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ICC-ES Evaluation Report

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DIVISION: 05 00 00—METALS
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Section: 05 73 13—Glazed Decorative Metal Railings

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Section: 08 81 00—Glass Glazing
Section: 08 88 00—Special Function Glazing

DIVISION: 32 00 00—EXTERIOR IMPROVEMENTS
Section: 32 35 00—Screening Devices

REPORT HOLDER:

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EVALUATION SUBJECT:

GRS™ GLASS BALUSTRADE GUARD SYSTEM FOR MONOLITHIC TEMPERED GLASS APPLICATIONS

1.0 EVALUATION SCOPE

Compliance with the following codes:

- 2012, 2009 and 2006 *International Building Code*® (IBC)
- 2012, 2009 and 2006 *International Residential Code*® (IRC)

Properties evaluated:

- Structural
- Durability

2.0 USES

The GRS Glass Rail System structural glass balustrades described in this report are intended for interior and exterior weather-exposed applications, and are suitable for use in most natural environments. The GRS system may be used for residential, commercial and industrial applications for guards along balconies, porches, mezzanines, stairs and similar locations except where vehicle impact resistance is required. The system is compatible with all construction types.

3.0 DESCRIPTION

3.1 General:

The GRS Glass Rail System utilizes an extruded aluminum base shoe, complying with 6063-T52, to anchor and support fully tempered structural glass balustrades ($^1/_2$-inch [12.7 mm], $^5/_8$-inch [15.9 mm], or $^3/_4$-inch [19.1 mm], depending on use) which support the selected top rail and/or handrail (various profiles are made of stainless steel complying with 304 or 316, brass complying with C26000, or aluminum complying with 6063-T6) to construct building guards. A complete GRS specification requires identification of the top rail (cap rail) profile and material; glass thickness with the maximum and minimum light widths; glazing system (either wet or a specific dry glazing method); base shoe; and anchorage to the supporting structure. When a handrail is used, the handrail profile, mounting bracket, and mounting bracket spacing must be specified. A complete installation requires either a top rail or a handrail. The base shoe may be installed with non-structural cladding of any compatible material bonded to it with adhesive. Figure 1 shows the typical guard elevation with the components. The complete GRS specifications must be noted on plans submitted to the building official for approval.

The profiles, section properties and strengths of the various base shoes are detailed in Section 4.2.3 of this report.

The profiles, section properties and strengths of the various top rails are detailed in Section 4.2.4.

The profiles, section properties and strengths of the various handrails are detailed in Section 4.2.7.

The glass must be Kind FT fully tempered glass conforming to the requirements of ANSI Z97.1-09, ASTM C 1048-04 and CPSC 16 CFR 1201. The fully tempered glass must have an average Modulus of Rupture $F_r \geq$ 24,000 psi. Glass type, condition, class, form, quality and finish as defined in ASTM C1036 must meet these standards and the modulus of rupture.

3.2 Durability:

The materials incorporated in the system described in this report are inherently corrosion-resistant. The material type specified must be appropriate for the environment of the installation. Information verifying the durability must be submitted to the building official, when requested.

4.0 DESIGN AND INSTALLATION

4.1 General:

Installation of the GRS glass balustrade guards must comply with the manufacturer's published instructions, this report and 2012 IBC Sections 1013 and 1607.8.1, 2009 IBC Section 1607.7.1, IBC Section 2407, or IRC Section R312, whichever is applicable. Handrails/grab rails must comply with 2012 IBC Section 1009.12 or 2012 IRC Section R311.7.8, 2009 IRC Section R311.7.7, or 2006 IRC Section R311.7.8, whichever is applicable. The

manufacturer's published installation instructions, called "GRS Glass Railing Dry Glaze Taper-Loc System for Tempered Glass Applications (AVD3919-2/11)," must be available at the jobsite at all times during installation. In the event of a conflict between this report and the manufacturer's instructions, this report governs.

4.2 Design:

4.2.1 Loading: The applicable project-specific loads must be identified. Minimum required loads are one of the following:

- 50 plf (0.73 kN/m) on the top rail in any direction
- 200 lbs (0.89 kN) on the top rail in any direction, and 50 lbs (0.22 kN) on one square foot at any location perpendicular to the glass balustrade
- The wind load on the full area of glass, in psf

Wind load must be determined by a qualified individual based on the project-specific conditions, taking into account the balustrade location on the structure. For installations in compliance with the IRC Section R312, the 50 plf (0.73 kN/m) top rail load is not applicable.

4.2.2 Glass: The glass thickness must be at least the thickness necessary to safely support the live loads and wind loads. The allowable glass loads are based on allowable glass edge stresses. Table 1 of this report provides allowable wind load in pounds per square foot for a given glass thickness, assuming the allowable stress noted in Section 4.2.2.1. Sandblasted glass must have a $^3/_4$-inch nominal thickness, with the allowable loads based on a $^1/_2$-inch (12.7 mm) thickness as noted in the tables of this report.

Minimum spacing between glass lights is $^1/_4$ inch (6.4 mm) for $^1/_2$-inch- and $^5/_8$-inch-thick (12.7 and 15.9 mm) glass lights, and $^1/_2$ inch (12.7 mm) for $^3/_4$-inch-thick (19.1 mm) glass lites.

4.2.2.1 Glass Stress: Glass lights serve as balusters to support the top rail or grab rail and form the guard infill. Allowable glass bending stress is the modulus of rupture used for the designs noted in this report divided by a factor of 4 [24,000/4 = 6,000 psi (41.3 MPa)]. Tension bending stress is based on the minimum glass thickness, except for wind loads. A wind load stress in accordance with ASTM E1300 was used in development of this report.

4.2.2.2 Holes and Notches: Holes and notches must not be located within the first third of the balustrade height from the base shoe. Holes and notches must conform to ASTM C1048. Holes or notches located within the first third of the balustrade height from the base shoe are outside the scope of this report.

4.2.3 Base Shoes:

The appropriate base shoe must be selected based on glass thickness, installion method and loading. Figure 2 shows the base shoe options. Tables 2a through 2g provide the allowable wind loads for the base shoes, glass thickness and anchorages. The base shoe must be installed in accordance with the manufacturer's published installation instructions and this report. The end anchor must be installed within 12 inches (305 mm) of the end of the base shoe and no less than $1^1/_2$ inches (38 mm) from the centerline of the anchor. A minimum of two anchors are required for any base shoe section.

4.2.3.1 Steel Substrate: The base shoe is attached to a structural steel member with a minimum thickness of $^1/_4$ inch (6.4 mm) using $^1/_2$-by-$^3/_4$-inch (12.7 by 19.1 mm), ASTM F-837 Alloy Group 1 (any condition), stainless steel, socket head cap screws installed into tapped holes. When installation is in a through-bolt condition, the cap screw length must be increased to a length sufficient to permit proper installation with full engagement of the nut. When installation is to weld blocks, drainage blocks or solid shims more than 2 inches (51 mm) long by the full base shoe width at each anchor, no reduction in allowable wind loads is required.

4.2.3.1.1 Surface-mounted to Steel: The allowable wind loads must be as shown in Table 2a. Guard height (Hg) is from bottom of base shoe to top of guard. An appropriate top rail or grab rail must be used.

4.2.3.1.2 Fascia-mounted to Steel: The allowable wind loads must be as shown in Table 2b (heights from top of base shoe to top of guard).

4.2.3.2 Concrete Substrate: The base shoe is attached to a concrete member with a minimum thickness of 5 inches and minimum compression strength of 3,000 psi (20.6 MPa), and in an uncracked condition. The attachment is made using either a $^3/_8$-inch-diameter-by-4-inch screw-in Hilti HUS-EZ (KH-EZ) anchor in accordance with ESR-3027, or a Hilti HSL-3 M8 x $3^3/_4$-inch (95 mm) anchor in accordance with ESR-1545. Minimum spacing between anchors is 6 inches (152 mm). For 12-inch-on-center (305 mm) anchor spacing, anchor locations may be moved to avoid reinforcement, provided the same number of anchors is provided and no two anchors are closer than 6 inches (152 mm) center-to-center.

4.2.3.2.1 Concrete Strength: The allowable wind load (W^1) for concrete strengths between 3000 psi (20.6 MPa) and 5,000 psi (34.4 MPa) may be adjusted by applying the adjustment factor in the following equation:

$c_w = \sqrt{(f'_c/3000)}$

$W' = cw*W$

where W is allowable wind load from the tables

f'_c = specified concrete compressive strength, in psi

4.2.3.2.2 Sand-lightweight Concrete: When installation is into sand-lightweight concrete, the allowable wind loads from the tables in this report must be reduced by a factor of 0.6.

