29 January 2014

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SUBJ: GLASS AWNING SUPPORT SYSTEM

The Glass Awning Support System utilizes stainless steel fittings to construct frameless tempered laminated glass awnings. The system is intended for interior and exterior weather exposed applications and is suitable for use in all natural environments. The system may be used for residential, commercial and industrial applications. The Glass Awning Support System is designed for the following criteria:

The design loading conditions are:
Concentrated load = 50 lbs any direction, any location
Uniform load = 25 psf vertical, live, wind or snow load

The glass awning is not intended to support significant concentrated live loads or personnel. It shall not be used to walk, stand or step on.

The Awning Support System will meet or exceed all requirements of the 2006, 2009 and 2012 International Building Codes, and stated codes adopted from these codes. Stainless steel components are designed in accordance with SEI/ASCE 8-02 *Specification for the Design of Cold-Formed Stainless Steel Structural Members* and AISC Design Guide 27 *Structural Stainless Steel*. Wood components and anchorage to wood are designed in accordance with the *National Design Specification for Wood Construction* (through 2012 edition).

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Signed 01/29/2014

DESIGN CRITERIA
IBC Section 3105 Awnings and Canopies
IBC Section 2404.4

LOADS
DEAD LOAD
Glass weight = 6.7 psf typical for 9/16" laminated glass
SNOW LOAD
Snow loads shall be determined in accordance with ASCE/SEI 7-05 or 7-10 as appropriate Chapter 7. Unbalanced and drift loads should be considered when appropriate.
WIND LOAD
Wind loading shall be determined in accordance with ASCE/SEI 7-05 Chapter 6 for roof overhangs, 7-10 Chapter 30 or as required by the applicable building code.

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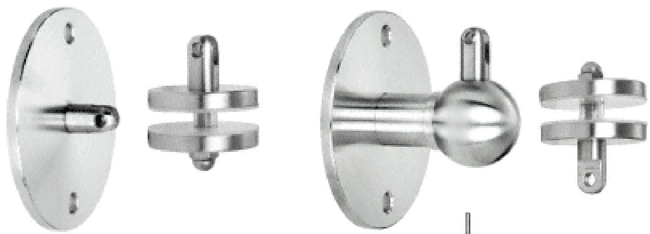
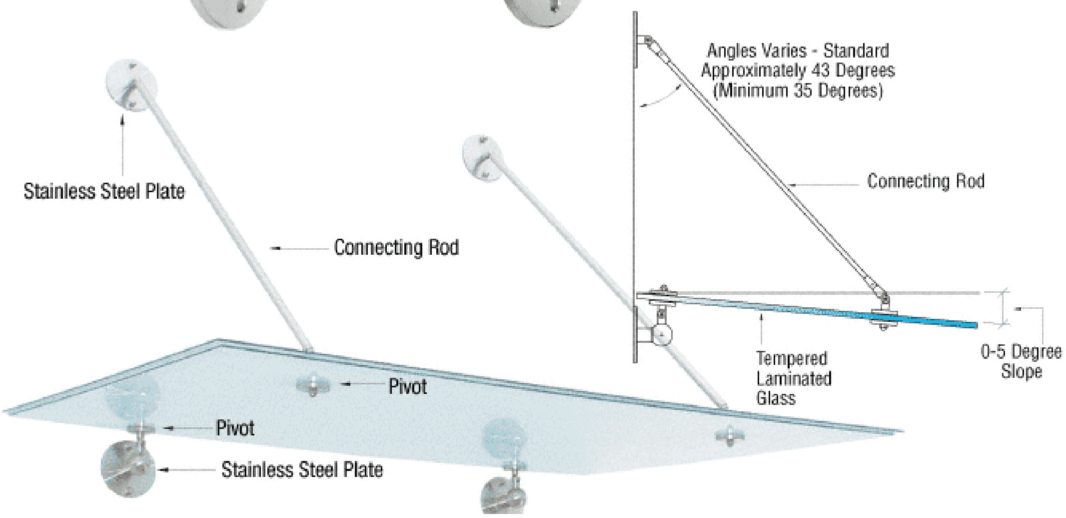
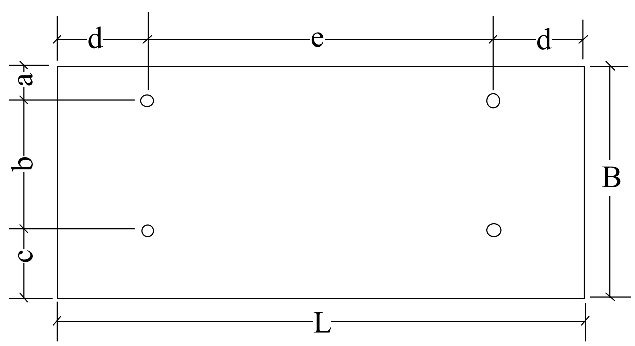
CRL GLASS AWNING SUPPORT SYSTEM





Support hardware for flat panel awnings such as laminated glass. (GAS90 shown above)



a = 2-13/16” (72mm)
12” ≤ b ≤ 35-3/8”
2.5” ≤ c ≤ 9 -13/16”
2.5” ≤ d ≤ 13-3/8”
e ≤ 45-1/4”
B ≤ 48”
L ≤ 72”
35˚ ≤ α ≤ 55˚ (Rod angle)

Support Rod: 1/2” (12 mm) diameter stainless steel

$I = 0.00307\ in^4$, $A = 0.196\ in^2$

$r = 0.125$ in

Maximum allowable rod length: 62”

kl/r = 0.5*62”/0.125” = 256

$F_a = 12\pi^2 E/[23(kl/r)^2] = 2{,}121$ psi (allowable compression stress)

$P_a = 2{,}121\ psi*0.31\ in^2 = 658\#$ compression force (wind uplift)

$T_a = øA_nF_y/1.6 = 0.85*0.196*45ksi/1.6 = 4{,}686\#$

Typical hanger rod and rod end

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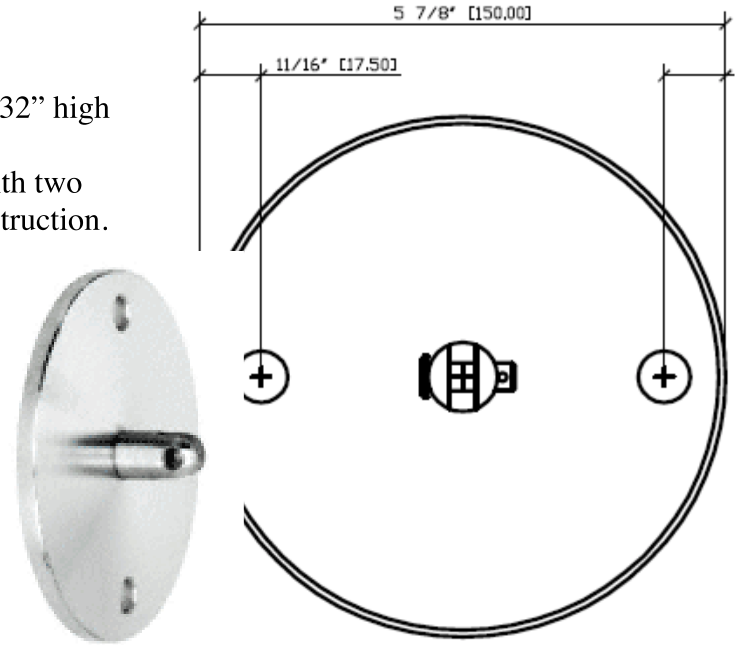
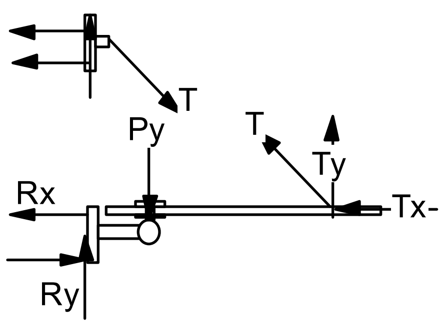
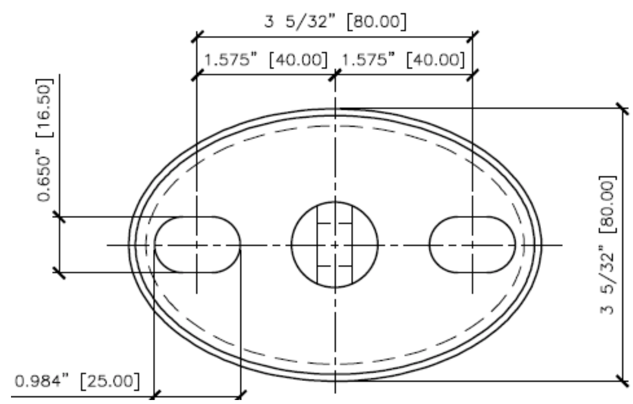
Wall Mount-
Two styles of wall bracket
GAS 90 Round - 5-7/8” diameter
GAS 190 Oblong - 4-23/32” long x 3-5/32” high

The wall plate is mounted to the wall with two screws, type dependent on the wall construction.



