FAX 412-681-6840

Blumcraft OF PITTSBURGH
460 MELWOOD STREET, PITTSBURGH, PENNSYLVANIA 15213 • TELEPHONE: (AREA CODE 412) 681-2400

PHYSICAL TEST REPORTS

BLUMCRAFT TEMPERED GLASS RAILING SYSTEMS

Please find attached results for physical tests and design calculations for Blumcraft all glass railings without posts.

Attachment 1 gives the results of physical tests for lateral loading conditions.

Attachment 2 gives the results of physical tests for combined lateral and vertical loading conditions.

Attachment 3 gives the results of design calculations for the Blumcraft glass railing system for 1/2" and 3/4" thick glass railings with fully tempered glass.

Attachments:

1) Test results for horizontal loading of 1/2" thick glass rail.
2) Test results for combined horizontal and vertical loading of 1/2" and 3/4" thick glass rail.
3) Design calculations for Blumcraft glass railing system (1/2" thick and 3/4" thick glass)

ATTACHMENT 1

TEST RESULTS FOR HORIZONTAL LOADING OF

1/2" THICK GLASS RAIL

PITTSBURGH TESTING LABORATORY

ESTABLISHED 1881

PITTSBURGH, PA.

LABORATORY NO. 655715

Corrected 6/1/67

May 27, 1967

ORDER NO. PG-19491

CLIENT'S NO.

REPORT

Report of: Tests of Tempered Rail Glass, RG-200

Report to: Blumcraft of Pittsburgh
460 Melwood Avenue
Pittsburgh, Pennsylvania 15218

Mr. W. J. Horgan delivered to our laboratory five (5) glass panels, 1' wide and 4' high, for load deflection tests.

The panels were tested while vertical in a floor mount submitted by Mr. Horgan. The loads were applied at heights of 30", 36", 43-7/16" and 47-7/16". At each height the following loads were applied: 20, 35, 50, 75 and 100 pounds per linear foot.

Sample #1 was tested to failure and Sample #2 was tested with strain gages. Gages #1 and #2 were mounted 3/4" above the floor mount. Gages #3 and #4 were mounted 24" above the floor mount. Gages #5 and #6 were mounted 1" below the bottom of the handrail. Gages #1, #3 and #5 were mounted on one side of the glass. Gages #2, #4 and #6 were mounted directly opposite on the other side of the glass.

The following data was recorded.

		Height			
		30"	36"	43-7/16"	47-7/16"
Sample Identification	Load	Deflection			
Glass I	20	.279	.317	.550	.700
	35	.322	.560	.992	1.250
	50	.461	.813	1.440	1.720
	75	.717	1.182	2.160	2.610
	100	1.098	1.685	2.915	3.650
	120	-	-	-	4.480
	140	-	-	-	4.890
	160	-	-	-	6.210
	180	-	-	-	6.800
	200	-	-	-	7.400
	220	-	Glass broken		10.200

PITTSBURGH TESTING LABORATORY
ESTABLISHED 1881
PITTSBURGH, PA.

LABORATORY NO. 655715

Corrected 6/1/67 May 27, 1967 ORDER NO. PG-19491

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Sample Identification	Load	Height 30" Deflection	36"	43-7/16"	47-7/16"
Glass II	20	.170	.310	.540	.680
	35	.340	.570	1.000	1.220
	50	.500	.830	1.420	1.750
	75	.770	1.260	2.150	2.480
	100	1.050	1.700	2.300	3.490
Glass III	20	.170	.350	.600	.700
	35	.330	.620	1.070	1.200
	50	.500	.900	1.520	1.750
	75	.780	1.350	2.300	2.670
	100	1.090	1.820	3.100	3.600
Glass IV	20	.175	.370	.475	
	35	.320	.620	.820	
	50	.480	.900	1.200	
	75	.760	1.370	1.800	
	100	1.080	1.850	2.400	
Glass V	20	.200	.370	.450	
	35	.330	.620	.800	
	50	.510	.900	1.200	
	75	.800	1.350	1.820	
	100	1.075	1.820	2.450	

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PITTSBURGH, PA.

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REPORT

GLASS TEST #2

Load	Strain Gage No.	Strain in Micro-Inches L=30"	L=36"	L=43-7/16"	L=47-7/16"
P-20	1	+ 110	+ 130	+ 160	+ 180
	2	- 105	- 135	- 160	- 175
	3	+ 25	+ 55	+ 85	+ 100
	4	- 35	- 55	- 85	- 100
	5	- 10	-	-	+ 10
	6	- 10	-	-	- 10
P-35	1	+ 190	+ 230	+ 285	+ 310
	2	- 190	- 235	- 280	- 310
	3	+ 50	+ 95	+ 135	+ 175
	4	- 45	- 95	- 150	- 180
	5	- 15	-	-	+ 15
	6	- 10	-	-	- 10
P-50	1	+ 275	+ 330	+ 405	+ 455
	2	- 275	- 340	- 410	- 440
	3	+ 70	+ 135	+ 210	+ 255
	4	- 75	- 135	- 215	- 250
	5	- 20	-	-	+ 20
	6	- 15	-	-	- 15
P-75	1	+ 400	+ 510	+ 620	+ 685
	2	- 400	- 515	- 620	- 670
	3	+ 100	+ 205	+ 305	+ 370
	4	- 100	- 205	- 320	- 375
	5	- 15	-	-	+ 25
	6	- 15	-	-	- 25
P-100	1	+ 550	+ 680	+ 830	+ 915
	2	- 560	- 685	- 830	- 905
	3	+ 140	+ 260	+ 405	+ 485
	4	- 145	- 270	- 420	- 490
	5	- 15	-	-	+ 35
	6	- 15	-	-	- 30

