300 Glass Thickness Selection Procedure," Civil Engineering Department, Texas A & M University, 1996.

[4] Duser, A.V., Jagota, A., and Bennison, S.J., "Analysis of Glass/Polyvinyl Butyral Laminates Subjected to Uniform Pressure," *Journal of Engineering Mechanics*, ASCE, Vol 125, No. 4, ~~435–441, 1999.~~1999, pp. 435–441.

[5] Beason, W. L. and Morgan, J. R., "Glass Failure Prediction Model," ~~*Journal of Structural Engineering*, Vol 111, No. 9 2058–2059, 1985.~~ Journal of Structural Engineering, Vol 111 , No. 9, 1985, pp. 2058–2059.

[6] Vallabhan, C. V. G., "Interactive Analysis of Nonlinear Glass Plates," *Journal of Structural Engineering*, ASCE, Vol 102, No. 2, February 1983, pp. 489–502.



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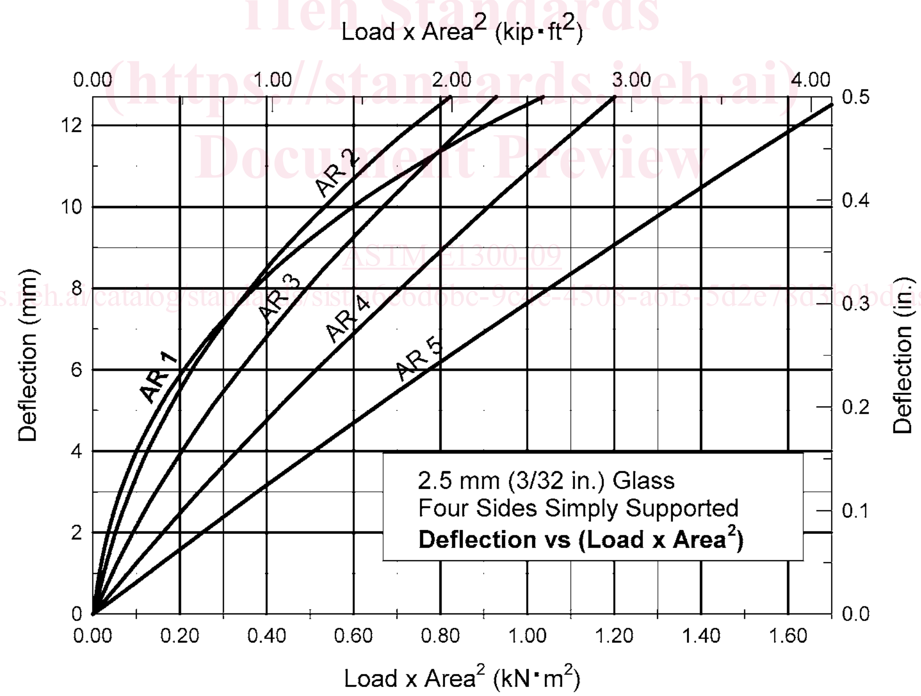
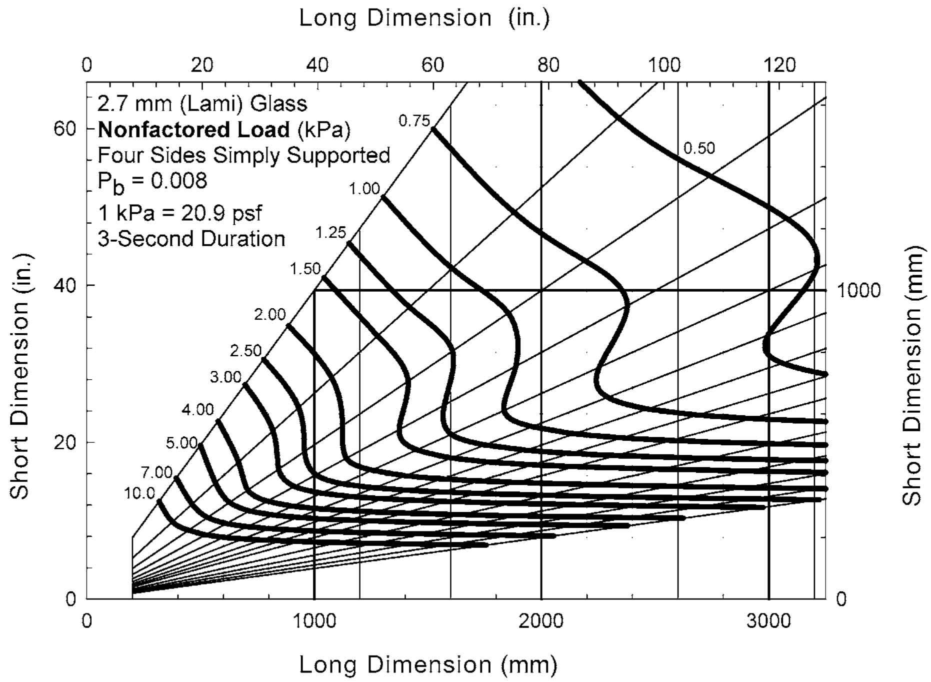