For gravity loads and downward wind loads the bottom bracket will have downward shear loads with inward (compression) loads
Top bracket will have combined withdrawal and shear loads acting in line with the tie rod.





Reaction from connecting rod:
$T = V/(\sin\alpha)$ (Rod tension or compression)
α = rod angle 35˚ min to 55˚ max, typically rod length is sized for $\alpha = \pm 45$˚
Horizontal load -
$H = V/(\tan\alpha)$
For wind uplift bar will act in compression.
$1.22V \le T \le 1.74V$

Tension strength of rod at end- 1/2” nominal (12mm)
Eyelet strength:
$T_n = A_nF_u = 0.188*0.25*2*75\text{ksi} = 7{,}050\#$
Rod yield strength:
$T_{ny} = AF_y = 0.175\text{in}^2*30\text{ksi} = 5{,}250\#$
Allowable tension load:
$T_a = 7{,}050/2 = 3{,}525$ or $5{,}250/1.67 = 3{,}144\#$ (controls)

Allowable vertical downward load based on $\alpha = 35$˚
$V_a = 3{,}144\#/1.74 = 1{,}807\#$

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Strength of rod in compression: (GAS90 & GAS190)
Compression strength is a function of the square of the rod length:

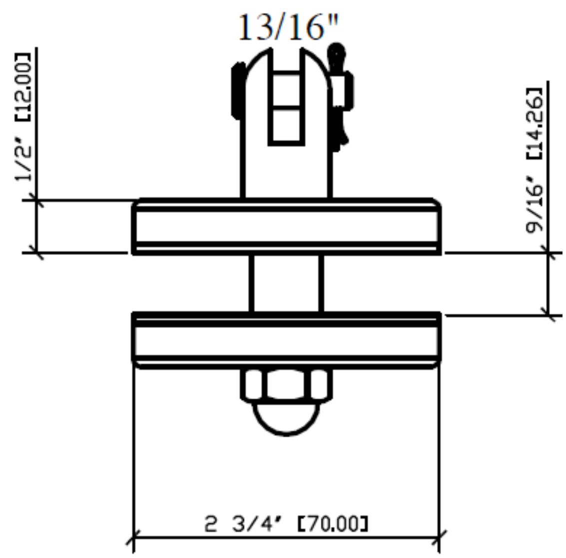
$A_{bar} = (0.472/2)^2 * \pi = 0.175 \text{ in}^2$
$r = d/4 = 0.472/4 = 0.118$
$k = 1.00$ (side sway prevented)
$kL/r = 1.0*L/0.118" = 8.4746 L$
$F_n = \pi^2 E_t/(kL/r)^2$
$F_n = \pi^2 E_t/(8.4746L)^2 = 0.1374E_t/L^2$

$P_n = A*F_n = 0.175*0.1374E_t/L^2 = 0.02405*E_t/L^2$

Bar length in	Est F_n ksi	Rev'd E_t	Rev'd F_n	P_n lbs	$P_s = P_u/1.67$ lbs
37	2.53	28000	2.81	492	295
45	1.71	28000	1.90	333	199
54	1.19	28000	1.32	231	138

P_u = maximum factored compression load for the given rod length (standard rod lengths shown.)
P_s = allowable compression load assuming all uplift is from wind load.

Glass fitting to connector rod:
GAS90 Fittings
Connected with 11/32" diameter shear pin in double shear.
Pin shear strength:
$V_n = 0.45F_uA = 0.45*75\text{ksi}*0.0928\text{in}^2 = 3{,}132\#$
Allowable load on pin:
$R_a = 2*3{,}132/2.0 = 3{,}132\#$



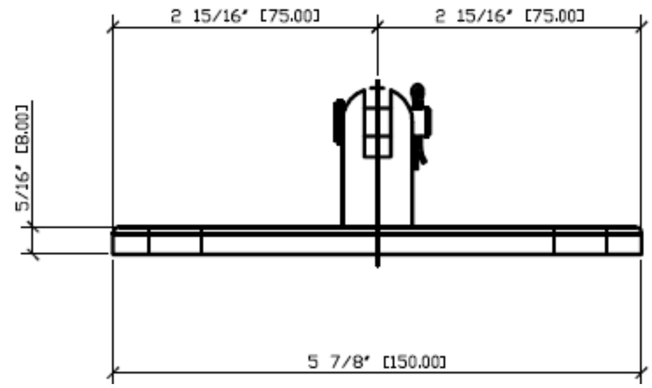
Strength of connector at pin hole:
$R_n = A_nF_u = 0.5625*0.25*75\text{ksi} = 10{,}547\#$

Bending strength of fitting bar-
13/16" bar $Z = 13/16^3/6 = 0.089 \text{ in}^3$,
$F_y > 30$ ksi
$M_a = 0.089 \text{ in}^3*30 \text{ ksi}/1.67 = 1{,}600\#"$
Allowable horizontal load component:
$H = 1{,}600"\#/1.0" = 1{,}600\#$

Glass attachment clamp:
1/2" rod with cap nut:
Tension strength-
$T_a = A_tF_u/2.0 = 0.1419\text{in}^2*70\text{ksi}/2.0 = 4{,}967\#$
$V_a = 0.45F_uA_g/2.0 = 0.45*70\text{ksi}*0.196\text{in}^2/2.0 = 3{,}087\#$

Allowable vertical (Y_a) and horizontal (H_a) loads-
$Y/4{,}967 + H/3{,}087 \leq 1.2$

Wall connection plate:

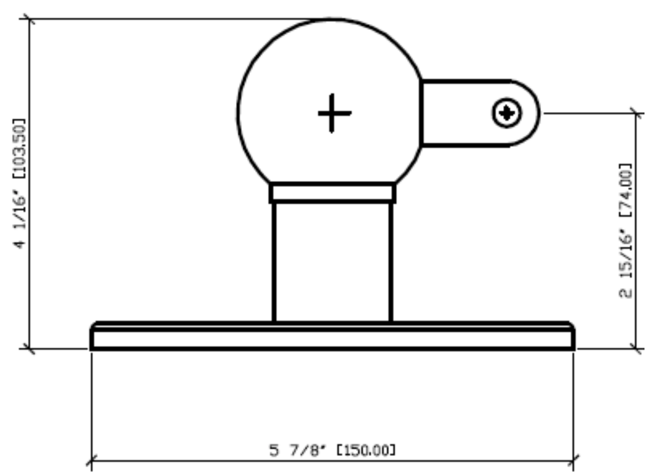


Pin strength same as previously checked. bar strength same as checked for glass bracket.

Anchorage to wall shall be checked based on specific wall construction.