\+ = Tension
\- = Compression

PITTSBURGH TESTING LABORATORY

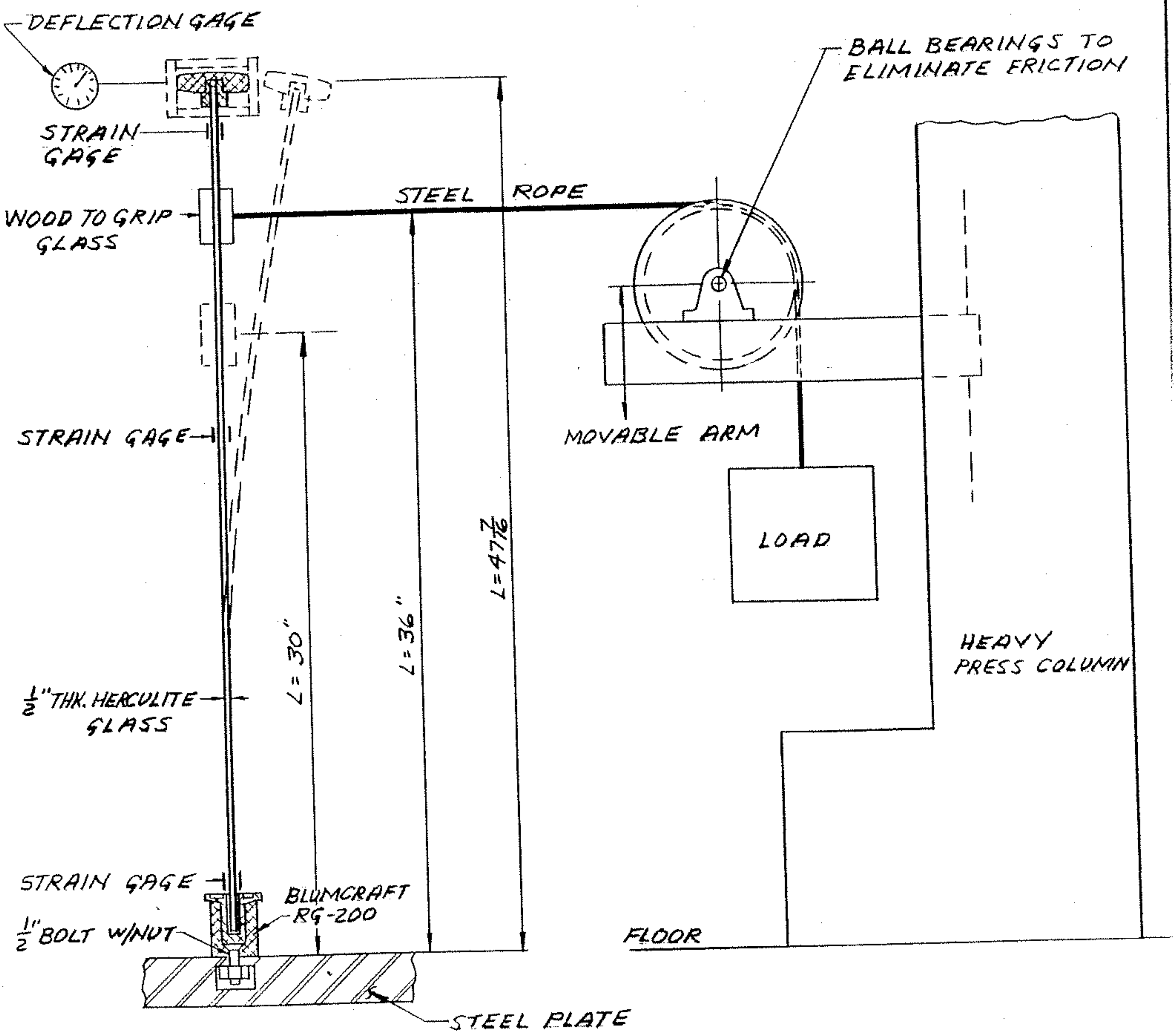
Earl Gallagher

Earl Gallagher, Manager
Physical Testing Department

The maximum recommended working temperature is 550^0 F.

Herculite is, of course, incombustible but it is not considered and effective fire barrier and has no Underwriter's rating.