FIG. A1.1 (upper chart) Nonf-Factored Load Chart for 2.5 mm (3⁄32 in.) Glass with Four Sides Simply Supported (lower chart) Deflection Chart for 2.5 mm (3⁄32 in.) Glass with Four Sides Simply Supported



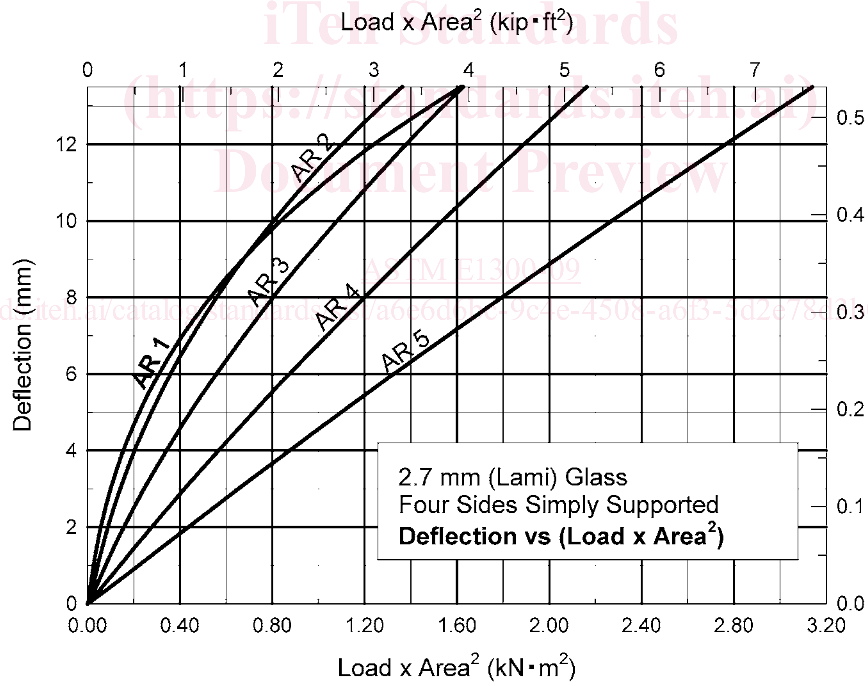


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FIG. A1.2 (upper chart) Non-Factored Load Chart for 2.7 mm (Lami) Glass with Four Sides Simply Supported (lower chart) Deflection Chart for 2.7 mm (Lami) Glass with Four Sides Simply Supported