4.2.3.2.3 Adjusted Wind Load: For a 42-inch (1067 mm) guard height, the allowable wind load from the tables in this report must be greater than 26 psf (1.25 kN/m^2) in order for the guard anchorage to be able to support the 50 plf (0.73 kN/m) live load. When typical anchor spacing is 12 inches (305 mm) on center, additional anchors may be added to the base shoe (for 10-foot (304 mm) base shoes or shorter lengths) as follows to provide a 26 psf (1.25 kN/m^2) allowable wind load and a 50 plf (0.73 kN/m) top rail live load:

- 26.0 psf ≥ W′ > 23.6 psf, add one anchor
- 23.6 psf ≥ W′> 21.7 psf, add two anchors
- psf ≥ W′ > 20.0 psf, add three anchors

For **SI:** 1 psf = 0.0479 kN/m^2

Added anchors must be distributed to divide the base shoe into approximately equal segments.

4.2.3.2.4 Surface-mounted: When edge distance is equal to or greater than 3.75 inches (95 mm) (concrete edge parallel to the anchor and to the centerline of the anchor), the allowable wind loads must be as provided in Table 2c for the guard height (Hg) from bottom of the base shoe. For edge distances less than 3.75 inches (95 mm), required for the full anchor strength, the allowable wind load must be as provided in Table 2d. Linear interpolation between Tables 2c and 2d is permitted for edge distances from 1.75 inches to 3.75 inches.

4.2.3.2.4.1 When installation is to drainage blocks or solid shims, 2 inches long by the full base shoe width at each anchor, the allowable wind loads must be as provided in Table 2e.

4.2.3.2.5 Fascia-mounted: When fascia-mounted to a slab edge, beam, wall or similar item, the minimum concrete thickness must be 6 inches (152 mm). The top and bottom of the base shoe must not extend past the concrete edge. The allowable wind load must be as determined using Table 2f, where guard height is total height above the top of the base shoe. Applicable adjustment factors from Sections 4.2.3.2.1 and 4.2.3.2.2 must be applied. Minimum wind loads must be verified in accordance with Section 4.2.3.2.3

4.2.3.2.5.1 Fascia-mounted over Drainage Blocks: When installation is with aluminum drainage blocks 2 inches (51 mm) wide by 4 inches (102 mm) deep at each anchor, the allowable wind load must be reduced by multiplying by 0.95 as shown in the following equation:

$W' = 0.95W$

4.2.3.3 Wood Substrate: Wood must have a moisture content under 19 percent at the time of fabrication and be a species and grade with specific gravity G ≥ 0.49. For exterior locations all base shoes, fasteners must be stainless steel (304 or 316). Fasteners must be tightened so that the base shoe is in tight contact with the supporting wood.

4.2.3.3.1 Surface-mounted: All base shoes are similar and interchangeable.

4.2.3.3.1.1 Exterior: Direct surface mounting to wood in exterior locations is prohibited. When surface-mounted, the base shoe must be attached to steel or aluminum brackets attached to the wood structure. Refer to Figure 3 for the aluminum bracket, and to Figure 4 for the steel bracket. Allowable wind load for these options are:

36-inch guard height, W = 46.7 psf (2.24 kN/m^2)

42-inch guard height, W = 34.3 psf (1.64 kN/m^2)

The wind load when the attachment uses a continuous angle with #14x3-inch (76 mm) wood screws at 3 inches (76 mm) on center, is:

42-inch guard height, W = 68.8 psf (3.289 kN/m^2)

4.2.3.3.1.2 Interior: Base shoes surface-mounted directly to wood with a specific gravity G ≥ 0.49 and a compressive strength perpendicular to the grain ≥ 625 psi (4.1 MPa), are limited to locations where the supporting wood is at or below the in-service moisture content of 15 percent and will not be subject to wetting. The base shoe must be anchored with $^3/_8$-inch-by-5-inch (9.5 mm by 127 mm) lag screws. The B5L base shoe must not be used for surface mounting to wood when guard height exceeds 24 inches.

4.2.3.3.1.2.1 One- and Two-family Dwellings and IRC Applications [(200 pounds (0.89 kN) Top Rail Live Load Only)]: When installed in private residences, the anchors must be installed at 12 inches (305 mm) on center or less. For a 36-inch (914 mm) guard height, the minimum number of anchors is four; and for a 42-inch (1067 mm) guard height, the minimum number of anchors is five.

4.2.3.3.1.2.2 Other Locations [(50 plf (0.73 kN/m) Top Rail Live Load)]: When installed in applications where the 50 plf (0.73 kN/m) live load is applicable in accordance with 2012 IBC Section 1607.8.1 or 2009 and 2006 IBC Section 1607.7.1, the anchors must be installed at 6 inches (152 mm) on center or less. The minimum number of anchors in any guard segment is five.

4.2.3.3.2 Fascia-mounted: The base shoes must be attached with $^1/_2$-inch-by-4-inch (12.7 mm by 102 mm) lag screws installed directly to the structural wood member. The top of the base shoe must be flush with or below the top of the beam corner radius and the beam must extend below the bottom of the base shoe. The allowable wind load must be as determined in accordance with Table 2g. Linear interpolation for other heights or anchor spacing is allowable.

4.2.4 Top Rails: A top rail is required for a code-compliant guard installation. The term “cap rail” denotes the same thing as “top rail” and the two may be used interchangeably. The top rail is installed in accordance with the details provided in the manufacturer’s installation details referenced in Section 4.1 of this report.

4.2.4.1 Support: The top rail must be installed so as to remain in place in the event of the failure of any one glass light. This requires the use of a minimum of three glass lights or a combination of other top rail supports and glass lights totaling three, minimum. Figure 5 illustrates the top rail support conditions. The top rail end condition (Figure 6) must be checked to verify that the rail will remain in place in the event of failure of the end glass light. End support must be designed when required for a code-compliant installation. The stabilizing end cap shown in Figure 14 is an acceptable method of end support.

4.2.4.2 Top Rail Profiles: The top rail profiles are shown in Figure 7. The allowable glass light widths for the top rail profiles are given in Table 3, based on live loads of 50 plf (0.073 kN/m) uniform load or 200 pounds (0.89 kN) concentrated load, whichever is critical. Glass light widths must be less than or equal to the maximum widths shown in Table 3. If the end light width exceeds the value shown in Table 3, the top rail must be attached to a wall or post. The end light must be at least as wide as the minimum light width indicated in Table 1 for the specified glass thickness and guard height.

4.2.4.3 Stainless Steel End Post: Where the glass end light exceeds the allowable end light width shown in Table 3, the top rail must be supported at the end by means of a post or wall attachment. A stainless steel post inserted in the base shoe and top rail may be used, as shown in Figure 6. The post minimum width for a maximum glass height of 42 inches (1067 mm) must be as shown in Table 4. Posts may either match glass thickness or fit tightly into the base shoe.

4.2.5 Taper-Loc® X Dry Glazed System:

4.2.5.1 Description: This is a dry glazing system where the glass is clamped inside the base shoe by the Taper-Loc® Shoe Setting Plate (an L-shaped piece on the back side) and the Taper-Loc® Shim Plates (front side), as illustrated in Figure 8. The glass is locked in place by the compressive forces created by the Taper-Loc® shim plates being compressed together by the installation tool. Use of the calibrated installation tool assures that the proper compressive forces are developed. The Taper-Loc® system is compatible with all base shoes except for the B5L, which is too shallow for the tapers.

4.2.5.2 Use: The appropriate Taper-Loc® set must be used for the specified base shoe and glass thickness, and installed in accordance to the manufacturer’s printed instructions using the calibrated installation tool. Figure 8 shows the applicable dimensions. The spacing of the Taper-Loc® sets must be as noted in Figure 8.

4.2.6 Wet Glazing: Glass may be wet glazed into any of the base shoes using a pourable grout that is compatible with aluminum and glass (see Figure 9).

4.2.6.1 Installation: Minimum grout compressive strength must exceed 1,500 psi (10.3 Mpa) at 24 hours, and 4,000 psi (27.6 MPa) at 28 days. The grout must be mixed, placed and cured in accordance with the grout manufacturer's instructions. Wet glazing grout must be continuous in the base shoe, filling all voids, and extend to the roll-in rubber glazing channel in the base shoe.

4.2.7 Handrails:

4.2.7.1 Use: Handrails are required along ramps and stairs in accordance with 2012 IBC Section 1009.15, 2009 IBC Section 1009.12, 2006 IBC Section 1009.10, 2012 IRC Section 1010.9, or 2009 and 2006 IRC Section 1010.8, as applicable; and the handrail must meet the requirements of IBC Section 1012, or 2012 IRC Sections R311.7.8 and R311.8.3, 2009 IRC Sections R311.7.7 and R311.8.3, or 2006 IRC Sections R311.5.6 and R311.6 (2006), whichever is applicable.