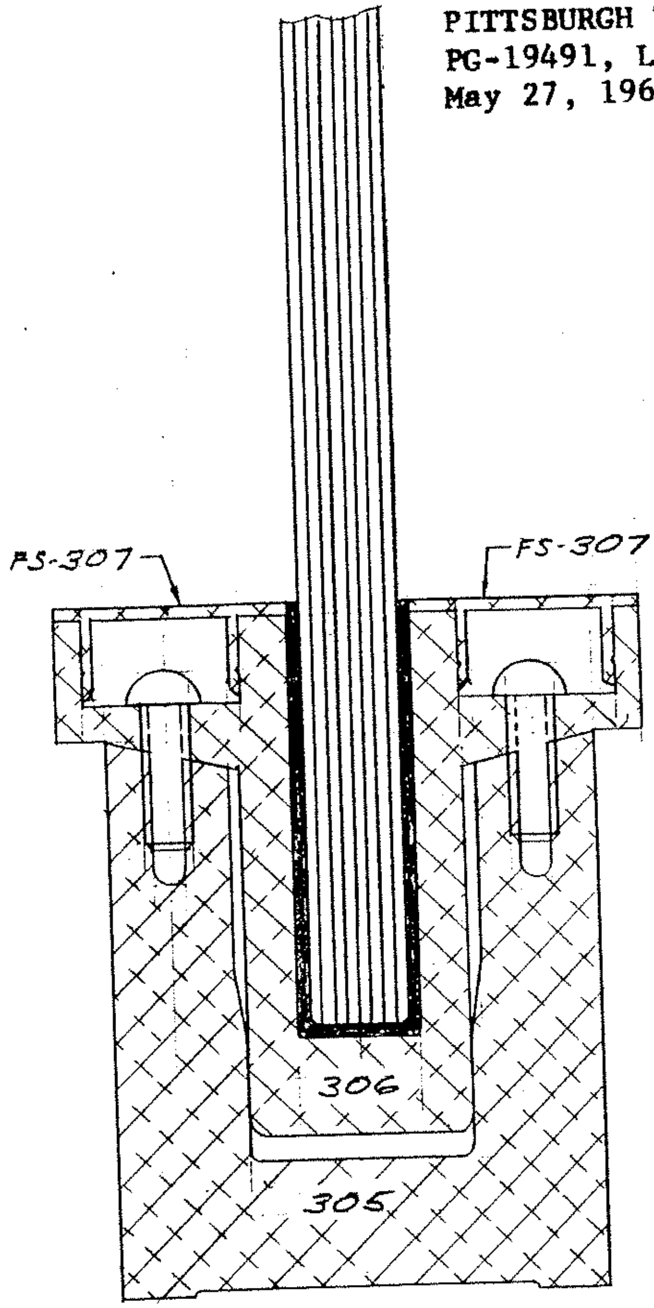
For a Herculite supported railing, with load applied horizontally at the railing top, the average load per lineal foot of Herculite required to cause breakage = 48,000t2/H where t = thickness of Herculite in inches and H = height of rail above bottom glass clamp. Thus for a 36" high railing, the average breaking load would be about 330 pounds per lineal foot.



LOAD TEST EQUIPMENT FOR RAILGLASS

PITTSBURGH TESTING LABORATORY
PG-19491, Lab. No. 655715
May 27, 1967

Earl Gallagher, Manager
Physical Testing Depart.



BLUMCRAFT
RG-200 ALUMINUM BASE
FULL SIZE

ATTACHMENT 2

TEST RESULTS FOR COMBINED

HORIZONTAL AND VERTICAL

LOADING OF 1/2" THICK GLASS

RAIL

NOTE: THIS LABORATORY TEST REPORT AND CALCULATIONS HAVE BEEN CHECKED AND VERIFIED BY REGISTERED ENGINEERS IN THE STATES OF NEW YORK AND CALIFORNIA. REFER TO PAGE 8.

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PITTSBURGH TESTING LABORATORY

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850 POPLAR STREET, PITTSBURGH, PA. 15220

PLEASE REPLY TO:
P. O. BOX 1646
PITTSBURGH, PA. 1523[illegible]

AREA CODE 412 TELEPHONE 922-4000

CLIENT'S No.

LABORATORY No. 735160
ORDER No. PG-19491
Date: 3-7-73

REPORT

Report of : Tests of 1/2" Thick Tempered Glass Rail, RG-200

Report to : Blumcraft of Pittsburgh
460 Melwood Avenue
Pittsburgh, Pennsylvania

Two (2) glass panels, one foot (1') wide by four feet (4') high, were tested at Blumcraft of Pittsburgh under the supervision of PITTSBURGH TESTING LABORATORY Personnel Mr. Jay Prestera and Mr. Frank Pit.

The panels were tested while in vertical position simulating actual use condition. Loads were applied simultaneously in vertical (lateral) and horizontal directions in three (3) load stages. These stages, design load, 150% of design load, and 250% of design load were preceded and followed by periods of zero load at which readings were also taken.

Twelve (12) strain gages were placed as shown on enclosure #1 on each panel. Mounting and reading of gages was performed by PITTSBURGH TESTING LABORATORY personnel.

A dial indicator was placed at top to measure deflection of rail.

Loads were applied by means of weights suspended on supports. (See enclosure #2)

THIS LABORATORY TEST REPORT AND CALCULATIONS HAVE BEEN CHECKED AND VERIFIED BY REGISTERED ENGINEERS IN THE STATES OF NEW YORK AND CALIFORNIA. REFER TO PAGE 8.

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CLIENT'S No.

REPORT

LABORATORY No. 735160

ORDER No. PG-19491

Date: 3-7-73

TESTING PROCEDURE:

Design Load:	50 PLF Lateral Load 100 PLF Vertical Load
150% of Design Load:	75 PLF Lateral Load 150 PLF Vertical Load
250% of Design Load:	125 PLF Lateral Load 250 PLF Vertical Load

Step #1 - Take readings at zero load
#2 - Take readings at design load
#3 - Take readings at zero load
#4 - Take readings at 150% design load
#5 - Take readings at zero load
#6 - Take readings at 250% design load
#7 - Take readings at zero load

The following data was recorded for the two panels:

DEFLECTION READINGS:

	Panel No. 1	Panel No. 2
Zero Load	0.000 In.	0.000 In.
Design Load	1.295	1.775
Zero Load	0.018	0.011
150% Design Load	2.280	2.756
Zero Load	0.025	0.013
250% Design Load	4.116	4.862
Zero Load	0.032	0.031

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LABORATORY No. 735160

CLIENT'S No.

ORDER No. PG-19491

REPORT

Date: 3-7-73

STRAIN GAGE READINGS: (In Micro-Inches)

Panel No. 1

Step No.	1	2	3	4	5	6	7
Gage No. 1	0	+20	+5	+65	-5	+145	+25
2	0	+205	+5	+365	+5	+675	+25
3	0	+210	+10	+370	0	+670	+20
4	0	+390	0	+635	0	+1110	+20
5	0	+375	+5	+620	+5	+1125	+5
6	0	+370	0	+650	0	+1140	0
7	0	-20	0	-60	0	-90	+10
8	0	-205	-5	-365	+5	+175	+25
9	0	Gage not operating					
10	0	-350	0	-600	0	-1040	+40
11	0	-365	-5	-635	-5	-1125	-35
12	0	-360	-10	-610	0	-1050	+30

\+ Tension
\- Compression

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CLIENT'S No.