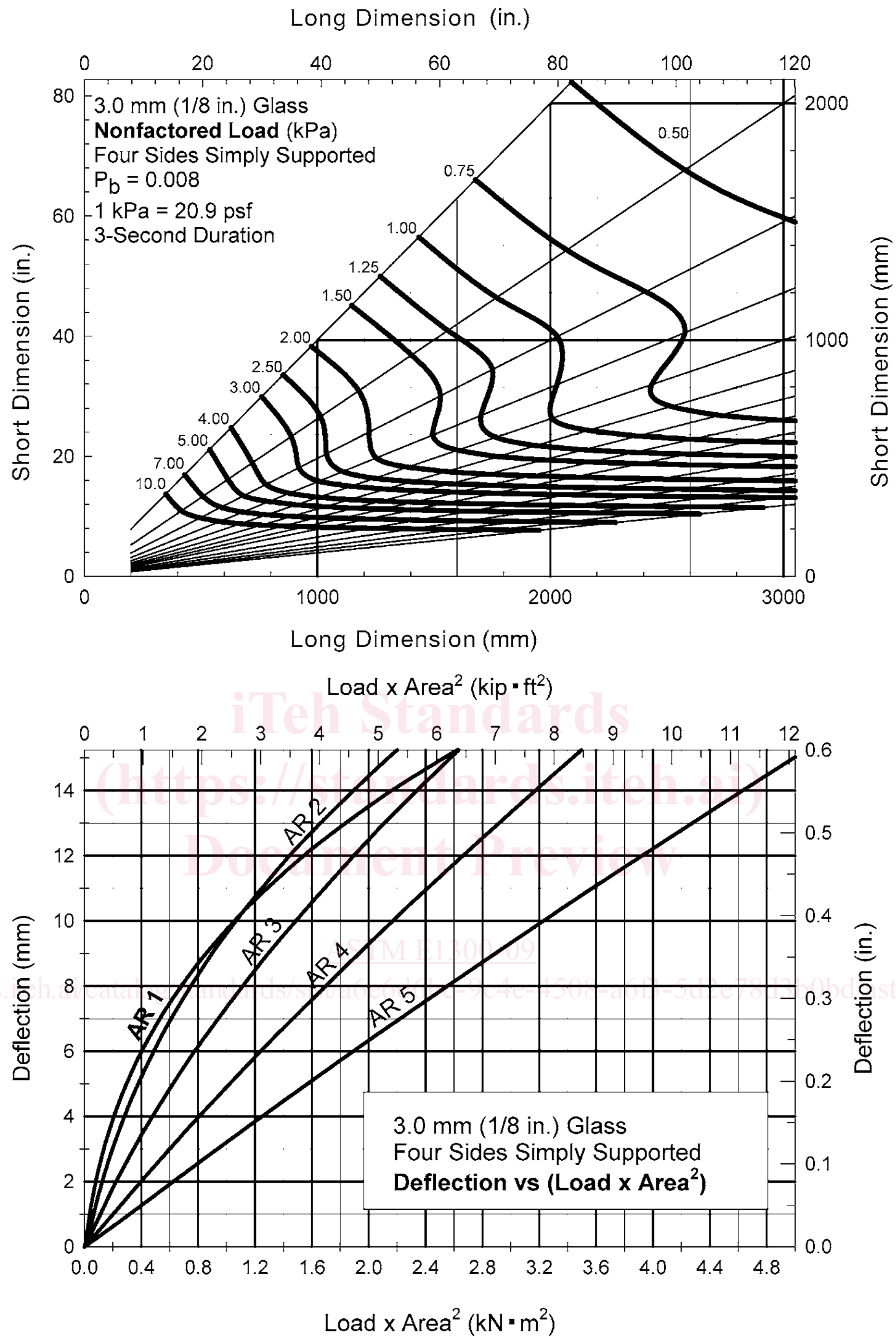

FIG. A1.3 (upper chart) Nonf-Factored Load Chart for 3.0 mm (⅛ in.) Glass with Four Sides Simply Supported
(lower chart) Deflection Chart for 3.0 mm (⅛ in.) Glass with Four Sides Simply Supported