Determine maximum allowable loads:
Solving for Y:
Based on H = 1,600# (maximum based on bracket bar strength)
$Y < (1.2-1{,}600/3{,}087)*4{,}967 = 3{,}202\#$

Strength of wall bracket:



Allowable horizontal load on bracket based on glass bearing stress:
For snow loads- 0.47*10,600psi = 4,982 psi
$H_a = 0.5"*0.5"*4{,}982\ psi = 1{,}245\#$

Pin shear strength:
$V_n = 0.45F_uA = 0.45*75ksi*0.0928in^2 = 3{,}132\#$
Allowable load on pin:
$R_a = 3{,}132/2.0 = 1{,}566\#$

Maximum allowable vertical load on bracket:
1-1/4" bar $Z = 5/4^3/6 = 0.3255\ in^3$,
$F_y > 30$ ksi
$M_a = 0.3255\ in^3*30\ ksi/1.67 = 5{,}848\#"$
Allowable vertical load component:
$H = 5{,}844"\#/2.5" = 2{,}339\#$

Glass bearing will limit horizontal load component to 1,245#

Maximum load on rod for 35˚ angle: Controlled by glass bracket.
$H \le 1{,}245\#$
$Y \le 1{,}245 * \tan 35˚ = 872\#$
$T \le \sqrt{(1{,}245^2+872^2)} = 1{,}520\#$
Maximum load on rod for 45˚ angle:
$H \le 1{,}245\#$
$Y \le 1{,}245 * \tan 45˚ = 1{,}245\#$
$T \le \sqrt{(1{,}245^2+1{,}245^2)} = 1{,}761\#$
Maximum load on rod for 55˚ angle: Controlled by wall bracket.
$Y \le 1{,}600\#$
$H \le 1{,}600 * \tan 35˚ = 1{,}120\#$
$T \le \sqrt{(1{,}600^2+1{,}120^2)} = 1{,}953\#$

Load share tributary to connecting rods:
$A_r = b/2+c$ Tributary width to connecting rod
For typical panel sizes with standard dimensions of a = 2 13/16” and c = 9 13/16”
$A_r = 1.434'$ for 24” width
$A_r = 1.792'$ for 36” width
$A_r = 2.042'$ for 42” width
$A_r = 2.292'$ for 48” width

Maximum allowable load on awning:
For downward loads - dead, live, snow, wind downward:
L in feet. Based on allowable vertical load of 1,120# (45˚ rod angle)
$U = 872\#/(A_r*L/2)$:
U = 973#/L for 36” width
U = 854#/L for 42” width
U = 760#/L for 48” width
Multiply above by 0.7 for $\alpha = 35˚$ and 1.4 for $\alpha = 55˚$.

For wind uplift:
$W_{net} = 0.9D + W$ (2009 IBC) or $0.6D+0.6W$ (2012 IBC)
Typical glass dead load = 6.7 psf for 9/16” laminated glass.
$W_{net} = P_s/(A_r*L/2)$
$W_{net} = 329\#/L$ for 36” width
$W_{net} = 195\#/L$ for 42” width
$W_{net} = 120\#/L$ for 48” width

Load share tributary to wall brackets:
$A_r = a + b/2$ Tributary width to connecting rod
For typical panel sizes with standard dimensions of a = 2 13/16” and c = 9 13/16”
$A_r = 1.208'$ for 36” width
$A_r = 1.458'$ for 42” width
$A_r = 1.708'$ for 48” width
For Anchorage to steel-

Controlled by screw strength-
For 1/2” bolts with nuts will develop full connecting rod strength.

For 1/2” screws to 1/4” steel backing - thread cutting bolts or tapped holes-
$T_a = A_{sn}*t_c*0.6*F_{tu}/3$
where $t_c = 0.25$”; $A_{sn} = 1.107$” and $F_{tu} = 58$ ksi (A36 steel plate)
$T_n = 1.107”*0.25*0.6*58$ ksi/3 = 3.2 k
$V_a = 1{,}500\#$
Develops full connecting rod strength.

For 1/2” screws to 1/8” steel backing - thread cutting bolts-
$T_n = 1.107”*0.125*0.6*58$ ksi/3 = 1.6 k
$V_a = 750\#$

Combined tension and shear at allowable rod load-
H = 1,245#, Y = 872
T = 1,245/2 + 872*1.3125/5.125 = 846# < 1,600#
Develops full connecting rod strength.

For anchorage to CMU, normal weight grouted- For GAS90 Brackets
Use 1/2” x 3” Hilti HUS screws strength from ESR-3056 or ITW Red Head Tapcon with special inspection
$T_a = 556\#$
$V_a = 1{,}476\#$
Maximum allowable load on awning:
Must reduce tension load for anchor strength-
Try: H = 820# and Y = 574# ($\alpha = 35^{\circ}$)
T = 810/2 + 574*1.3125/5.125 = 552# < 556#
combined:
552/556 + (0.5*574/1,476) = 1.19 ≤ 1.2 okay

For downward loads - dead, live, snow, wind downward:
L in feet. Based on allowable vertical load of 556#
$U = 556\#/(A_r*L/2)$:
U = 623#/L for 36” width
U = 545#/L for 42” width
U = 484#/L for 48” width
Higher loads require custom anchor design outside the scope of this report.

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For anchorage to Concrete ($f'_c \geq 2{,}500$ psi)- For GAS90 Brackets
Use 1/2" x 3" Hilti HUS screws strength from ESR-3056 or ITW Red Head Tapcon with special inspection
$T_a = 1{,}331\#$
$V_a = 2{,}000\#$
Maximum allowable load on awning:
Check anchor strength for maximum allowable awning loads
Try: H = 1,600# and Y = 1,120# ($\alpha = 35^\circ$)
T = 1,600/2 + 1,120*1.3125/5.125 = 1,087# < 1,331#
combined:
1,087/1,331 + (0.5*1120/2000) = 1.10 ≤ 1.2 okay
Anchors are adequate to support full allowable awning loads.

For anchorage to wood -
(1/2") x 3" Wood lag screw with 2-1/2" embedment into solid wood.

Screw withdrawal strength:
From NDS Table 11.2A for G ≥ 0.43
W = 302 #/in
$C_d = 0.9$ for dead loads
$C_d = 1.15$ for snow or live loads
$C_d = 1.6$ for wind loads

W' = 0.9*2.5"*302 = 680# (DL)
W' = 1.15*2.5"*302 = 868# (LL & SL)
W' = 1.6*2.5"*302 = 1,208# (WL)

Shear strength:
From NDS Table 11K
$Z\perp = 290\#$
$Z\perp = 0.9*290 = 261\#$ (DL)
$Z\perp = 1.15*290 = 334\#$ (LL & SL)
$Z\perp = 1.6*290 = 464\#$ (WL)

Combined lateral and withdrawal loads - NDS 11.4.1
$Z_\alpha' = (W'*Z')/[W'\cos^2\alpha + Z'\sin^2\alpha]$

For upper (connecting rod) bracket:
For $\alpha = 45^\circ$ (connecting rod at 45°)
For DL + SL typical controlling case-
$Z_\alpha' = (868*334)/[868\cos^2 45 + 334\sin^2 45] = 482\#$

Allowable rod force on bracket:
$V_a = 2*482\# = 964\#$

Vertical = Horizontal component:
$Y = H = 964/\sqrt{2} = 682\#$

Check For $\alpha = 35^\circ$ (connecting rod at 35˚)
For DL + SL typical controlling case-
$Z_\alpha' = (868*334)/[868\cos^2 35 + 334\sin^2 35] = 418\#$
Allowable rod force on bracket:
$V_a = 2*418\# = 836\#$

Vertical component:
$Y = 836*\sin 35^\circ = 480\#$
Horizontal component:
$H = 836*\cos 35^\circ = 685\#$

Check For $\alpha = 55^\circ$ (connecting rod at 55˚)
For DL + SL typical controlling case-
$Z_\alpha' = (868*334)/[868\cos^2 55 + 334\sin^2 55] = 569\#$
Allowable rod force on bracket:
$V_a = 2*569\# = 1{,}138\#$

Vertical component:
$Y = 1{,}138*\sin 55^\circ = 932\#$
Horizontal component:
$H = 1{,}138*\cos 55^\circ = 653\#$

For GAS90 Brackets mounted to wood:
Maximum allowable load on awning:
For downward loads - dead, live, snow, wind downward:
L in feet.
For $\alpha = 35^\circ$ Based on allowable vertical load of 480#
$U = 480\#/(A_r*L/2)$:
U = 768#/L for 24” width
U = 535#/L for 36” width
U = 470#/L for 42” width
U = 418#/L for 48” width

For $\alpha = 45^\circ$ Based on allowable vertical load of 682#
$U = 682\#/(A_r*L/2)$:
U = 1,091#/L for 24” width
U = 760#/L for 36” width
U = 668#/L for 42” width
U = 594#/L for 48” width

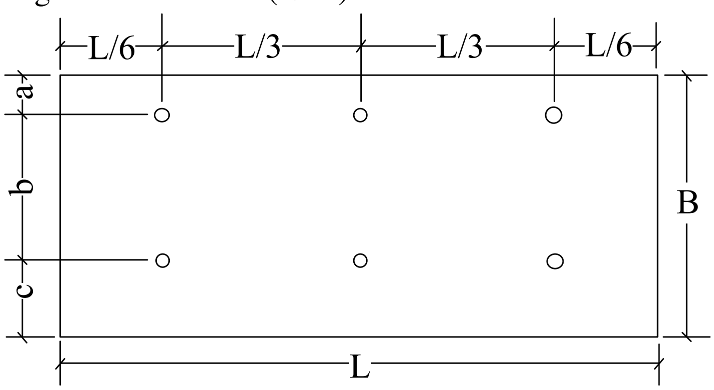
For α = 55˚ Based on allowable vertical load of 932#
U = 932#/(A_r*L/2):
U = 1,491#/L for 24” width
U = 1,039#/L for 36” width
U = 913#/L for 42” width
U = 812#/L for 48” width

For angles between 35˚ and 55˚ linear interpolation may be used.