4.2.7.2 Brackets: The handrails may use any of the brackets or combination of brackets shown in this report. C.R. Laurence brackets covered by this report are HR2S, HR2D, HR3E, HR2F, HR15G, and HR2J (see Figure 11).

4.2.7.3 Handrail: The handrails may use any of the rails noted below:

- $1^1/_4$-inch Schedule 40 pipe - steel, stainless steel or aluminum
- $1^1/_2$-inch Schedule 40 pipe - steel, stainless steel or aluminum
- $1^1/_2$-inch OD by $^1/_8$-inch tube - stainless steel or aluminum
- $1^1/_2$-inch OD by 0.05-inch tube - stainless steel
- 2-inch OD by 0.05-inch tube - stainless steel

4.2.7.4 Installation: Handrails may be installed to glass balustrade guards using the through-glass mounting brackets shown in this report (see Figure 11). The brackets must be installed in accordance with the manufacturer's instructions. The glass holes must comply with Section 4.2.2.2 of this report.

4.2.7.5 Support: The handrail must be installed so as to remain in place in the event of the failure of any one glass light. This requires the use of a minimum of three glass lights or a combination of other handrail supports and glass lights totaling three, minimum, similar to the toprail support illustrated in Figure 5. The handrail end condition must be checked to verify that the rail will remain in place in the event of failure of the end glass light. End support must be designed when required for a code-compliant-installation.

4.2.7.6 Spacing: The bracket spacing must be within the limits shown in Table 5, with dimensions as defined in Figure 10.

4.2.7.7 Attachment: The handrail, when supported by the glass balustrade, must be attached to one of the brackets noted in this report, in accordance with the detail shown in Figure 12, and to the glass as shown in Figure 13. Alternative attachment must be designed to safely support the loads as given in 2012 IBC Section 1607.8.1 or 2009 and 2006 IBC Section 1607.7.1, whichever is applicable. The stabilizing end cap shown in Figure 14 may be used to attach the handrail or top rail to a wall or perpendicular post face.

5.0 CONDITIONS OF USE

The C.R. Laurence Glass Rail System described in this report complies with, or is a suitable alternative to what is specified in, those codes listed in Section 1.0 of this report, subject to the following conditions:

5.1 The product is limited to installation where it is not subject to vehicle impacts.

5.2 Installation must comply with this report, the manufacturer's published installation instructions, and Sections 1012, 1013 and 2407 of the IBC or Sections R311 and R312 of the IRC, whichever is applicable. When the manufacturer's instructions conflict with this report, this report governs.

5.3 The supporting structure must be designed and constructed to support the loads imposed by the GRS guards in accordance with the applicable code. The anchorage to the frame must be as specified in this report or designed to provide the required strength for the specified balustrade height and imposed loads. Drawings and design details for the GRS system, using the information noted in this report, must be included on construction plans submitted to the building official for approval. The drawings and details must be prepared by a registered design professional where required by the statutes of the jurisdiction in which the project is to be constructed.

5.4 When use is in exterior locations, the wind loads on the GRS guards must not exceed the values noted in this report. For glass heights other than those noted in this report, the allowable wind loads must not exceed the value calculated by the following equation:

$$W = \frac{(M_{gmax}/2.5)}{(0.55*H^2)}$$

where:

H = glass height above supports, in feet

$M_{gmax}/2.5$ = 352 ft-lb for $^1/_2$-inch fully tempered glass

566.4 ft-lb for $^5/_8$-inch fully tempered glass

827.2 ft-lb for $^3/_4$-inch fully tempered glass

For **SI:** 1 ft – 1 lbf = 1.356 N-m

5.5 When installed where exposed to moisture, the base shoe anchors must be of a material intended for the use and identified by the manufacturer as acceptable for exterior applications. When installed in a corrosive environment, such as one where there is exposure to salt water or pool water, the anchors must be 316 stainless steel.

5.6 All metals in contact with aluminum must be either an alloy approved for direct aluminum contact, or isolated from the aluminum by an approved coating.

5.7 The GRS systems described in this report must not be used in Wind-Borne Debris Regions.

5.8 A proper top rail or handrail must be installed in accordance with the manufacturer's instructions and this report when guards are required by Section 1013 of the IBC or Section 312 of the IRC, as applicable.

5.9 All glass must be fully tempered, fabricated, and inspected in accordance with ASTM C1048, and the glass fabricator must provide certification of compliance with ASTM C1058 for fully tempered glass. Glass must be procured directly from a qualified glass fabricator and is not produced or supplied by C.R. Laurence Co., Inc.

5.10 The CRL GRS™ and Taper-Loc® components, except for the glass, are supplied by C.R. Laurence Co., Inc., of Los Angeles, California.

6.0 EVIDENCE SUBMITTED

6.1 Data in accordance with the ICC-ES Acceptance Criteria for Glass Railing and Balustrade Systems (AC439).

6.2 Manufacturer's published installation instructions.

6.3 GRS engineering analysis reports:

6.3.1 GRS – Glass Rail System Wet Glazed or Taper-Loc® System Dry-Glazed Base Shoes, dated April 13, 2012.

6.3.2 GRS – Glass Rail System – Top Rails and Handrails, dated April 13, 2012.

7.0 IDENTIFICATION

The CRL GRS™ and Taper-Loc® guard system components described in this report are identified by a stamp on the packaging bearing the manufacturer's name (C.R. Laurence Co., Inc., sometimes abbreviated as CRL); product description and/or part number; and the ICC-ES evaluation report number (ESR-3269).

TABLE 1

ALLOWABLE LOADS ON GLASS[4]		
Glass thickness[1] (inches)	Allowable wind load 36-inch Guard Height[2] (psf)	42-inch Guard Height[3] (psf)
$^1/_2$″	71.1 psf	52.2 psf
$^5/_8$″	114.4 psf	84.1 psf
$^3/_4$″	167.1 psf	122.8 psf

For **SI:** 1 inch = 25.4 mm; 1 psf = 0.0479 kN/m^2.

MINIMUM GLASS LITE WIDTH[5]		
Glass thickness[1] (inch)	36-inch Guard Height[2]	42-inch Guard Height[3]
$^1/_2$-inch	2 foot 6-inches	2 foot- 10.5-inches
$^5/_8$-inch	1 foot 7-inches	1 foot 10-inches
$^3/_4$-inch	1 foot 0-inches	1 foot – 3-inches

For **SI:** 1 inch = 25.4 mm; 1 foot = 305 mm; 1 psf = 0.0479 kN/m^2.

[1]Nominal glass thickness shown, minimum thickness: 0.469″ for $^1/_2$-inch; 0.595″ for $^5/_8$-inch and 0.719″ for $^3/_4$-inch.
[2]Glass height above top of base shoe = 32-inches
[3]Glass height above top of base shoe = 38-inches
[4]The allowable wind loads may be adjusted for other lite heights by:

$$W' = \frac{W_{42} * 42^2}{H_g^{\ 2}}$$

where H_g = total guard height measured from bottom of base shoe to top of cap rail in inches.
W_{42} = Allowable load at 42-inch guard height.

[5]The minimum glass lite width is permitted to be provided the 6-inches top rail/guardrail is continuous across the total glass width of 1.5 times the minimum width or attached to additional supports at rail ends.

TABLE 2A—SURFACE-MOUNTED SHOE

Surface mounted to steel with $^1/_2$-inch cap screws @ 12-inches on center[1]:		
Total guard height (Hg) from bottom of base shoe		
$^1/_2$-inch cap screw to steel Base Shoe	**36-inch Height Allowable wind load***	**42-inch Height**
B5A, B5G, B5S, B5T	75.3 psf	55.3 psf
B5L	67.7 psf	49.8 psf
B6S	78.9 psf	58.0 psf
B7S	82.8 psf	60.9 psf
Surface mounted to steel with $^1/_2$-inch cap screws @ 6-inch on center:		
$^1/_2$-inch cap screw to steel Base Shoe	36-inch Height Allowable wind load*	42-inch Height
B5A, B5G, B5S, B5T	150.0 psf	110.2 psf
B5L	134.5 psf	98.8 psf
B6S	157.2 psf	115.5 psf
B7S	165.1 psf	121.3 psf

For **SI:** 1 inch = 25.4 mm; 1 psf = 0.0479 kN/m^2.

[1]Allowable wind load may be limited by glass strength. See Table 1 in this report.