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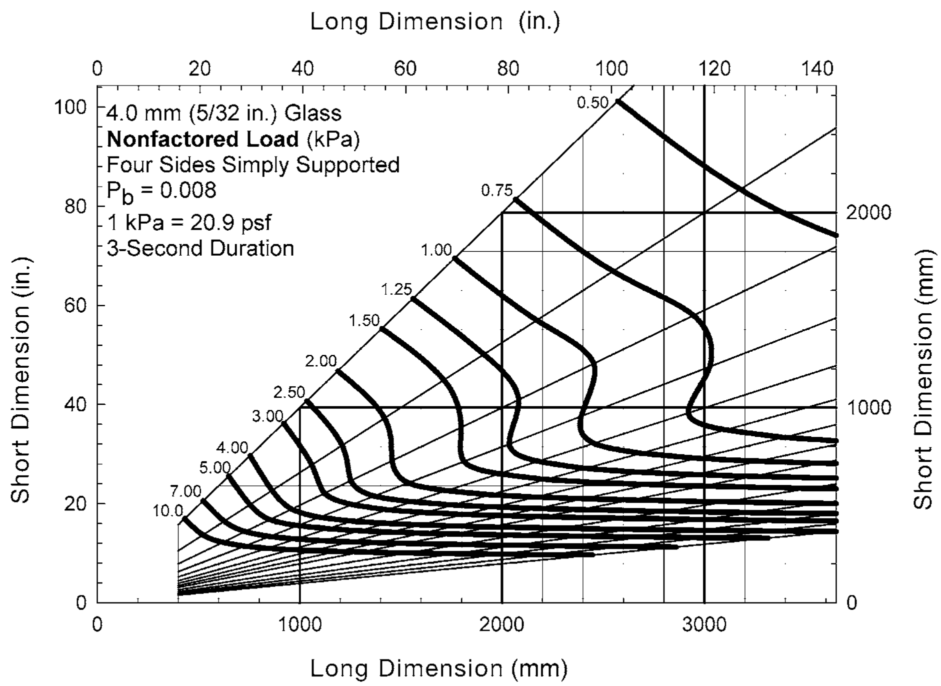