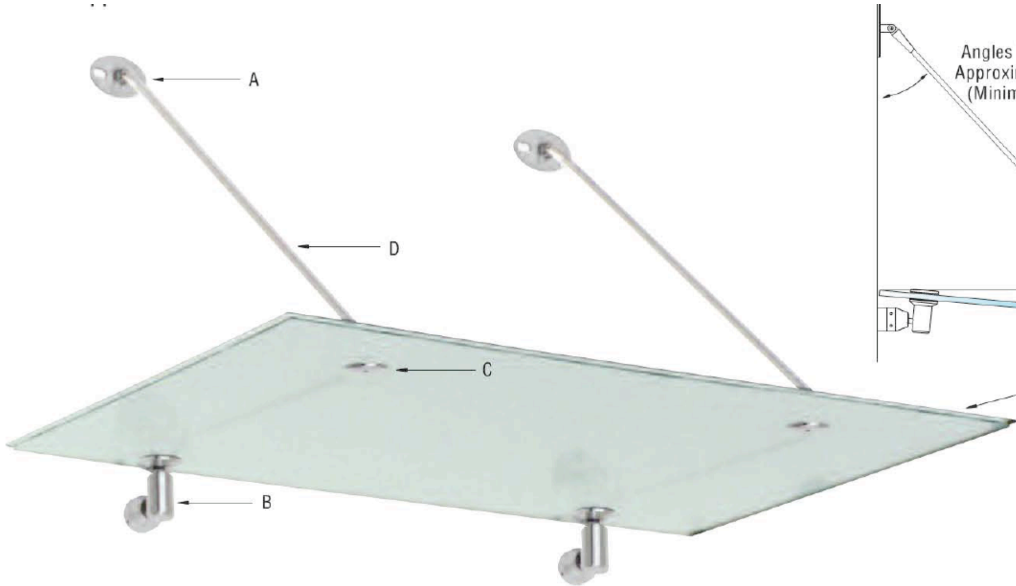
For wind uplift - no reduction for mounting to wood.

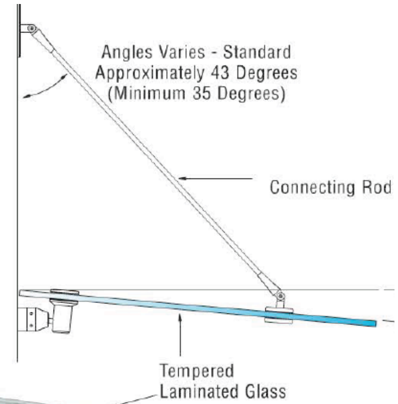
Wall bracket anchorage strength will be same and thus will support the tributary loads based on allowable loads calculated for the connecting rods.

THREE SUPPORTS ON AWNING
Higher loading may be achieved by adding a third support at the awning centerline.
When using the third center support the end supports shall be located at one sixth of the awning length from the ends (1/6L).

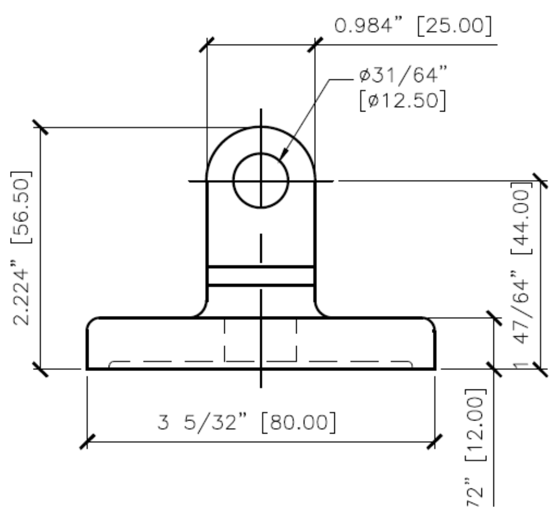


GAS190





Connecting rod same as for GAS90



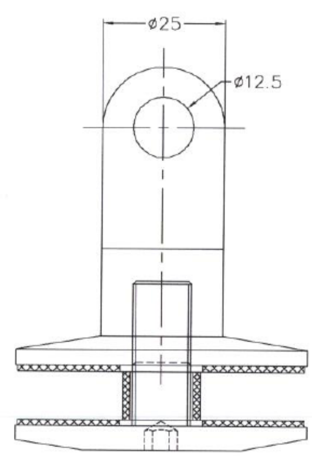
Wall mounting bracket for connecting rod:
25/64" x 1" bar $Z = 0.39"*1^2/4 = 0.0975\ in^3$
$F_y = 30$ ksi
$M_S = 0.0975\ in^3*30\ ksi/1.67 = 1{,}751\#"$
Allowable vertical component load:
Y= 1,751"#/1.234" = 1,419#

Glass Point support bracket:
Y= 1,751"#/1.0" = 1,715#

Glass bearing on point support:
H_{ag} = 0.625"*0.5"*4,982 psi = 1,557#
Allowable vertical component at $\alpha = 35°$:
Y_a = 1,557#*tan35° = 1,090#

Allowable vertical component at $\alpha = 45°$:
Y_a = 1,557*tan45° = 1,557#

Allowable vertical component at $\alpha = 55°$:
Y_a = 1,557*tan55° = 2,224#



Threads into upper standoff body 1/2" thread into tapped holes-
$T_a = A_{sn}*t_c*0.6*F_{tu}/3$
where t_c = 0.25"; A_{sn} = 1.107" and F_{tu} = 70 ksi (316 Stainless)
T_a = 1.107"*0.5*0.6*70 ksi/3 = 7.75 k
V_a = 0.45**70ksi*0.196/2.0 = 3,087#

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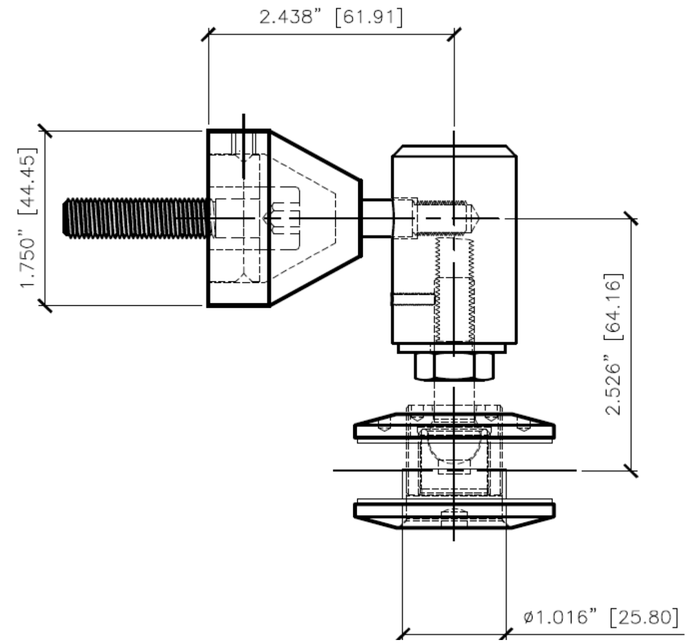
5/8” diameter bracket bar:
M_s = 0.9*0.0407in^3*45 ksi/1.6 = 1,030#”
H = 1,030#”/1.125” = 915# doesn’t control strength
1/4” connector pin strength:
V_s = 0.85*25ksi*0.049in^2/1.6 = 650# > 630# okay

Bottom Wall Mount:
May be mounted above or below glass.
Swivel head on glass standoff can pivot in wall mount to over 5˚ any direction.