LABORATORY No. 735160

ORDER No. PG-19491

Date: 3-7-73

REPORT

STRAIN GAGE READINGS: (In Micro-Inches)

Panel No. 2

Step No.	1	2	3	4	5	6	7
Gage No. 1	0	+60	+10	+90	0	+140	0
2	0	+270	0	+410	0	+710	0
3	0	+270	0	+400	0	+710	0
4	0	+540	+40	+810	+50	+250	-900
5	0	+380	0	+640	-10	+1190	-10
6	0	+220	-490	-10	-660	+140	-860
7	0	-60	0	-90	0	-150	0
8	0	-280	0	-430	0	-750	0
9	0	-320	0	-470	0	-790	0
10	0	-560	-80	-840	-100	-1490	-100
11	0	-460	-10	-690	-10	-1230	-10
12	0	-440	+40	-690	+60	-1120	+60

+ Tension
- Compression

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REPORT

LABORATORY No. 735160

ORDER No. PG-19491

Date: 3-7-73

TESTED STRESS VALUES: (At position 1 inch above base)

	Panel No. 1	Panel No. 2
Zero Load	0 psi	0 psi
Design Load	3970 psi	3990 psi
Zero Load	0 psi	0 psi
150% Design Load	6668 psi	7770 psi
Zero Load	0 psi	0 psi
250% Design Load	11812 psi	11728 psi
Zero Load	0 psi	0 psi

Following all tests there were no cracks, strain indications or other visible signs of failure.

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ORDER No. PG-19491

Date: 3-7-73

REPORT

CALCULATED DATED:

Subject: Strength and deflection calculations for Blumcraft RG-200 ½-inch thick tempered glass rail.

Reference: 1) New York Building Laws - 1972 Manual, Volume 2

2) PPG Industries TSR-101, "Structural Handbook for Glass."

1. DESCRIPTION OF RAIL SYSTEM

The Blumcraft RG-200 Railing System consists of a ½-inch thick tempered glass panel, with the bottom edge cemented in an aluminum channel. The channel is bolted directly into the building structure with ½-inch bolts 12" on center. The hand rail assembly is bonded and mechanically connected to the top edge of the glass. The loads applied to the handrail are carried by the glass panel acting as a cantelever beam with its lower edge fixed in the channel, which is also fixed by the anchor bolts.

2. REQUIRED DESIGN LOADS, TEST LOADS AND DEFLECTION RECOVERY

The following loads are specified in Reference (1); Paragraphs C26-902.3 (b) and C26-1002.4 (a) and (b):

Load on Rail	Design* Load (plf)	Test Loads w/o damage (plf)	Test Loads w/o collapse (plf)
Lateral	50	75	125
Vertical	100	150	250

* These are the design live loads specified for railings. There are no dead loads acting on the rail system.

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Date: 3-7-73

REPORT

Deflection: Reference (1), Par. C26-1002.4 (c) states that after application of 150 percent of the design load, recovery from deflection shall be at least 75 percent of the deflection at load.

3. CALCULATION OF GLASS STRESSES AND RAIL DEFLECTION

A 12-inch long section of the fail will be tested, and for convenience, these calculations will be based on a 12-inch length.

Section properties of glass (12" wide, ½" thick):

$$I = \frac{bt^3}{12} = \frac{(12)(0.5)^3}{12} = 0.125 \text{ in.}^4$$

$$\text{Section modulus} = I/_{t/2} = \frac{0.125}{.25} = 0.50 \text{ In.}^3$$

a. Moments due to lateral load only:

Pl = lateral load = 50 lb/ft. x 1 ft. = 50 lb. (desig
Pl x 150 percent = 75 lb.
Pl x 250 percent = 125 lb.
H = 48.75"
h = 48.75 - 3.375 + 45.375"
Ml = Pl x h = 50 x 45.375 = 2269 lb-inches
Ml x 150 percent = 3403 " "
Ml x 250 percent = 5672 " "

b. Deflection due to lateral load:

$$D = \frac{Pl^3}{3EI} \; ; \; \frac{l^3}{3EI} = \frac{48.75^3}{3(10^7)(.125)} = 3.0895 \times 10^{-2} = .0309$$

D = .0309 x 50 = 1.55" for design load
= .0309 x 75 = 2.32" for 150 percent design load
= .0309 x 125 = 3.86" for 250 percent design load

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ORDER No. PG-19491
Date: 3-7-73

REPORT

c. Additional moment about base of glass due to vertical load:

$M_v + P_v$ x deflection = 100 x 1.55 = 155 lb-inch for design load

= 150 x 2.32 = 348 lb-inch for 150 percent test load

= 250 x 3.86 = 965 lb-inch for 250 percent test load

d. Total moment and bending stress at base of glass:

Load Condition	Ml	M_v	Total M	Stress
Design Load	2269	155	2424	4848 psi
150% Design Load	3403	348	3751	7502 psi
250% Design Load	5672	965	6637	13274 psi