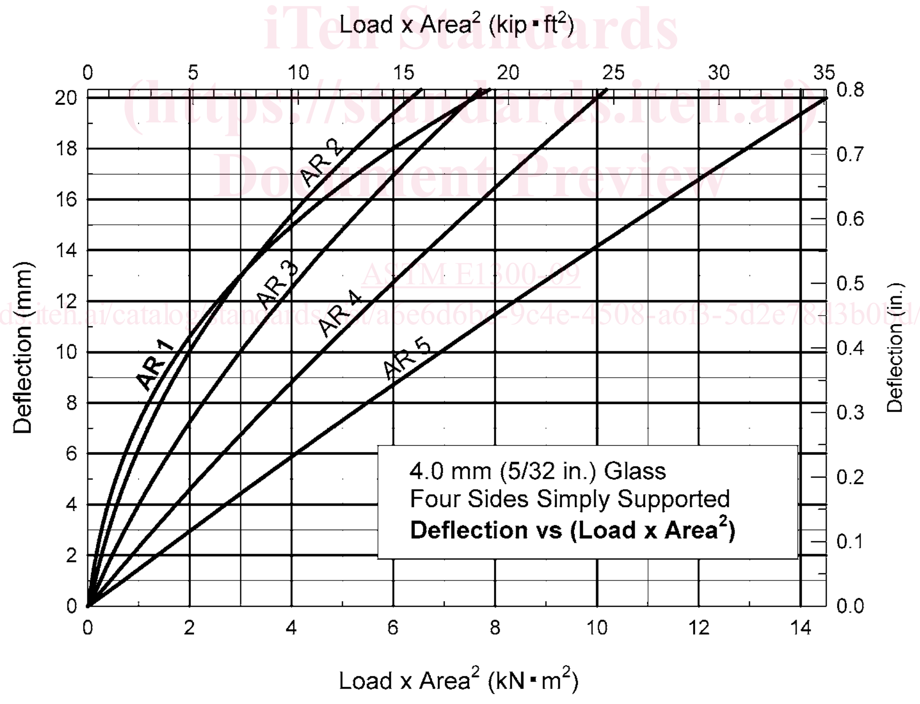

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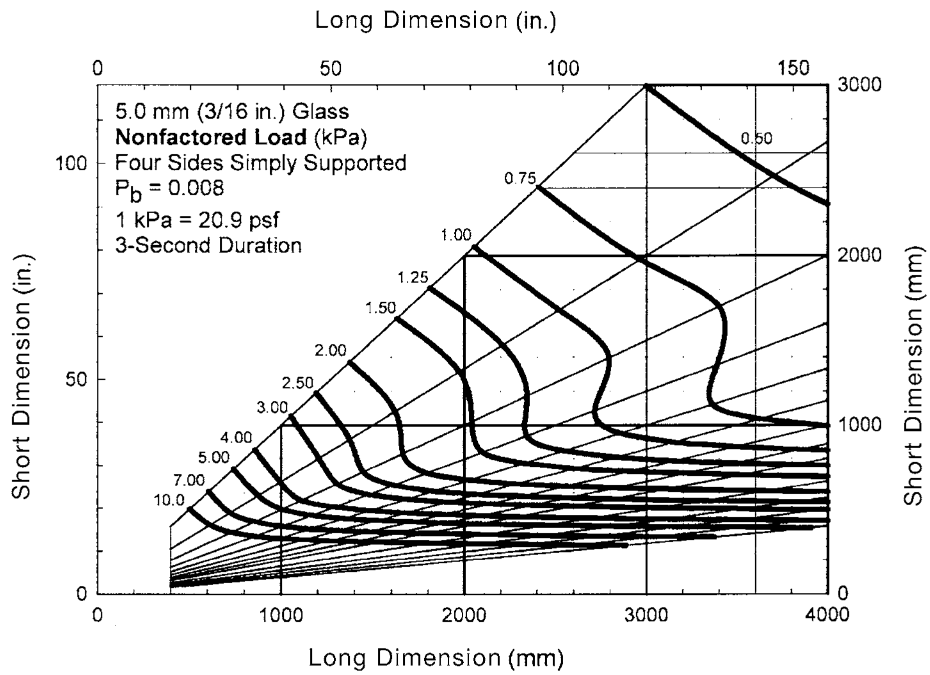
FIG. A1.4 (upper chart) Nonf-Factored Load Chart for 4.0 mm (5⁄32 in.) Glass with Four Sides Simply Supported
(lower chart) Deflection Chart for 4.0 mm (5⁄32 in.) Glass with Four Sides Simply Supported



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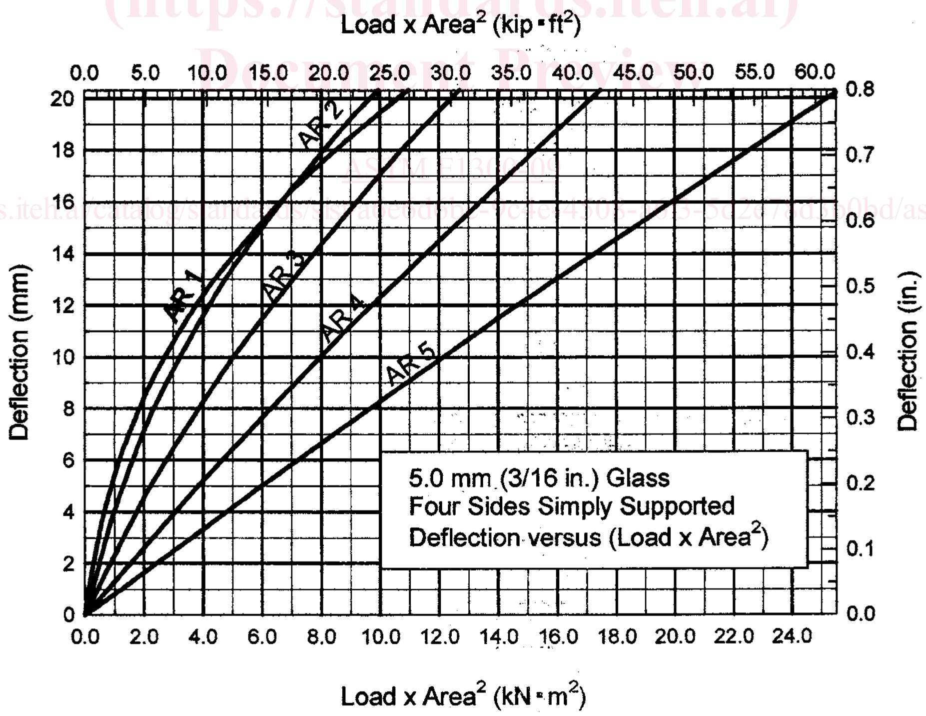

FIG. A1.5 (upper chart) Nonf-Factored Load Chart for 5.0 mm (3⁄16 in.) Glass with Four Sides Simply Supported
(lower chart) Deflection Chart for 5.0 mm (3⁄16 in.) Glass with Four Sides Simply Supported