Glass fitting and swivel head strength:

M10 threaded rod 316 Stainless steel
Shear strength:
A_t = 57.99mm^2 = 0.0899in^2
A_v = 78.54mm^2 = 0.1217in^2
øV_n = 0.65*0.1217in^2*42.8 ksi = 3,386#
øT_n = 0.75*0.0899in^2*71.2 ksi = 4,800#
Strength of swivel ball joint: Shear failure around socket rim:
øV_n = 0.85*42ksi*0.95*0.55”*π*0.065”= 3,809#
Maximum allowable horizontal load on fitting:
øM_n = 0.9*3,809#*0.39” = 1,337#” (based on rod in tension couple)
or for pure bending in rod:
Z = 0.39”^{3}/6 = 0.00989in^3
M_n = 75ksi*0.00989in^3 = 742#”
for typical eccentricity = 1/4”+3/16” = 0.4375
P_n = 742#”/0.4375” = 1,695#
H_a = 1,695/1.67 = 1,015#
Determine allowable load
$(M/M_a)+(T/T_a) \leq 1.2$
$T/T_a \leq 0.2$
T = 0.2*4800# = 960#

Check connection rod between standoff fitting body and wall mount:
A_t = 0.1495 in^2
A_v = 0.196 in^2
V_a = 0.55*75ksi*0.1495in^2/2= 3,083#
T_a = 0.1495in^2*75 ksi/2 = 5,606#
Z = 0.5^3/6 = 0.02083 in^3
M_a = 0.02083*75ksi/1.67 = 936”#

Imposed moment on rod from glass-
M = H*2.526" + Y*0.92"

Allowable horizontal load assuming Y = 1/2H
936"# = H*2.526" + 0.5*H*0.92" = 2.986H
H = 936/2.986 = 313#

Attachment to wall - anchor loading from allowable fitting load:
Y = 156#
T = (156*2.438"+313#*2.526")/0.875 - 313# = 1,025#
For maximum allowable uplift:
H = 233#; Y = 233#
T = (233*2.438"+233#*2.526")/0.875 +233# = 1,555#

Wall fitting strength will limit allowable loads on awning.

For GAS190 Brackets
Maximum allowable load on awning:
For downward loads - dead, live, snow, wind downward:
L in feet.
For $\alpha = 35^\circ$ Based on allowable horizontal load of 313#, vertical load = 219#
U = 219#/(A_r*L/2):
U = 244#/L for 36" width
U = 214#/L for 42" width
U = 191#/L for 48" width

For $\alpha = 45^\circ$ Based on allowable horizontal load = 313#, vertical load of 313#
U = 313#/(A_r*L/2):
U = 349#/L for 36" width
U = 307#/L for 42" width
U = 273#/L for 48" width

For $\alpha = 55^\circ$ Based on allowable horizontal load = 313#, vertical load of 447#
U = 447#/(A_r*L/2):
U = 498#/L for 36" width
U = 438#/L for 42" width
U = 389#/L for 48" width

Allowable uplift will be same as for GAS90 fitting.

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Wall Anchors:
Top bracket - connecting rod to wall
Same anchor options as for GAS90 fitting.
Maximum anchor loads based on allowable awning loads:
H = 313# and Y = 447#
T = 313/2 + 447*1.3125/1.578 = 528#
All anchor alternatives will meet this loading.

Bottom bracket anchor-
For maximum allowable loads based on bracket strength:
V = 447#
T = (313#*2.526 + 2.438"*447/2)/0.875 - 313 = 1,213#
5/16" bolt-
To steel with nut-
T_a = 0.0524in^2*75ksi/2 = 1,965#
V_a = 0.45*75ksi*0.0767in^2/2 = 1,294#

To concrete or CMU -
5/16" rod set with epoxy - Hilti HIT-HY 200 with 4" embedment.

To wood
5/16" hanger bolt
W = 212#/in from NDS Table 11.2A for G ≥ 0.43
W' = 3"*212*1.15 = 731#
Z⊥ = 170# NDS Table 11.2K
Maximum vertical load = 170#
Maximum allowable horizontal load:
Try Y = 1/2H
T = H*2.526/0.875 - H + 2.438*0.5H/0.875 = 731#
Solving for H:
H = 731/3.28 = 223#

For GAS190 Brackets
Maximum allowable load on awning for anchorage to wood-
For downward loads - dead, live, snow, wind downward:
L in feet.
For α = 45° Based on allowable horizontal load = 223#, vertical load of 223#
U = 223#/(A_r*L/2):
U = 249#/L for 36" width
U = 219#/L for 42" width
U = 195#/L for 48" width

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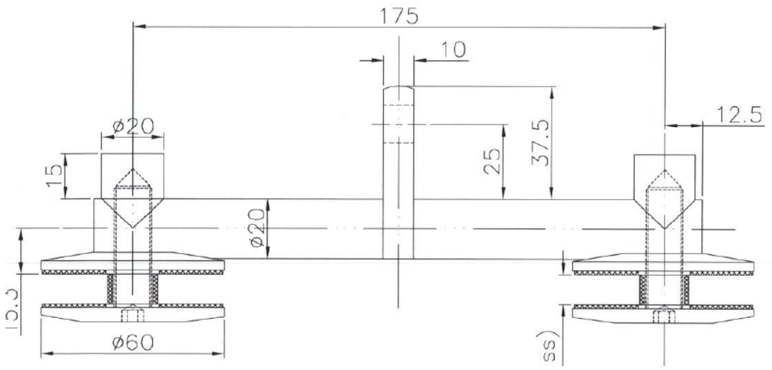
Double bracket (Two adjacent awning panes)



Bending on connection bar between double bracket and wall mount.

$Z = 0.5^3/6 = 0.0208\ in^3$

$M_S = 0.0208*50\ ksi*0.9/1.6 = 586\#"$

P = 586#"/1" = 586#

293# allowable for each pane.

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GLASS STRENGTH

Glass is fully tempered 2 layer laminated safety glass conforming to the specifications of ANSI Z97.1, ASTM C 1048-97b and CPSC 16 CFR 1201. The average Modulus of Rupture for the glass F_r is 24,000 psi. Glass may be designed for a safety factor of 2.5 in accordance with ASTM E1300-12a.

Allowable glass bending stress, based on under 0.08% probability of failure:
Wind: 9,600 psi
Snow or live loads: 4,550 psi
Dead Loads: 3,300 psi

Effective glass thickness based on the E1300-12a Appendix X9:

For 9/16" Laminated glass:
$h_1 = h_2 = 0.219"$
$h_v = 0.06"$
a = 24" Glass light:
$h_s = 0.5(h_1+h_2)+h_v = 0.5(0.219*2)+0.06 = 0.279"$
$h_{s;1} = h_{s;2} = (h_s h_1)/(h_1+h_2) = (0.279*0.219)/(2*0.219) = 0.1395"$
$I_s = h_1 h^2_{s;2} + h_2 h^2_{s;1} = 2*(0.219*0.1395"^2) = 0.00852$
$\Gamma = 1/[1+9.6(EI_s h_v)/(Gh^2_s a^2)]$
For heat and size PVB interlayer shear modulus of 70 psi ($T \le 120$ F°)

For typical light width a = 24":
$\Gamma = 1/[1+9.6(10{,}400{,}000*0.00852*0.06)/(70*0.279^2*24^2)] = 0.058$
effective thickness for deflection for 24" glass width:
$h_{ef;w} = (h_1{}^3 + h^3{}_2 + 12\Gamma I_s)^{1/3} = (0.219^3 + 0.219^3 + 12*0.058*0.00852)^{1/3} = 0.300 \le 0.498$
effective thickness for glass stress:
$h_{1;ef;\sigma} = [h_{ef;w}{}^3/(h+2\Gamma h_{s:1})]^{1/2} = [0.300^3/(0.219+2*0.058*0.1395)]^{1/2} = 0.339 \le 0.498$