PITTSBURGH TESTING LABORATORY

Jay Prestera
Staff Engineer

M. Y. Ruyan
Vice President
New York P.E. #046421

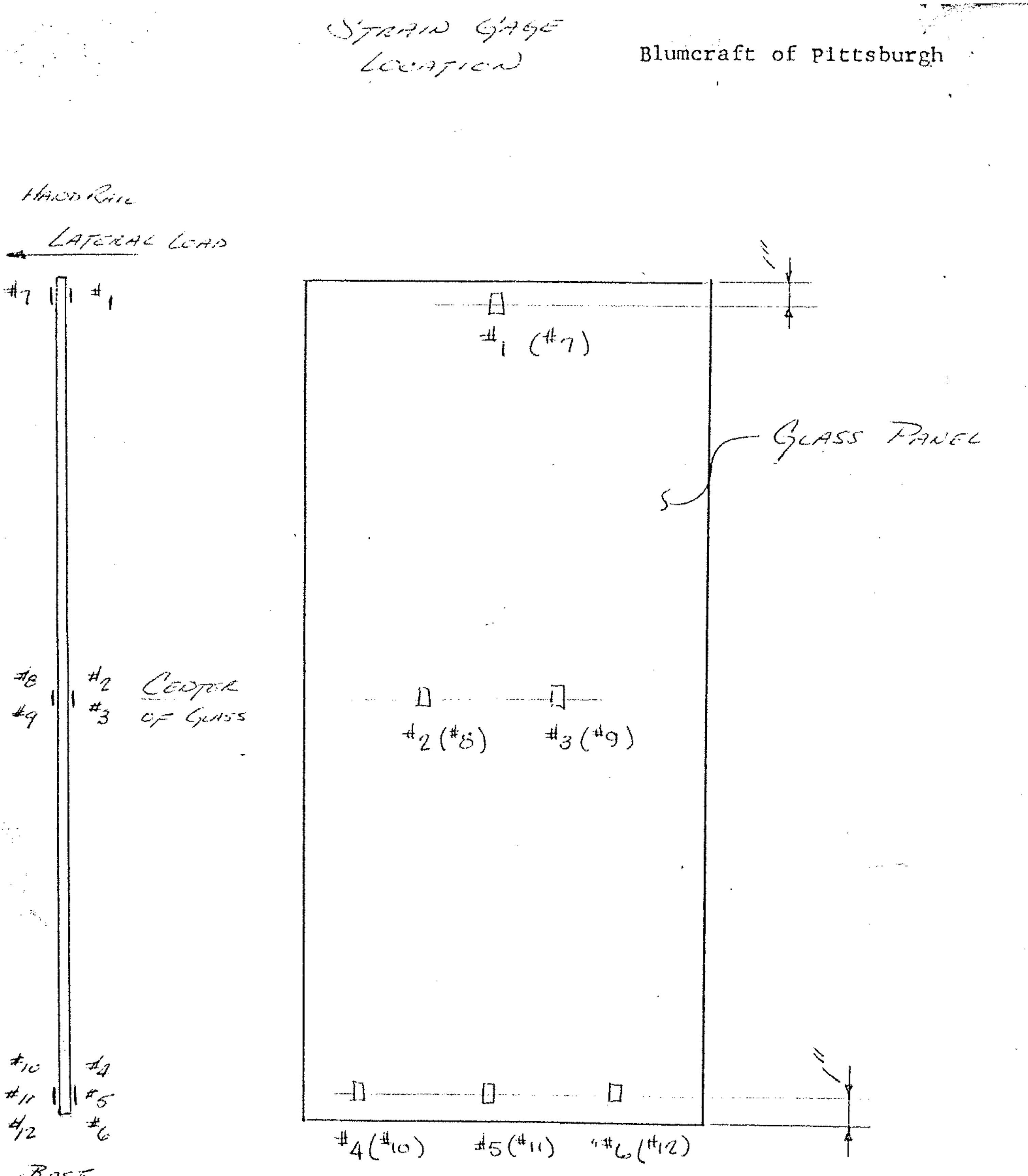
Checked and Verified Calculations on 4/25/73.

Edward J. Cockerill
Civil Engineer, P.E.
Assistant District Manager
San Francisco District Office

REGISTERED PROFESSIONAL ENGINEER EDWARD J. COCKERILL No. 20580 CIVIL STATE OF CALIFORNIA

cc: 3-Client

Blumcraft of Pittsburgh



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PG-19491 Lab No. 735160

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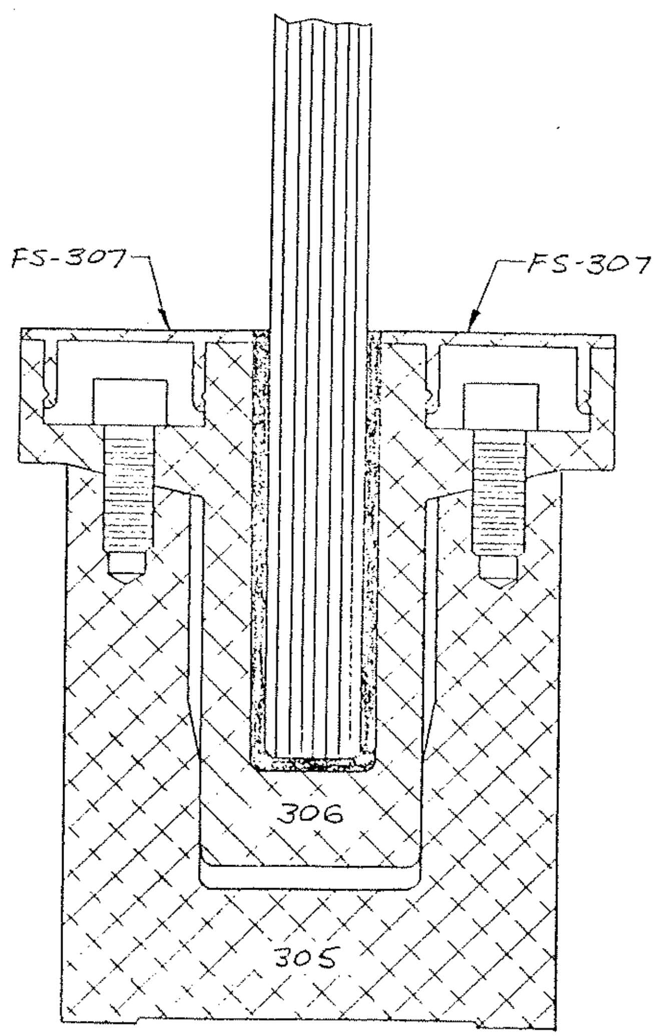