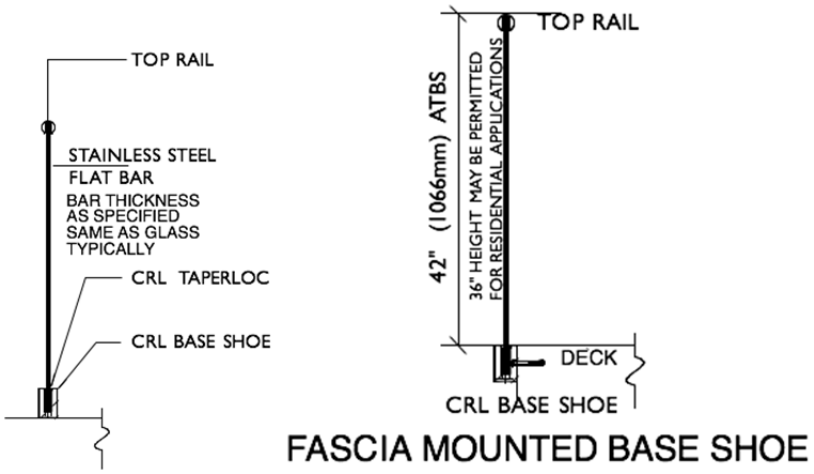


TABLE 2B—FASCIA-MOUNTED SHOE

Fascia mounted to steel with $^1/_2$-inch cap screws @ 12-inches on-center[1]:		
Total Guard Height above top of base shoe		
$^1/_2$″-inch cap screw to steel Base Shoe	36″-inch Height Allowable wind load*	42″-inch Height
B5A, B5G, B5S	68.7 psf	51.2 psf
B5L	47.5 psf	35.3 psf
B6S	68.7 psf	51.2 psf
B7S	68.7 psf	51.2 psf
Fascia mounted to steel with $^1/_2$-inch cap screws @ 6-inch on-center:		
$^1/_2$-inch cap screw to steel Base Shoe	36-inch Height Allowable wind load*	42-inch Height
B5A, B5G, B5S	138.2 psf	103.0 psf
B5L	95.6 psf	71.2 psf
B6S	138.2 psf	103.0 psf
B7S	138.2 psf	103.0 psf

For **SI:** 1 inch = 25.4 mm; 1 psf = 0.0479 kN/m^2.

[1]Allowable wind load may be limited by glass strength. See Table 1 in this report.

TABLE 2C—ANCHORAGE TO CONCRETE

For anchorage to concrete Surface Mounted:		
$^3/_8$-inch diameter x 4-inch Hilti HUS-EZ (KH-EZ) in accordance with ESR-3027 or Hilti HSL-3 M8 x $3^3/_4$-inches anchor in accordance with ESR-1545. f'c = 3,000 psi[B] (20.6 MPa)[2] embed depth = 2.5-inches (63.7 mm) effective depth		
Concrete anchors ≥ 3.75 inches edge distance[1,2,3,4]		
Anchor spacing to concrete	**12-inches O.C.**	
Total Guard Height (Hg) Base Shoe	36-inches Allowable wind load	42-inches Allowable wind load
B5G, B5S, B5T	42.7 psf	31.4 psf
B5A	41.2 psf	30.3 psf
B5L	39.0 psf	28.6 psf
B6S	45.6 psf	33.5 psf
B7S	47.9 psf	35.2 psf
Anchor spacing to concrete	**6-inches O.C.**	
Total Guard Height (Hg)	36-inches	42-inches
B5G, B5S, B5T 68.6 psf	68.6 psf	50.4 psf
B5A	66.9 psf	49.2 psf
B5L	61.5 psf	45.2 psf
B6S	73.2 psf	53.8 psf
B7S	75.7 psf	55.6 psf

For **SI:** 1 inch = 25.4 mm; 1 psf = 0.0479 kN/m^2. See footnotes at the end of Table 2d.

TABLE 2D—ANCHORAGE TO CONCRETE

Surface Mounted Base Shoes:		
Concrete anchors 2.35-inches edge distance[1,2,3,4]		
Anchor spacing to concrete	**12-inches on-center**	
Total Guard Height (Hg) Base Shoe	36-inches Allowable wind load	42-inches Allowable wind load
B5G, B5S, B5T	35.5 psf	26.1 psf
B5A	34.0 psf	25.0 psf[a]
B5L (3.047-inches min edge dist)	35.4 psf	26.0 psf[a]
B6S	37.2 psf	27.3 psf
B7S	39.1 psf	28.7 psf
[a]Doesn't meet 50 plf live load on top rail required by Section 1607.8.1 of the IBC. See section 4.2.1 of this report.		
Concrete anchors 1.75-inches edge distance		
Anchor spacing to concrete	**6-inches on-center**	
Total Guard Height (Hg)	36-inches	42-inches
B5G, B5S, B5T	50.8 psf	37.3 psf
B5A	49.9 psf	36.6 psf
B5L	45.6 psf	33.5 psf
B6S	53.3 psf	53.3 psf
B7S	56.0 psf	41.1 psf
B7S 2.35-inches edge distance	61.9 psf	45.5 psf

For **SI:** 1 inch = 25.4 mm; 1 psf = 0.0479 kN/m^2.

[1]Linear interpolation between guard heights, anchor spacing and edge distances is permitted.
[2]Adjustment for concrete strength other than f'$_c$ = 3,000 psi, see section 4.2.3.2.1 of this report.
[3]Adjustment for sand light-weight concrete: W' = 0.6*W
[4]Allowable wind load maybe limited by glass strength. See Table 1 in this report.

TABLE 2E

SURFACE MOUNTED WITH DRAIN BLOCKS ON CONCRETE[1,2,3,4]

Concrete anchors ≥ 3.75-inches edge distance

Anchor spacing to concrete	**12-inches on-center**	
Total Guard Height (Hg)	36-inches	42-inches
Base Shoe	Allowable wind load	Allowable wind load
B5G, B5S, B5T	41.2 psf	30.2 psf
B5A	41.2 psf	30.2 psf
B5L	37.0 psf	27.2 psf
B6S	44.0 psf	32.3 psf
B7S	50.5 psf	37.1 psf

Anchor spacing to concrete	**6-inches on-center**	
Total Guard Height (Hg)	36-inches	42-inches
B5G, B5S, B5T	66.9 psf	49.2 psf
B5A	66.9 psf	49.2 psf
B5L	60.2 psf	44.2 psf
B6S	71.2 psf	52.3 psf
B7S	74.6 psf	54.8 psf

Concrete anchors 2.35-inches edge distance[1,2,3]

Anchor spacing to concrete	**12-inches on-center**	
Total Guard Height (Hg)	36-inches	42-inches
Base Shoe	Allowable wind load	Allowable wind load
B5G, B5S, B5T	34.0 psf	25.0 psf[a]
B5A	34.0 psf	25.0 psf[a]
B5L (3.047-inches min edge dist)	30.6 psf	26.9 psf
B6S	36.2 psf	26.6 psf
B7S	41.6 psf	30.5 psf

[a]Doesn't meet 50 plf live load on top rail add extra anchor per 10 feet (3048 mm) length

Concrete anchors 2.35-inches edge distance

Anchor spacing to concrete	**6-inches on-center**	
Total Guard Height (Hg)	36-inches	42-inches
B5G, B5S, B5T	55.0 psf	40.4 psf
B5A	55.0 psf	40.4 psf
B5L	49.5 psf	36.4 psf
B6S	58.4 psf	42.9 psf
B7S	61.2 psf	45.0 psf

For **SI:** 1 inch = 25.4 mm; 1 psf = 0.0479 kN/m^2.

[1]Linear interpolation between guard heights, anchor spacing and edge distances is permitted.
[2]Adjustment for concrete strength other than f'$_c$ = 3,000 psi. See Section 4.2.3.2.1
[3]Adjustment for sand light-weight concrete:
W' = 0.6*W
[4]Allowable wind load may be limited by glass strength. See Table 1 in this report.

TABLE 2F—FASCIA MOUNTED WITH DRAIN BLOCKS (CONCRETE SUBSTRATE)

Fascia Mounted

Concrete anchors edge distance ≥ $^1/_2$ base shoe height

ATBS = Above Top of Base Shoe to top of guard.

Anchor spacing to concrete	**12-inch on-center**	
Total Guard Height ATBS	36-inch	42-inch
Base Shoe	Allowable wind load	Allowable wind load
B5A, B5G, B5S	49.7 psf	37.0 psf
B5L	42.0 psf	31.2 psf
B6S	49.7 psf	37.0 psf
B7S	49.7 psf	37.0 psf

Anchor spacing to concrete	**6-inches on-center**	
Total Guard Height ATBS	36-inches	42-inches
B5A, B5G, B5S	77.1 psf	57.5 psf
B5L	51.0 psf	37.9
B6S	77.1 psf	57.5 psf
B7S	77.1 psf	57.5 psf

For **SI:** 1 inch = 25.4 mm; 1 psf = 0.0479 kN/m^2.