For typical light width a = 36":
$\Gamma = 1/[1+9.6(10{,}400{,}000*0.00852*0.06)/(70*0.279^2*36^2)] = 0.122$
effective thickness for deflection:
$h_{ef;w} = (h_1{}^3 + h^3{}_2 + 12\Gamma I_s)^{1/3} = (0.219^3 + 0.219^3 + 12*0.122*0.00852)^{1/3} = 0.322 \le 0.498$
effective thickness for glass stress:
$h_{1;ef;\sigma} = [h_{ef;w}{}^3/(h+2\Gamma h_s)]^{1/2} = [0.322^3/(0.219+2*0.058*0.1395)]^{1/2} = 0.377 \le 0.498$

For typical light width a = 48":
$\Gamma = 1/[1+9.6(10{,}400{,}000*0.00852*0.06)/(70*0.279^2*48^2)] = 0.197$
effective thickness for deflection:
$h_{ef;w} = (h_1{}^3 + h^3{}_2 + 12\Gamma I_s)^{1/3} = (0.219^3 + 0.219^3 + 12*0.197*0.00852)^{1/3} = 0.345 \le 0.498$
effective thickness for glass stress:
$h_{1;ef;\sigma} = [h_{ef;w}{}^3/(h+2\Gamma h_{s:1})]^{1/2} = [0.345^3/(0.219+2*0.197*0.1395)]^{1/2} = 0.388 \le 0.498$

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1/2” laminated glass **with DuPont SGP interlayer** shear modulus of 5,000 psi (T ≤ 120 F°)
For 24” glass light width:
$\Gamma = 1/[1+9.6(10{,}400{,}000*0.00852*0.06)/(5{,}000*0.279^2*24^2)] = 0.815$
effective thickness for deflection:
$h_{ef;w} = (h_1^3 + h^3{}_2 + 12\Gamma I_s)^{1/3} = (0.219^3 + 0.219^3 + 12*0.815*0.00852)^{1/3} = 0.471 \leq 0.498$
effective thickness for glass stress:
$h_{1;ef;\sigma} = [h_{ef;w}{}^3/(h+2\Gamma h_{s:1})]^{1/2} = [0.471^3/(0.219+2*0.815*0.1395)]^{1/2} = 0.483 \leq 0.498$

For typical light width a = 36”:
$\Gamma = 1/[1+9.6(10{,}400{,}000*0.00852*0.06)/(5{,}000*0.279^2*36^2)] = 0.908$
effective thickness for deflection:
$h_{ef;w} = (h_1^3 + h^3{}_2 + 12\Gamma I_s)^{1/3} = (0.219^3 + 0.219^3 + 12*0.908*0.00852)^{1/3} = 0.485 \leq 0.498$
effective thickness for glass stress:
$h_{1;ef;\sigma} = [h_{ef;w}{}^3/(h+2\Gamma h_{s:1})]^{1/2} = [0.485^3/(0.219+2*0.908*0.1395)]^{1/2} = 0.491 \leq 0.498$

For typical light width a = 48”:
$\Gamma = 1/[1+9.6(10{,}400{,}000*0.00852*0.06)/(5{,}000*0.279^2*48^2)] = 0.946$
effective thickness for deflection:
$h_{ef;w} = (h_1^3 + h^3{}_2 + 12\Gamma I_s)^{1/3} = (0.219^3 + 0.219^3 + 12*0.946*0.00852)^{1/3} = 0.490 \leq 0.498$
effective thickness for glass stress:
$h_{1;ef;\sigma} = [h_{ef;w}{}^3/(h+2\Gamma h_{s:1})]^{1/2} = [0.490^3/(0.219+2*0.946*0.1395)]^{1/2} = 0.494 \leq 0.498$

Bending strength of glass for the given thickness:

$$S = \frac{12''*(t)^2}{6} = 2*(t)^2 \text{ in}^3/\text{ft}$$

Using minimum effective glass thickness for stress:
For PVB interlayer and 24” glass width:

$$S = 2*0.339^2 = 0.230 \text{ in}^3$$

Allowable bending moment on glass is:
Wind: M_{al} = 9,600 psi*0.230 in^3/ft = 2,208”#/ft = 184’#
Live: M_{al} = 4,550 psi*0.230 in^3/ft = 1,046.5”#/ft = 87.21’#
Snow: M_{al} = 4,550 psi*0.230 in^3/ft = 1,046.5”#/ft = 87.21’#
Dead: M_{al} = 3,300 psi*0.230 in^3/ft = 759”#/ft = 63.25’#

Dead load = 6.7 psf
Live = 20 psf
Snow and wind loads - check local requirements
Wind loads to be ASD level loads

Combined case:
M_d/49.5’# + (M_S or M_L)/68.25 ≤ 1.0 or
M_d/49.5’# + (M_w)/144’# ≤ 1.0 or
M_d/49.5’# + 0.75(M_S or M_L)/68.25 +0.75(M_w)/144’#
0.9*M_d/49.5’# + (M_w)/144’# ≤ 1.0

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Simplifying calculations by normalizing dead load to equivalent live or snow load:
D' = 6.7psf*4,550/3,300 = 9.2 psf
Normalizing wind load:
W' = (4,550/9,600)W = 0.474W

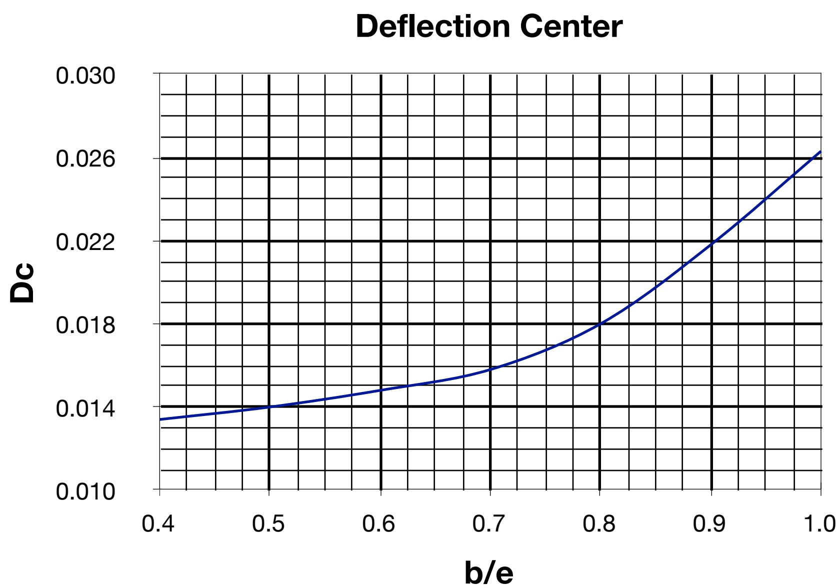
ALLOWABLE LOADS ON AWNING GLASS

Check glass deflection:
For deflection:
$t = h_{ef;w}$
$E = 10.4x10^6$ psi

For cantilever length
d ≤ 1/8e or ≤ 6"

$\Delta = D_c(1-\nu^2)ue^4/(Et^3)$;
u = uniform load on glass

Check dead load deflections as dead load deflections must be limited to avoid visible deflection:



$$\Delta = \frac{D_c(1-0.22^2)9.2psf/12*e^4}{(10.4x10^6\ psi\ *t^3)}$$

For 2' glass width and maximum allowable dead load deflection of L/360:

$$e/360 = \frac{D_c(1-0.22^2)9.2psf/12*e^4}{(10.4x10^6\ psi\ *0.30^3)}$$

Solving for e:
$e^3 = [(10.4x10^6\ psi\ *0.30^3)/(360D_c(1-0.22^2)9.2psf/12) = 1069.14/D_c$
solve for e by estimating D_c:
$D_c = 0.018$; $e = [1{,}069.14/0.018]^{1/3} = 39$"; b/2 = 24/39 =0.6; $D_c = 0.0148$
$D_c = 0.0148$; $e = [1{,}069.14/0.0148]^{1/3} = 41.65$"; b/2 = 24/41.65 = 0.58
Longest recommended main span without cantilevers is 41.65"

For a standard awning layout of d = 1/5e (Cantilever length is 1/5 of main span length)
Cantilever length shall not exceed 1/4e (1/4 of main span).
Deflections will not control because main span and cantilever deflections will balance.