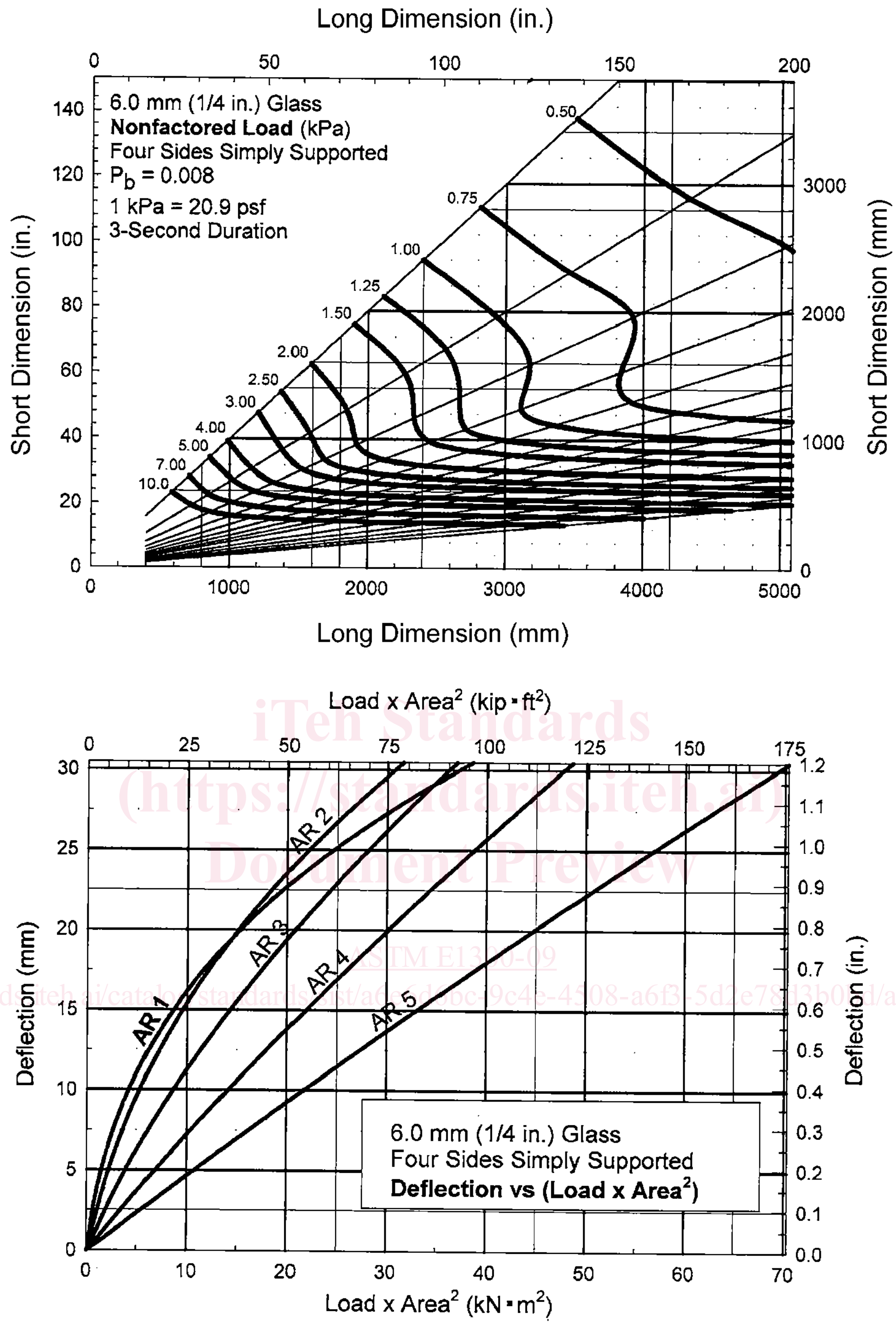

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FIG. A1.6 (upper chart) Non-Factored Load Chart for 6.0 mm (¼ in.) Glass with Four Sides Simply Supported
(lower chart) Deflection Chart for 6.0 mm (¼ in.) Glass with Four Sides Simply Supported