TABLE 2G—FACIA MOUNTED OVER DRAIN BLOCKS (WOOD SUBSTARTE)

Fascia Mounted		
To wood with $^1/_2$-inch lag screws with 2.37″ minimum embedment to wood G ≥ 0.49		
Anchor spacing 12-inch on center Interior or Dry locations mc ≤ 19%		
ATBS = Above Top of Base Shoe to top of guard.		
Total Guard Height ATBS	36-inches	42-inches
Base Shoe	Allowable wind load	Allowable wind load
B5A, B5G, B5S	48.7 psf	36.3 psf
B5L	41.4 psf	30.8
B6S	48.7 psf	36.3 psf
B7S	48.7 psf	36.3 psf
Anchor spacing 6-inch on-center.		
Total Guard Height ATBS	36-inches	42-inches
B5A, B5G, B5S	92.6 psf	69.0 psf
B5L	77.8 psf	57.9 psf
B6S	92.6 psf	69.0 psf
B7S	92.6 psf	69.0 psf
Anchor spacing 12-inch on-center. Exterior or wet locations where mc ≥ 19%		
Total Guard Height ATBS	36-inches	42-inches
Base Shoe	Allowable wind load	Allowable wind load
B5A, B5G, B5S	34.5 psf	25.7 psf*
B5L	29.4 psf	21.9*
B6S	34.5 psf	25.7 psf*
B7S	34.5 psf	25.7 psf*
*Does not meet 50 plf live load on top rail required by Section 1607.8.1 (2012) or 1607.7.1 (2009 and 2006) of the IBC. See Section 4.2.1 of this report.		
Anchor spacing to 6-inches on-center.		
Total Guard Height ATBS	36-inches	42-inches
B5A, B5G, B5S	66.9 psf	49.9 psf
B5L	56.8 psf	42.2 psf
B6S	66.9 psf	49.9 psf
B7S	66.9 psf	49.9 psf

For **SI:** 1 inch = 25.4 mm; 1 psf = 0.0479 kN/m^2.

The allowable wind loads may be adjusted for other light heights by equation 3:

$$W' = \frac{W_{42} * 42^2}{H_G^{\ 2}} \qquad \text{Eq. 3}$$

where H_G = glass height measured from top of base shoe to top of top rail in inches.

TABLE 3—ALLOWABLE GLASS LIGHT WIDTHS

Profile	Material	Max width (inches)	End lite width (inches)
GR15	Stainless	55	17
GR15	Brass	43	9
GRS/GRSC15	Stainless	73	15
GR16	Stainless	72	21
GR19	Aluminum	84	21
GR20	Stainless	96	33
GR20	Brass	96	20
GRS/GRSC20	Stainless	96	30
GR25	Stainless	96	58
GR25	Brass	96	32
GR25	Aluminum	96	40
GRS25	Stainless	96	30
GR30	Stainless	96	72
GR30	Brass	96	50
GR30	Aluminum	96	63
GR35	Stainless	96	72
GR35	Brass	96	56
GR35	Aluminum	96	85
GR40	Stainless	96	72
GR40	Brass	96	42
GR207	Stainless	96	34
GR257	Stainless	96	56
GR257	Brass	96	29
GR307	Stainless	98	69
GR307	Brass	96	37
GR307M	Aluminum	96	64
GROV4	Aluminum	96	60
WCR20	Wood	40	11
WCR25	Wood	83	21
WCR30	Wood	96	36
GRLC10	Stainless	83	24
GRL10	Stainless	81	24

For **SI:** 1 inch = 25.4 mm.

TABLE 4—PLATE POST SIZES

Plate Thickness (inches)	Minimum Width (Inches)	Base shoes
$^1/_2$	9	B5 series
$^5/_8$	5.75	B6 series
$^3/_4$	4	B7 series
1	2.25	B5 series
1.125	1.81	B6 series
1.25	1.437	B7 series

For **SI:** 1 inch = 25.4 mm.

TABLE 5—BRACKET SPACING[1]

Handrail	Material[2]	L2 in	Le in
$1^1/_4$-inch Sched 40	St or SS	96	24
$1^1/_4$-inch Sched 40	6063-T6 Al	84	21
$1^1/_2$-inch Sched 40	St or SS	115	34
$1^1/_2$-inch Sched 40	6063-T6 Al	96	29
$1^1/_2$-inch x $^1/_8$-inch Tube	SS	102	27
$1^1/_2$-inch x $^1/_8$-inch Tube	6063-T6 Al	62	15
$1^1/_2$-inch x 0.05-inch Tube	SS	50	12
2″ x 0.05-inch Tube	SS	92	22

For **SI:** 1 inch = 25.4 mm.

[1]See Figure 10 for additional details.
[2]St = A53 Steel, SS = 304 or 316 Stainless Steel

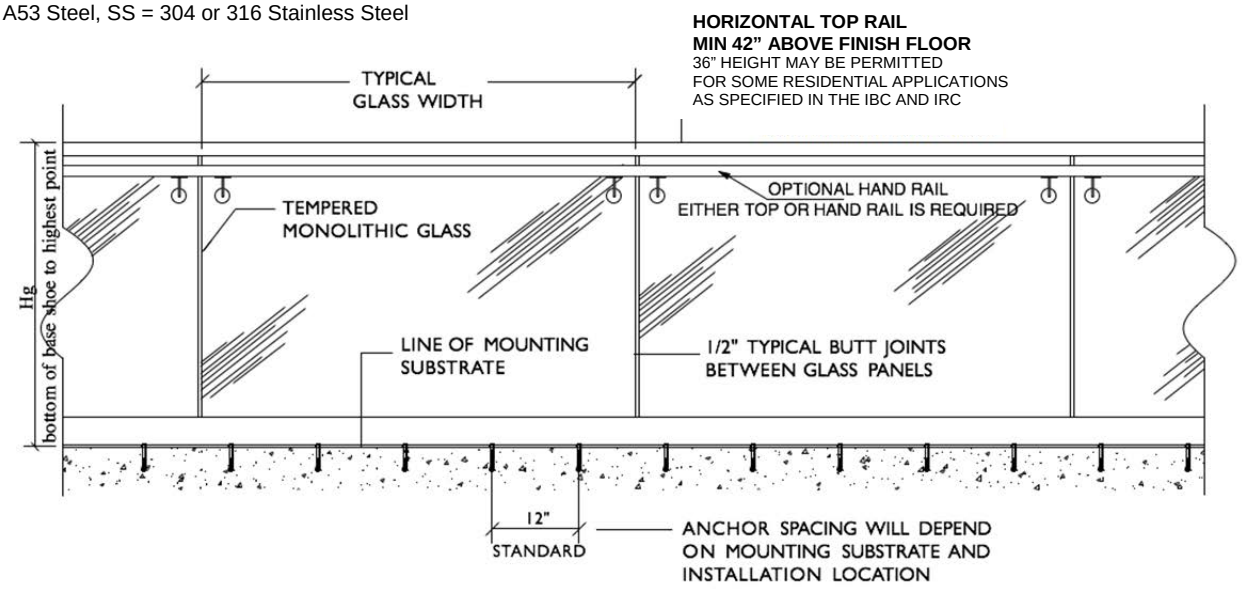
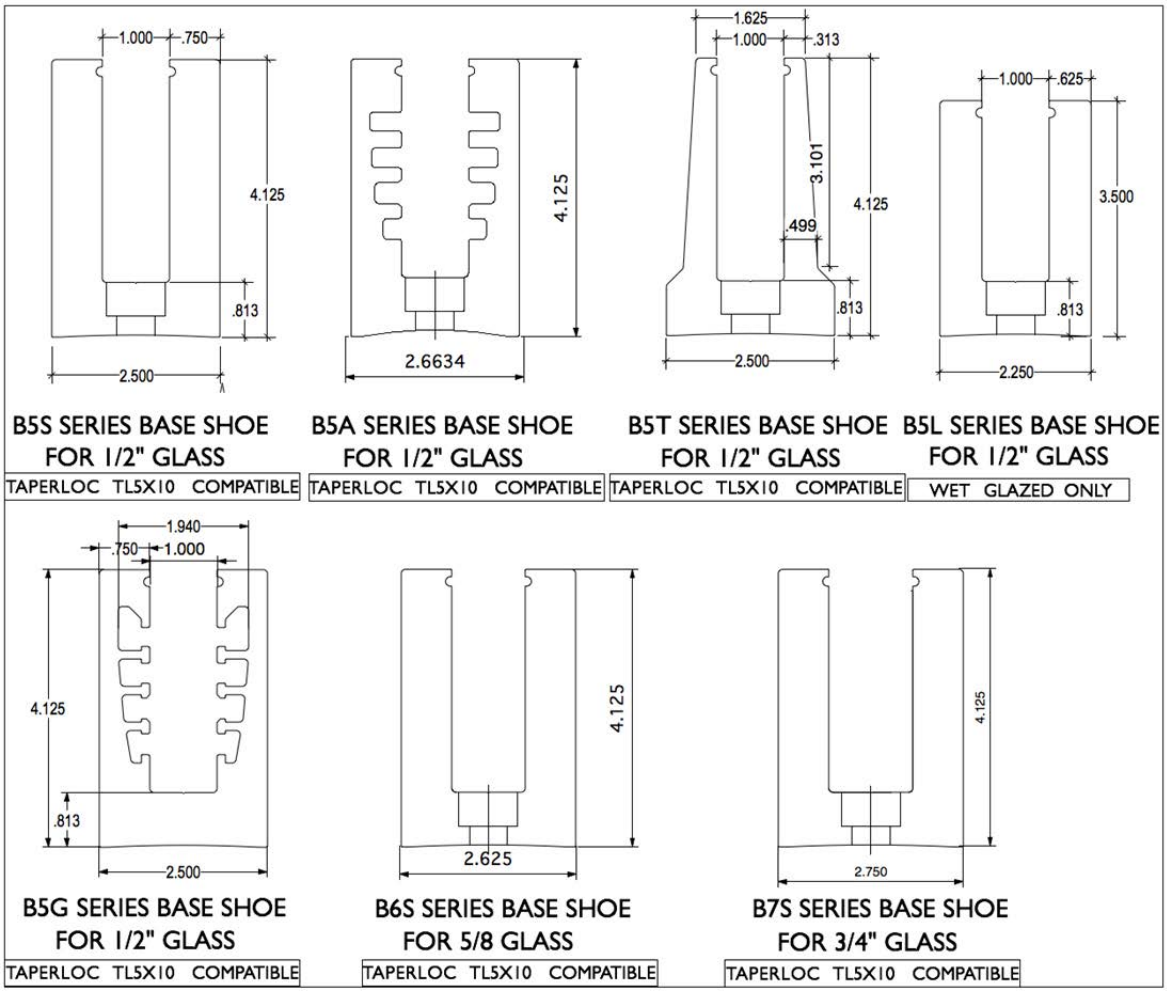