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Maximum bending moment will occur at center edge of the glass light or in line with the glass supports:

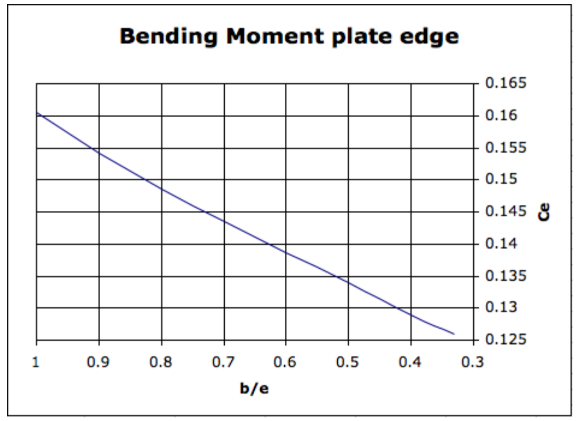
$M_{ec} = C_e*u*e^2$

C_e is from graph based on b/e where b is always the smaller dimension.

When b/e < 0.33 C_e may be taken as 0.125

For concentrated loads

$M_l = 2C_ePe$ for concentrated load P at the light center edge



For cantilever section

Use C_e based on b/d may be assumed 0.165

$M_c = (8C_e)u*d^2/2$ at support axis

Example for calculating allowable snow load:

For 2' glass width and e = 2' (distance between supports)

b/e = 1.0

From figure:

$C_e = 0.161$

$M_{ec} = C_e*u*e^2 = 0.161*u*2^2 \leq 87.21$'#

$u_{all} = 87.21/(0.161*2^2) = 135.4$ psf

$S_{all} = 135.4$psf - 9.2psf = 126.2 psf

For 2' awning width with PVB interlayer

Allowable uniform load may be calculated using:

$U = [(87.21/(C_e*e^2)]$

C_e taken from the figure for b/e

e (ft)	2.000	3.000	4.000	5.000	6.000	7.000
C_e	0.161	0.142	0.134	0.129	0.125	0.125
U psf	135.4	68.2	40.7	27.0	19.4	14.2
L or S psf	126.2	59.0	31.5	17.8	10.2	5.0
W psf	266.3	124.6	66.4	37.6	21.5	10.6

Typically minimum allowable live load is 20 psf.

Because unbalanced snow, live or wind loads must be considered allowable loads shall not be increased for the cantilevered ends unless a specific analysis is performed.

For 3' awning width with PVB interlayer

$S = 2*0.377^2 = 0.284\ in^3$

Allowable bending moment on glass is:

Wind: $M_{al} = 9{,}600\ psi*0.284\ in^3/ft = 2{,}726''\#/ft = 227.2'\#$

Live: $M_{al} = 4{,}550\ psi*0.284\ in^3/ft = 1{,}292''\#/ft = 107.68'\#$

Snow: $M_{al} = 4{,}550\ psi*0.284\ in^3/ft = 1{,}292''\#/ft = 107.68'\#$

Dead: $M_{al} = 3{,}300\ psi*0.284\ in^3/ft = 937''\#/ft = 78.1'\#$

Example for calculating allowable snow load:

For 3' glass width and e = 3' (distance between supports)

$b/e = 1.0$

From figure:

$C_e = 0.161$

$M_{ec} = C_e*u*e^2 = 0.161*u*3^2 \leq 107.68'\#$

$u_{all} = 107.68/(0.161*3^2) = 74.3\ psf$

$S_{all} = 74.3psf - 9.2psf = 65.1\ psf$

For 3' awning width with PVB interlayer

Allowable uniform load may be calculated using:

$U = [(107.68/(C_e*e^2)]$

C_e taken from the figure for b/e

e (ft)	2.000	3.000	4.000	5.000	6.000	7.000
C_e	0.165	0.161	0.147	0.138	0.134	0.130
U psf	163.2	74.3	45.8	31.2	22.3	16.9
L or S psf	154.0	65.1	36.6	22.0	13.1	7.7
W psf	324.8	137.4	77.2	46.4	27.7	16.3

Typically minimum allowable live load is 20 psf.

Because unbalanced snow, live or wind loads must be considered allowable loads shall not be increased for the cantilevered ends unless a specific analysis is performed.

CHECK DEAD LOAD DEFLECTIONS

For 3' glass width and maximum allowable dead load deflection of L/360:

$$e/360 = \frac{D_c(1-0.22^2)9.2psf/12*e^4}{(10.4x10^6\ psi\ *0.322^3)}$$

Solving for e:

$e^3 = [(10.4x10^6\ psi\ *0.322^3)/(360D_c(1-0.22^2)9.2psf/12) = 1322.02/D_c$

solve for e by estimating D_c:

$D_c = 0.018$; $e = [1{,}322.02/0.018]^{1/3} = 41.88''$; $b/2 = 36/41.88 = 0.86$; $D_c = 0.0208$

$D_c = 0.0208$; $e = [1{,}322.02/0.0208]^{1/3} = 39.91''$; $b/2 = 36/39.91 = 0.9$

Longest recommended main span without cantilevers is 39.9"

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For 4' awning width with PVB interlayer

$S = 2*0.388^2 = 0.301$ in^3

Allowable bending moment on glass is:

Wind: M_{al} = 9,600 psi*0.301 in^3/ft = 2,890"#/ft = 240.8'#

Live: M_{al} = 4,550 psi*0.301 in^3/ft = 1,370"#/ft = 114.13'#

Snow: M_{al} = 4,550 psi*0.301 in^3/ft = 1,370"#/ft = 114.13'#

Dead: M_{al} = 3,300 psi*0.301 in^3/ft = 993.3"#/ft = 82.78'#

Example for calculating allowable snow load:

For 4' glass width and e = 4' (distance between supports)

b/e = 1.0

From figure:

$C_e = 0.161$

$M_{ec} = C_e*u*e^2 = 0.161*u*4^2 \leq 114.13$'#

$u_{all} = 114.13/(0.161*4^2) = 44.3$ psf

S_{all} = 44.3psf - 9.2psf = 35.1 psf

For 4' awning width with PVB interlayer

Allowable uniform load may be calculated using:

$U = [(107.68/(C_e*e^2)]$

C_e taken from the figure for b/e

e (ft)	2.000	3.000	4.000	5.000	6.000	7.000
C_e	0.134	0.165	0.161	0.148	0.142	0.138
U psf	94.6	76.9	44.3	30.8	22.3	16.9
L or S psf	85.4	67.7	35.1	21.6	13.1	7.7
W psf	180.2	142.7	74.1	45.7	27.7	16.2

Typically minimum allowable live load is 20 psf.

Because unbalanced snow, live or wind loads must be considered allowable loads shall not be increased for the cantilevered ends unless a specific analysis is performed.

CHECK DEAD LOAD DEFLECTIONS

For 4' glass width and maximum allowable dead load deflection of L/360:

$$e/360 = \frac{D_c(1-0.22^2)9.2psf/12*e^4}{(10.4x10^6\ psi *0.345^3)}$$

Solving for e:

$e^3 = [(10.4x10^6\ psi *0.345^3)/(360D_c(1-0.22^2)9.2psf/12) = 1626.37/D_c$

solve for e by estimating D_c:

$D_c = 0.021$; $e = [1,626.37/0.021]^{1/3} = 42.625$"; b/2 = 42.625/48 = 0.888; $D_c = 0.0215$

$D_c = 0.0215$; $e = [1,626.37/0.0215]^{1/3} = 42.3$"; b/2 = 42.3/48 = 0.88 = 0.214

Longest recommended main span without cantilevers is 42.3"

For 2’ awning width with DuPont Sentry Glas Plus interlayer

$S = 2*0.483^2 = 0.4666\ in^3$

Allowable bending moment on glass is:

Wind: M_{al} = 9,600 psi*0.4666 in^3/ft = 4,479”#/ft = 373.26’#

Live: M_{al} = 4,550 psi*0.4666 in^3/ft = 2,123”#/ft = 176.91’#

Snow: M_{al} = 4,550 psi*0.4666 in^3/ft = 2,123”#/ft = 176.91’#

Dead: M_{al} = 3,300 psi*0.4666 in^3/ft = 1,540”#/ft = 128.31’#

For 3’ awning width with DuPont Sentry Glas Plus interlayer

Allowable uniform load may be calculated using:

$U = [(176.91/(C_e*e^2)]$

C_e taken from the figure for b/e

e (ft)	2.000	3.000	4.000	5.000	6.000	7.000
C_e	0.161	0.142	0.134	0.129	0.125	0.125
U psf	274.7	138.4	82.5	54.9	39.3	28.9
L or S psf	265.5	129.2	73.3	45.7	30.1	19.7
W psf	560.1	272.6	154.7	96.3	63.5	41.5

Typically minimum allowable live load is 20 psf.