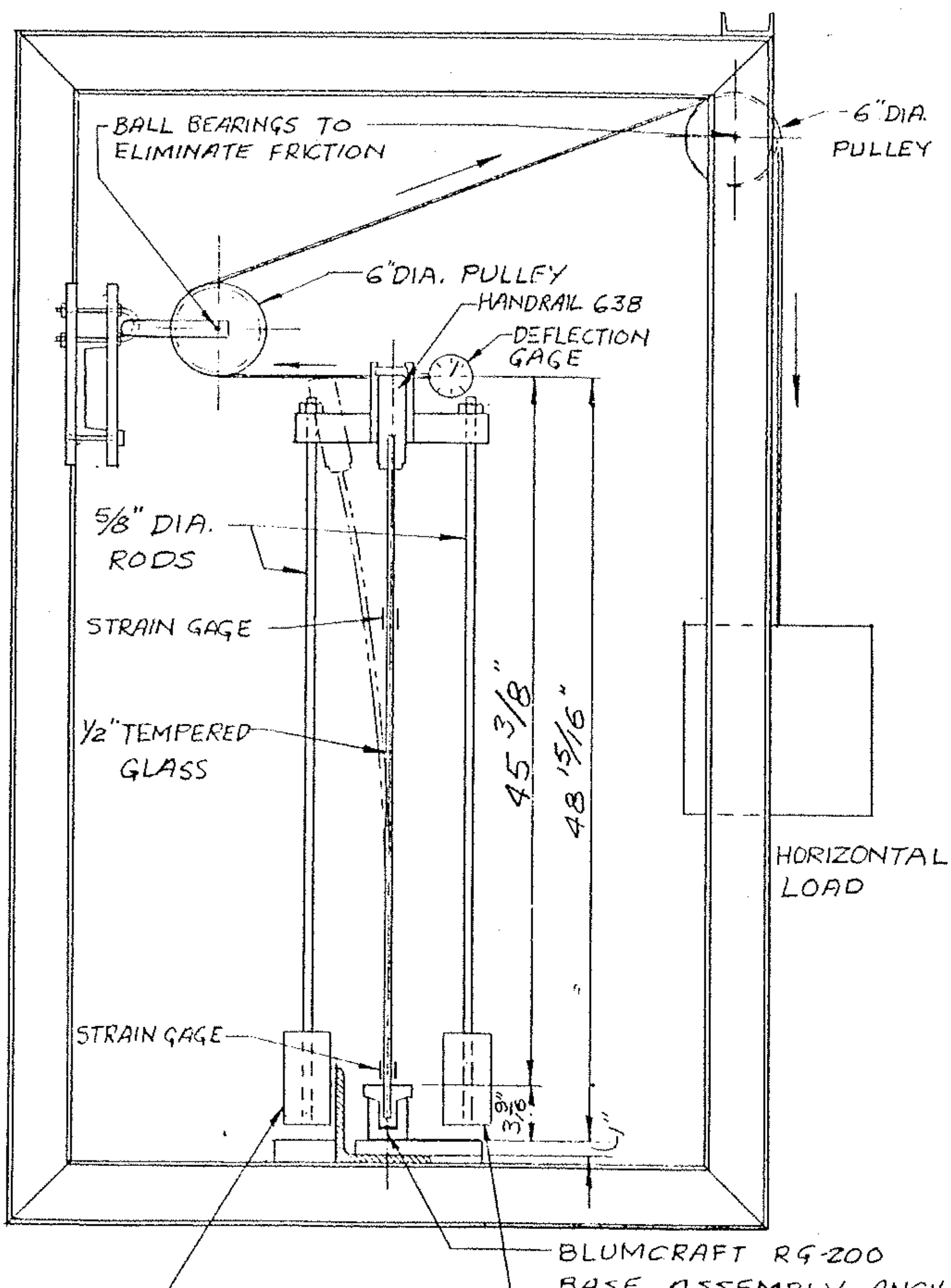
Pittsburgh Testing Laboratory Lab No.

BLUMCRAFT Pg-19491 735160

RG-200 ALUMINUM BASE

FULL SIZE

TEST RACK FRAME



ATTACHMENT 3

DESIGN CALCULATIONS FOR BLUMCRAFT GLASS RAILING SYSTEM

(1/2" THICK AND 3/4" THICK GLASS)

Blumcraft OF PITTSBURGH

CALCULATIONS OF GLASS STRESSES AND DEFLECTION

For all types of free-standing tempered glass railings without posts*
(1/2" and 3/4" thick glass)

Design loads are 50#/ft. lateral loads and 100#/ft. vertical loading.

Stresses and deflections will be based on a 42 in. high glass rail, cantilevered about the base. No credit will be taken for the added stiffness of the base.

Rail stresses and deflections are calculated for combined lateral and vertical loading for 100%, 150% and 250% of design loads. In addition, calculations are furnished for maximum lateral loading for maximum glass stress of 17000 psi.