FIGURE 1—TYPICAL GLASS RAILING ELEVATION



For **SI:** 1 inch = 25.4 mm.

FIGURE 2—BASE SHOES

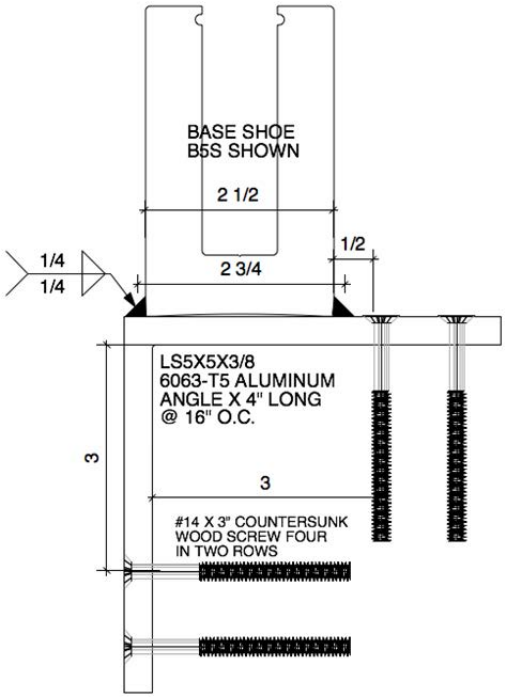


FIGURE 3—ALUMINUM BRACKET TO WOOD
(Dimensions are in inches; 1 inch = 25.4 mm)

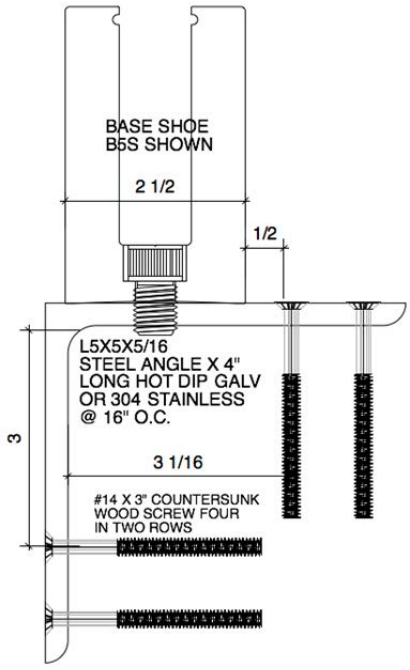


FIGURE 4—STEEL BRACKET TO WOOD
(Dimensions are in inches; 1 inch = 25.4 mm)