Because unbalanced snow, live or wind loads must be considered allowable loads shall not be increased for the cantilevered ends unless a specific analysis is performed.

For 2’ glass width and maximum allowable dead load deflection of L/360:

$$e/360 = \frac{D_c(1-0.22^2)9.2psf/12*e^4}{(10.4x10^6\ psi\ *0.471^3)}$$

Solving for e:

$e^3 = [(10.4x10^6\ psi\ *0.471^3)/(360D_c(1-0.22^2)9.2psf/12) = 4,138.32/D_c$

solve for e by estimating D_c:

$D_c = 0.018$; $e = [4,138.32/0.018]^{1/3}$ = 61.26”; b/2 = 24/61.26 =0.392; $D_c = 0.013$

$D_c = 0.013$; $e = [4,138.32/0.013]^{1/3}$ = 68.28”; b/2 = 24/68.28 = 0.351; $D_c = 0.0129$

Longest recommended main span without cantilevers is 68.28”

For 3’ awning width with DuPont Sentry Glas Plus interlayer

$S = 2*0.491^2 = 0.482\ in^3$

Allowable bending moment on glass is:

Wind: M_{al} = 9,600 psi*0.482 in^3/ft = 4,629”#/ft = 385.7’#

Live: M_{al} = 4,550 psi*0.482 in^3/ft = 2,194”#/ft = 182.82’#

Snow: M_{al} = 4,550 psi*0.482 in^3/ft = 2,194”#/ft = 182.82’#

Dead: M_{al} = 3,300 psi*0.482 in^3/ft = 1,591”#/ft = 132.59’#

For 3’ awning width with DuPont Sentry Glas Plus interlayer

Allowable uniform load may be calculated using:

$U = [(182.82/(C_e*e^2)]$

C_e taken from the figure for b/e

e (ft)	2.000	3.000	4.000	5.000	6.000	7.000
C_e	0.165	0.161	0.147	0.138	0.134	0.130
U psf	277.0	126.2	77.7	53.0	37.9	28.7
L or S psf	267.8	117.0	68.5	43.8	28.7	19.5
W psf	565.0	246.8	144.6	92.4	60.5	41.1

Typically minimum allowable live load is 20 psf.

Because unbalanced snow, live or wind loads must be considered allowable loads shall not be increased for the cantilevered ends unless a specific analysis is performed.

CHECK DEAD LOAD DEFLECTIONS

For 3’ glass width and maximum allowable dead load deflection of L/360:

$$e/360 = \frac{D_c(1-0.22^2)9.2psf/12*e^4}{(10.4x10^6\ psi\ *0.485^3)}$$

Solving for e:

$e^3 = [(10.4x10^6\ psi\ *0.485^3)/(360D_c(1-0.22^2)9.2psf/12) = 4{,}518.42/D_c$

solve for e by estimating D_c:

$D_c = 0.016$; $e = [4{,}518.42/0.016]^{1/3} = 65.61$”; b/2 = 36/65.61 = 0.55; $D_c = 0.0143$

$D_c = 0.0143$; $e = [4{,}518.42/0.0143]^{1/3} = 68.11$”; b/2 = 36/68.11 = 0.53

Longest recommended main span without cantilevers is 68.11”

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For 4' awning width with DuPont Sentry Glas Plus interlayer

$S = 2*0.494^2 = 0.4881\ in^3$

Allowable bending moment on glass is:

Wind: M_{al} = 9,600 psi*0.4881 in^3/ft = 4,685"#/ft = 390.46'#

Live: M_{al} = 4,550 psi*0.4881 in^3/ft = 2,221"#/ft = 185.06'#

Snow: M_{al} = 4,550 psi*0.4881 in^3/ft = 2,221"#/ft = 185.06'#

Dead: M_{al} = 3,300 psi*0.4881 in^3/ft = 1,611"#/ft = 134.23'#

For 4' awning width with DuPont Sentry Glas Plus interlayer

Allowable uniform load may be calculated using:

$U = [(185.06/(C_e*e^2)]$

C_e taken from the figure for b/e

e (ft)	2.000	3.000	4.000	5.000	6.000	7.000
C_e	0.134	0.165	0.161	0.148	0.142	0.138
U psf	153.4	124.6	71.8	50.0	36.2	27.4
L or S psf	144.2	115.4	62.6	40.8	27.0	18.2
W psf	304.3	243.5	132.2	86.1	57.0	38.3

Typically minimum allowable live load is 20 psf.

Because unbalanced snow, live or wind loads must be considered allowable loads shall not be increased for the cantilevered ends unless a specific analysis is performed.

CHECK DEAD LOAD DEFLECTIONS

For 4' glass width and maximum allowable dead load deflection of L/360:

$$e/360 = \frac{D_c(1-0.22^2)9.2psf/12*e^4}{(10.4x10^6\ psi\ *0.490^3)}$$

Solving for e:

$e^3 = [(10.4x10^6\ psi\ *0.490^3)/(360D_c(1-0.22^2)9.2psf/12) = 4,659.61/D_c$

solve for e by estimating D_c:

$D_c = 0.016$; $e = [4,659.61/0.016]^{1/3} = 66.28$"; b/2 = 48/66.28 = 0.72; $D_c = 0.016$

Longest recommended main span without cantilevers is 66.28"

Summary:
Allowable load on the awning is based on the minimum load from the applicable tables for the glass and for the mounting method:

Maximum Load on Rod Table 1			
	35°	**45°**	**55°**
H ≤	1,245#	1,245#	1,600#
Y ≤	872#	1,245#	1,120#
T ≤	1,520#	1,761#	1,953#

H = horizontal load, Y = vertical load and T = total axial load

Allowable Load On Awning Table 2				
	24”	**36”**	**42”**	**48”**
Downward	1,297#/L	973#/L	854#/L	760#/L
Wind Uplift	439#/L	329#/L	195#/L	120#/L

GAS90 Brackets- Anchorage to CMU Table 2a			
24”	**36”**	**42”**	**48”**
830#/L	623#/L	545#/L	484#/L

GAS90 Brackets- Mounted to Wood Table 2b			
	35°	**45°**	**55°**
24”	768#/L	1,091#/L	1,491#/L
36”	535#/L	760#/L	1,039#/L
42”	470#/L	668#/L	913#/L
48”	418#/L	594#/L	812#/L

GAS190 Brackets to Steel, Concrete or CMU Table 2c			
	35˚	**45˚**	**55˚**
24”	325#/L	465#/L	664#/L
36”	244#/L	349#/L	498#/L
42”	214#/L	307#/L	438#/L
48”	191#/L	273#/L	389#/L

GAS190 Brackets- Anchorage to Wood Table 2d			
	35˚	**45˚**	**55˚**
24”		332#/L	
36”		249#/L	
42”		219#/L	
48”		195#/L	

DESIGN EXAMPLE

Determine maximum allowable loads on awning - 36” wide x 8’ long with 6’ main span mounted with two GAS90 brackets to wood beam.

L = 8’, d = 1’, e = 6’ - With Sentry Glas Plus (SGP) interlayer:

From page 24:

U’ = 39.3 psf, L = or S = 30.1 psf, W = 63.5 psf and 0.75S/30.1 + 0.75W/63.5 ≤ 1.0

From Table 2b on page 26 for 45˚ mounting rod angle:

U = 760/8 = 95 psf > 39.3 psf and 63.5 psf

Glass strength controls.

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