I. SECTION PROPERTIES

Minimum glass thickness is 1/32" below nominal

t = .469 in. For 1/2" glass
= .719 in. For 3/4" glass

$$I = bt^3/12 = (12\ \text{in./ft.})\frac{(.469\ \text{in.})^3}{12} = .1032\ \text{in}^4/\text{ft.} \qquad \text{for 1/2" glass}$$

$$= (12\ \text{in./ft.})\frac{(.719\ \text{in.})^3}{12} = .3717\ \text{in}^4/\text{ft.} \qquad \text{for 3/4" glass}$$

$$Z = \frac{bt^2}{6} = (12\ \text{in./ft.})\frac{(.469\ \text{in})^2}{6} = .4399\ \text{in}^3/\text{ft.} \qquad \text{for 1/2" glass}$$

$$= (12\ \text{in.ft.})\frac{(.719\ \text{in})^2}{6} = 1.034\ \text{in}^3/\text{ft.} \qquad \text{for 3/4" glass}$$

II. LATERAL LOADING

Design load = 50#/ft.
150% design load = 75#/ft.
250% design load = 125#/ft.

Moments due to lateral loads

M = Fl = (50#/ft.)(42 in.) = 2100 in-#/ft. Design load
= (75#/ft.)(42 in.) = 3150 in-#/ft. 150% design load
= (125#/ft)(42 in.) = 5250 in-#/ft. 250% design load

Stresses due to lateral loads - 1/2" glass

σ = M/Z = (2100 in-#/ft./(.4399 in^3/ft.) = 4774 psi design load
= (3150 in-#/ft)/(.4399 in^3/ft.) = 7161 psi 150% design load
= (5250 in-#/ft)/(.4399 in^3/ft.) = 11,934 psi 250% design load

*These types include Blumcraft numbers RG-100, RG-100S, RG-200 and RG-450 for 1/2" thick tempered glass and Blumcraft numbers RG-100, RG-175S, RG-500 and RG-650 for 3/4" thick tempered glass.

II)Continued

Stresses due to lateral loads - 3/4" glass

σ = M/Z = (2100 in-#/ft)/(1.034 in^3/ft) = 2031 psi design load
= (3150 in-#/ft)/(1.034 in^3/ft) = 3046 psi 150% design load
= (5250 in-#/ft)/(1.034 in^3/ft) = 5077 psi 250% design load

Deflections due to lateral loads - 1/2" glass

$$\Delta = \frac{Fl^3}{3\ EI} = \frac{F(42\ in)^3}{3(10.6\times 10^6\ \#/in^2)(.1032\ in^4/ft)} = \quad = F\,\frac{(.02258\ in\text{-}ft)}{\#}$$

$= (50\#/ft)(.02258\ \frac{in\text{-}ft}{\#}) = 1.129$ in. design load

$= (75\#/ft)(.02258\ \frac{in\text{-}ft}{\#}) = 1.694$ in. 150% design load

$= (125\#/ft)(.02258\ \frac{in\text{-}ft}{\#}) = 2.823$ in. 250% design load

Deflections due to lateral loads - 3/4" glass

$$\Delta = \frac{Fl^3}{3\ EI} = \frac{F(42\ in)^3}{3(10.6\times 10^6\ \#/in^2)(3717\ in\#/ft)} = F(.006268\ in\text{-}ft/\#)$$

= (50#/ft)(.006268 in-ft/#) = .313 in. design load
= (74#/ft)(.006268 in-ft/#) = .470 in. 150% design load
= (125#/ft)(.006268 in-ft/#) = .784 in. 250% design load

III) VERTICAL LOADING

The vertical load is assumed to cause a moment due to being applied to the laterally-deflected handrail. Since glass fails due to tensile stress and the vertical loads cause compressive stresses at the base, the compressive loads can be neglected.

Design load = 100#/ft
150% design load = 150#/ft
250% design load = 250#/ft

Moments due to vertical loads - 1/2" glass

$M = F\Delta$ = (100 #/ft)(1.129 in) = 112.9 in-#/ft design load
= (150#/ft)(1.694 in) = 254.1 in-#/ft 150% design load
= (250#/ft)(2.823 in) = 705.8 in-#/ft 250% design load

III) Continued

Moments due to vertical loads - 3/4" glass

$M = F\Delta$ = (100#/ft)(.313 in) = 31.3 in#/ft — design load
= (150#/ft)(.470 in) = 70.5 in#/ft — 150% design load
= (250#/ft)(.784 in) = 196 in#/ft — 250% design load

Stresses due to vertical bending moments - 1/2" glass

$\sigma = M/Z$ = (112.9 in#/ft)/(.4399 in^3/ft) = 257 psi — design load
= (254.1 in#/ft)/(.4399 in^3/ft) = 578 psi — 150% design load
= (705.8 in#/ft)/(.4399 in^3/ft) = 1604 psi — 250% design load

Stresses due to vertical bending moments - 3/4" glass

$\sigma = M/Z$ = (31.3 in#/ft)/(1.034 in^3/ft) = 30 psi — design load
= (70.5 in#/ft)/(1.034 in^3/ft) = 68 psi — 150% design load
= (196 in#/ft)/(1.034 in^3/ft) = 190 psi — 250% design load

Additional deflections due to vertical loads - 1/2" glass

$$\Delta = \frac{Ml^2}{2\,EI} = \frac{M(42\text{ in})^2}{2(10.6 \times 10^6\ \#/in^2)(.1032\ in^4/ft)} = M\ (.0008063\ ft/\#)$$

= (112.9 in#/ft)(.0008063 ft/#) = .091 in. design load
= (254.1 in#/ft)(.0008063 ft/#) = .205 in. 150% design load
= (705.8 in#/ft)(.0008063 ft/#) = .569 in. 250% design load

Additional deflections due to vertical loads - 3/4" glass

$$\Delta = \frac{Ml^2}{2EI} = \frac{M\ (42\text{ in})^2}{2(10.6 \times 10^6\ \#/in^2)(.3717\ in^4/ft)} = M(.0002239\ ft/\#)$$

= (31.3 in-#/ft)(.0002239 ft/#) = .007 in.
= (70.5 in-#/ft)(.0002239 ft/#) = .016 in.
= (196 in-#/ft)(.0002239 ft/#) = .044 in.