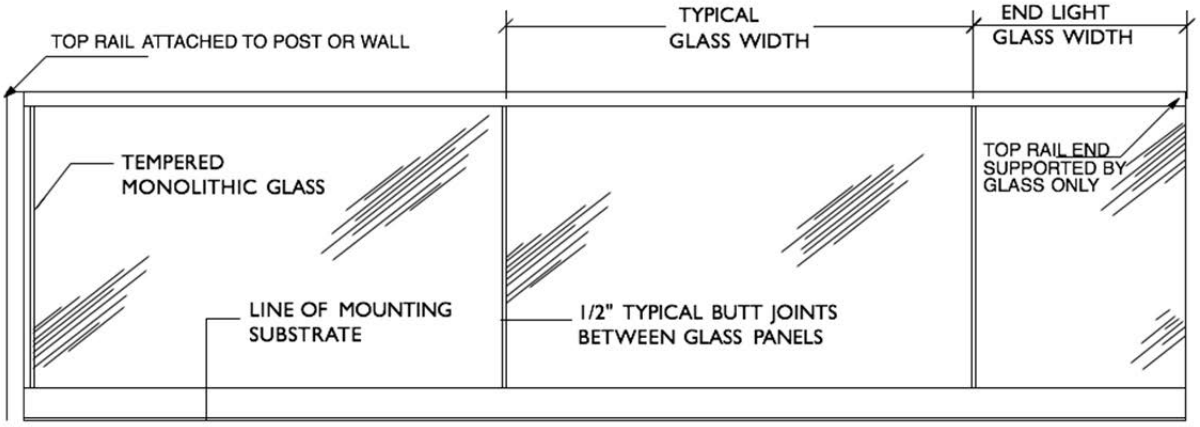


FIGURE 5—TOP RAIL SUPPORT OPTIONS

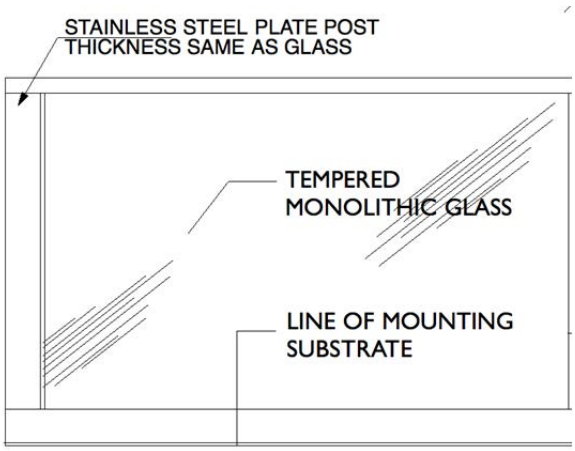
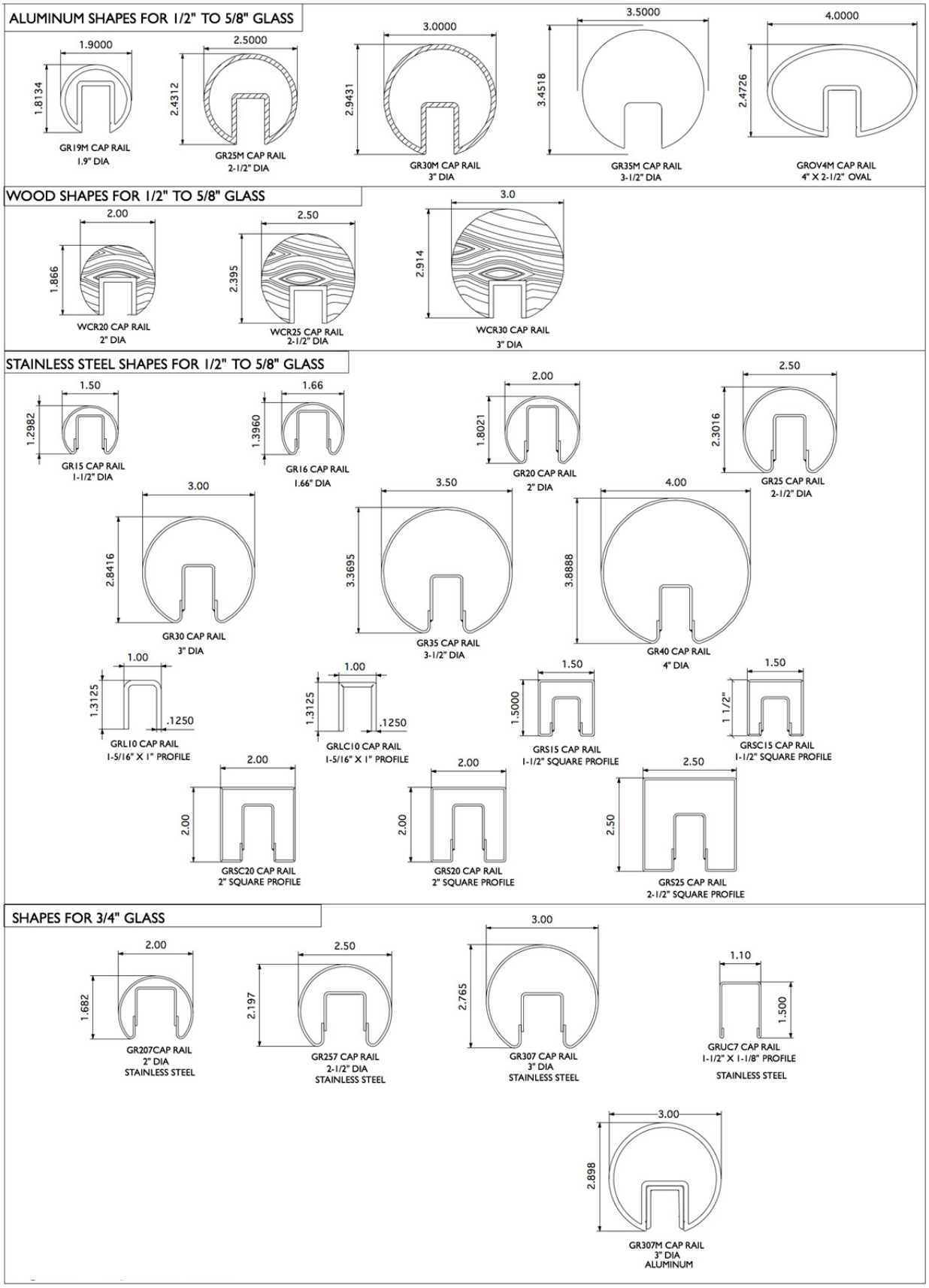
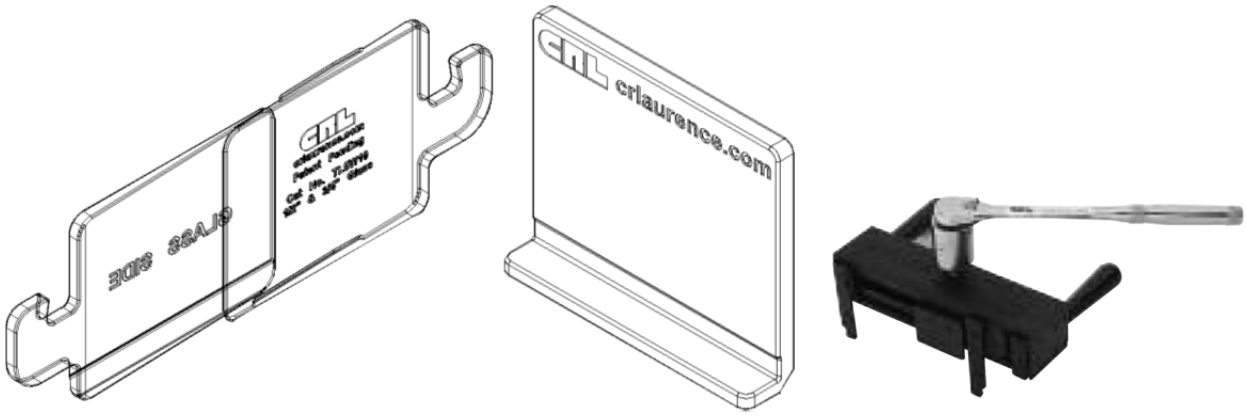


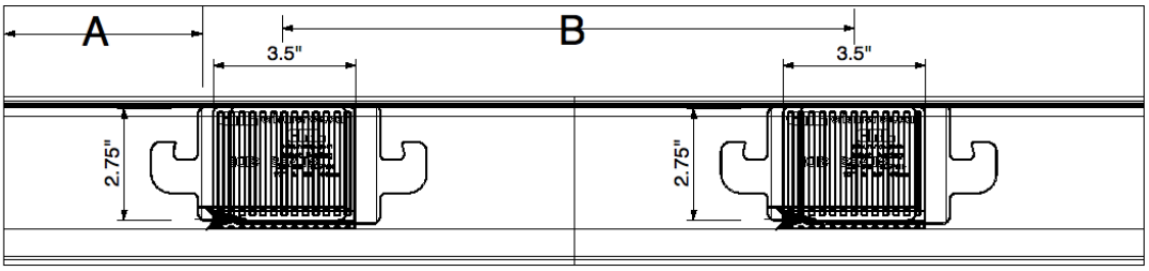
FIGURE 6—TOP RAIL SUPPORTED BY END PLATE POST



For **SI:** 1 inch = 25.4 mm.
Dimensions are in inches.

FIGURE 7—TOP RAIL PROFILES





For $^{1}/_{2}$-inch Fully Tempered Glass maximum glass light height = 42-inch:
Edge Distance: 2-inches ≤ A ≤ $8^{5}/_{8}$-inches; 51 mm ≤ A ≤ 219 mm
Center to center spacing: 7-inches ≤ B ≤ 14-inches: 178 mm ≤ B ≤ 356 mm

Panel Width/Required quantity of Taper-Loc® Plates:

6-inches to 14-inches (152 to 356 mm)	1 TL Plate
14-inches to 28-inches (356 to 711 mm)	2 TL Plates
28-inches to 42-inches (711 to 1,067 mm)	3 TL Plates
42-inches to 56-inches (1,067 to 1,422 mm)	4 TL Plates
56-inches to 70-inches (1,422 to 1,778 mm)	5 TL Plates
70-inches to 84-inches (1,778 to 2,134 mm)	6 TL Plates
84-inches to 96-inches (2,134 to 2,438 mm)	7 TL Plates

Adjustments to spacing:

1. For glass light heights over 42-inches A_{max} and B_{max} must be reduced proportionally.
   $A_{max} = 8^{5}/_{8} * (42/h)$
   $B_{max} = 14 * (42/h)$
   h = glass height

2. For glass light heights under 42-inches A_{max} and B_{max} must not be increased.

3. A_{min} and B_{min} are for ease of installation and can be further reduced as long as proper installation is achieved.

4. For glass thicknesses greater than $^{1}/_{2}$″ A_{max} and B_{max} may be increased as follows:
   $^{5}/_{8}$-inch Glass
   Edge Distance: 2-inches ≤ A ≤ 13.5″
   Center to center spacing: 7″ ≤ B ≤ 21″
   $^{3}/_{4}$-inch Glass
   Edge Distance: 2-inches ≤ A ≤ 19″
   Center to center spacing: 7″ ≤ B ≤ 31″

For **SI:** 1 inch = 25.4 mm.

FIGURE 8—TAPER-LOC® SHOE SETTING PLATE

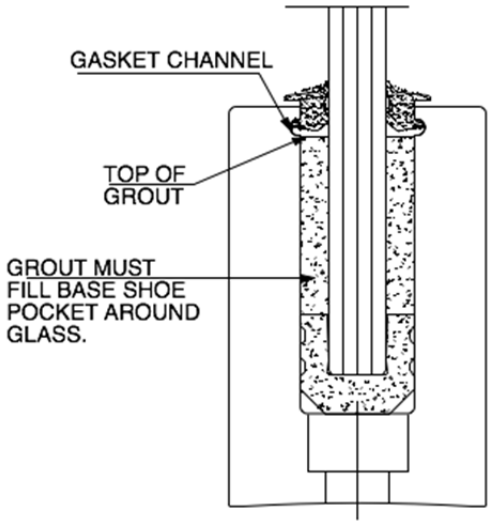


FIGURE 9—WET GLAZING

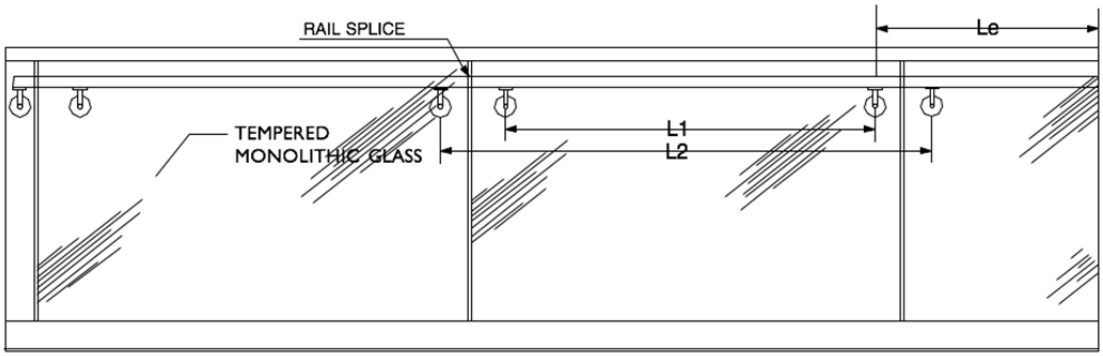


FIGURE 10—TOP RAIL SUPPORT OPTIONS

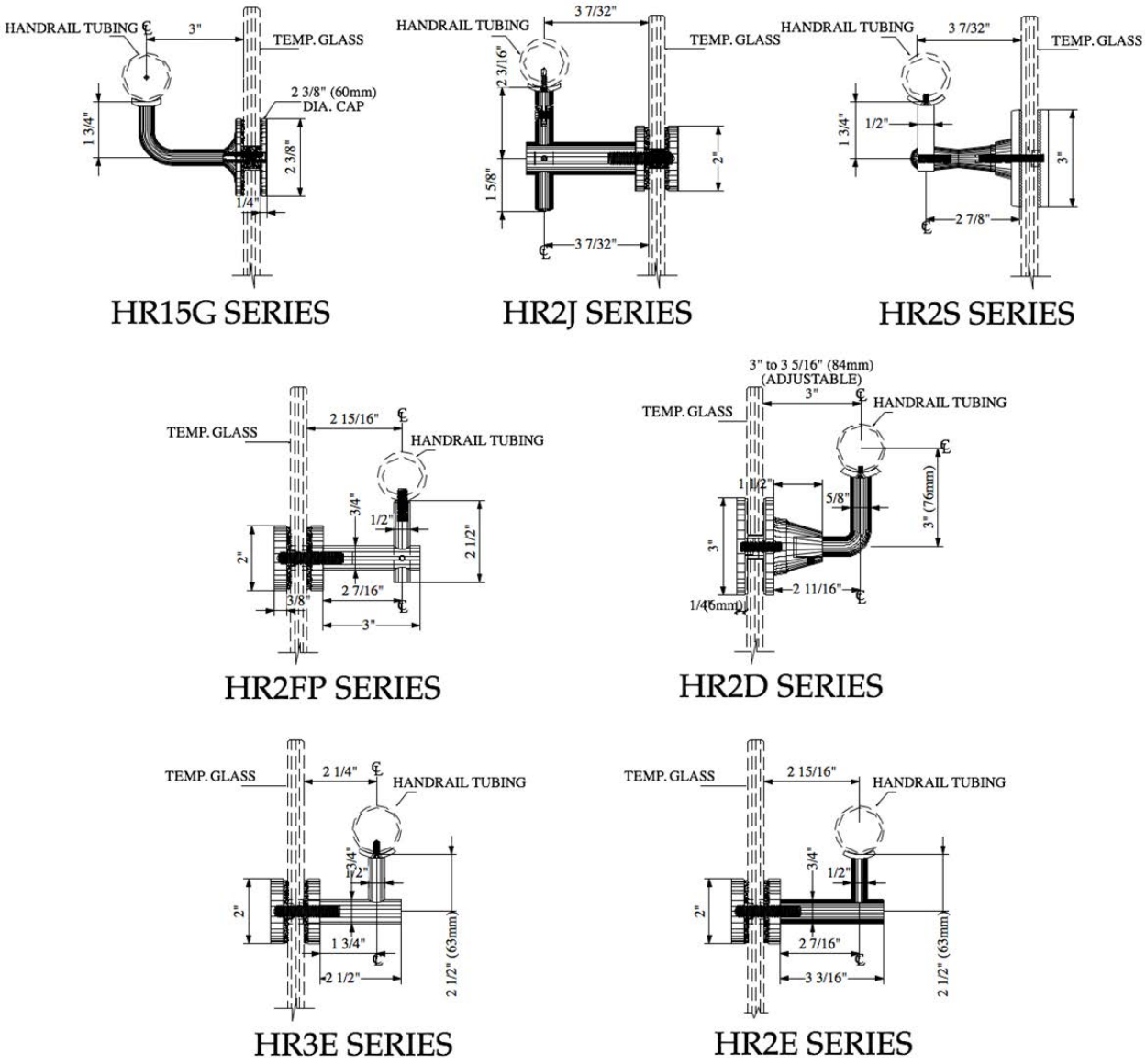


FIGURE 11—HANDRAIL BRACKETS

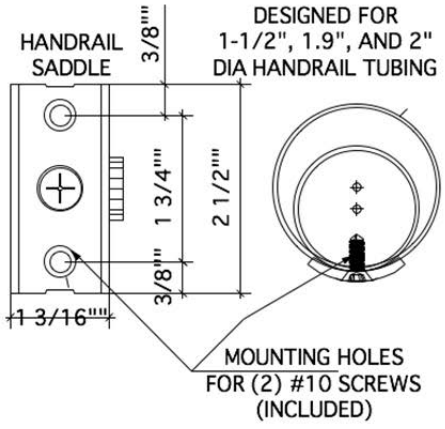


FIGURE 12—HANDRAIL ATTACHMENT

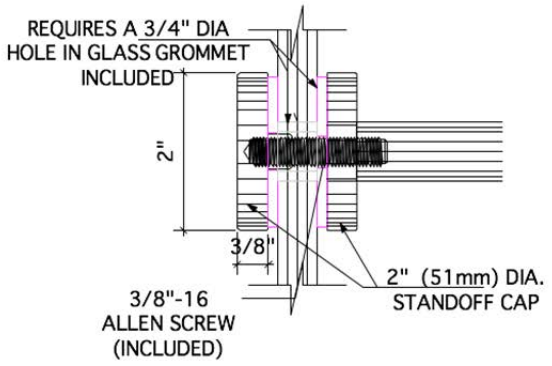


FIGURE 13—HANDRAIL ATTACHMENT TO GLASS

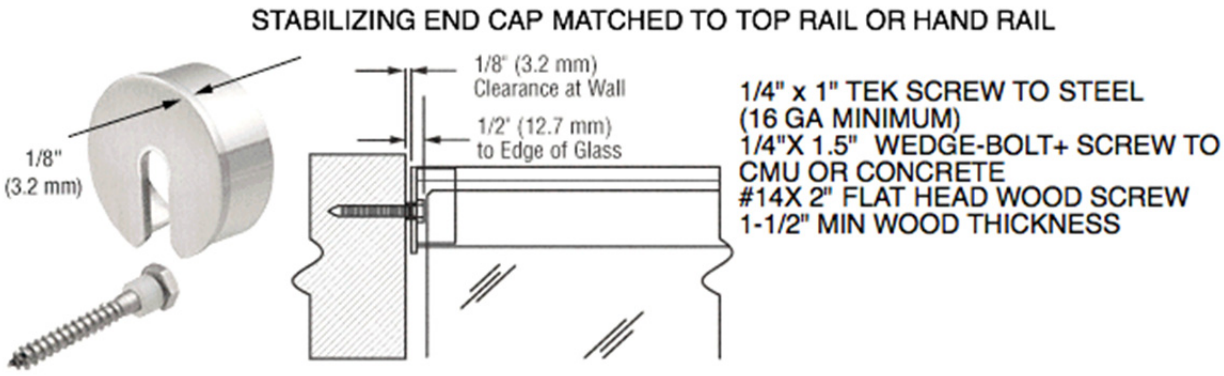


FIGURE 14—STABILIZING END CAP