IV) Combined stresses and deflections

1/2" Glass

Stresses	Deflections	
4774 + 257 = 5031 psi	1.129 + .091 = 1.220 in.	design load
7161 + 578 = 7739 psi	1.694 + .205 = 1.899 in.	150% design load
11934 + 1604 = 13538 psi	2.823 + .569 = 3.392 in.	250% design load

IV) Continued

3/4" Glass

Stresses	Deflections	
2031 + 30 = 2061 psi	.313 in + .007 in = .320 in.	design load
3046 + 68 = 3114 psi	.470 in + .016 in = .486 in.	150% design load
5077 + 190 = 5267 psi	.784 in + .044 in = .828 in.	250% design load

V) MAXIMUM LATERAL LOADING FOR ALLOWABLE STRESS OF 17000 PSI

$\sigma/N = M/Z = Fl/Z \quad F = \dfrac{\sigma Z}{lN}$

For $\sigma = 17000\ \#/in^2$, $l = 42$ in.

1/2" Glass $F = \dfrac{(17000\ \#/in^2)(.4399\ in^3/ft)}{(42\ in)(1.0\ \text{safety factor})}$ = 178 #/ft no safety factor

= 119 #/ft 1.5 safety factor

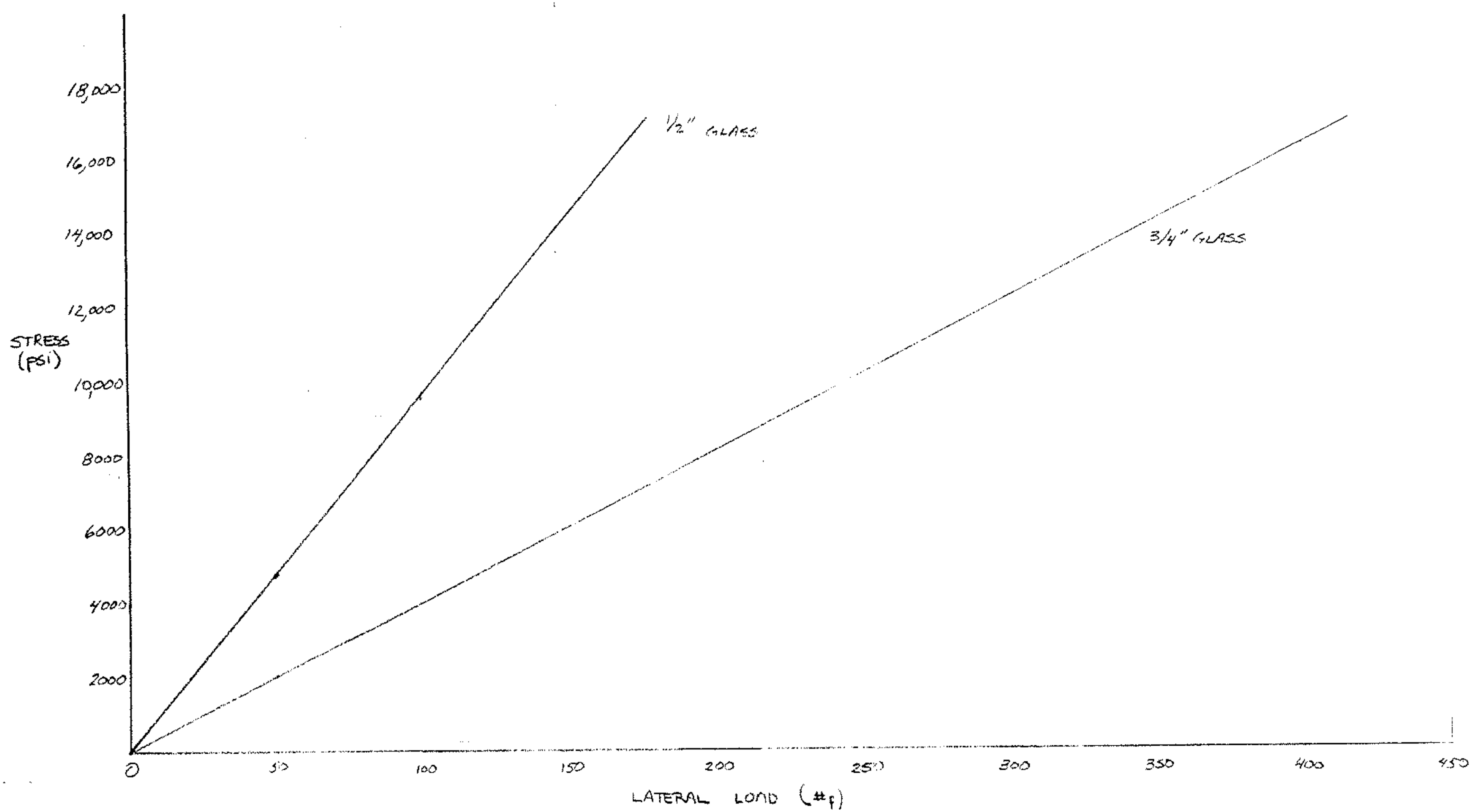
= 71 #/ft 2.5 safety factor

3/4" Glass $F = \dfrac{(17000\#/in^2)(1.034\ in^3/ft)}{(42\ in)(1.0\ \text{safety factor})}$ = 419 #/ft no safety factor

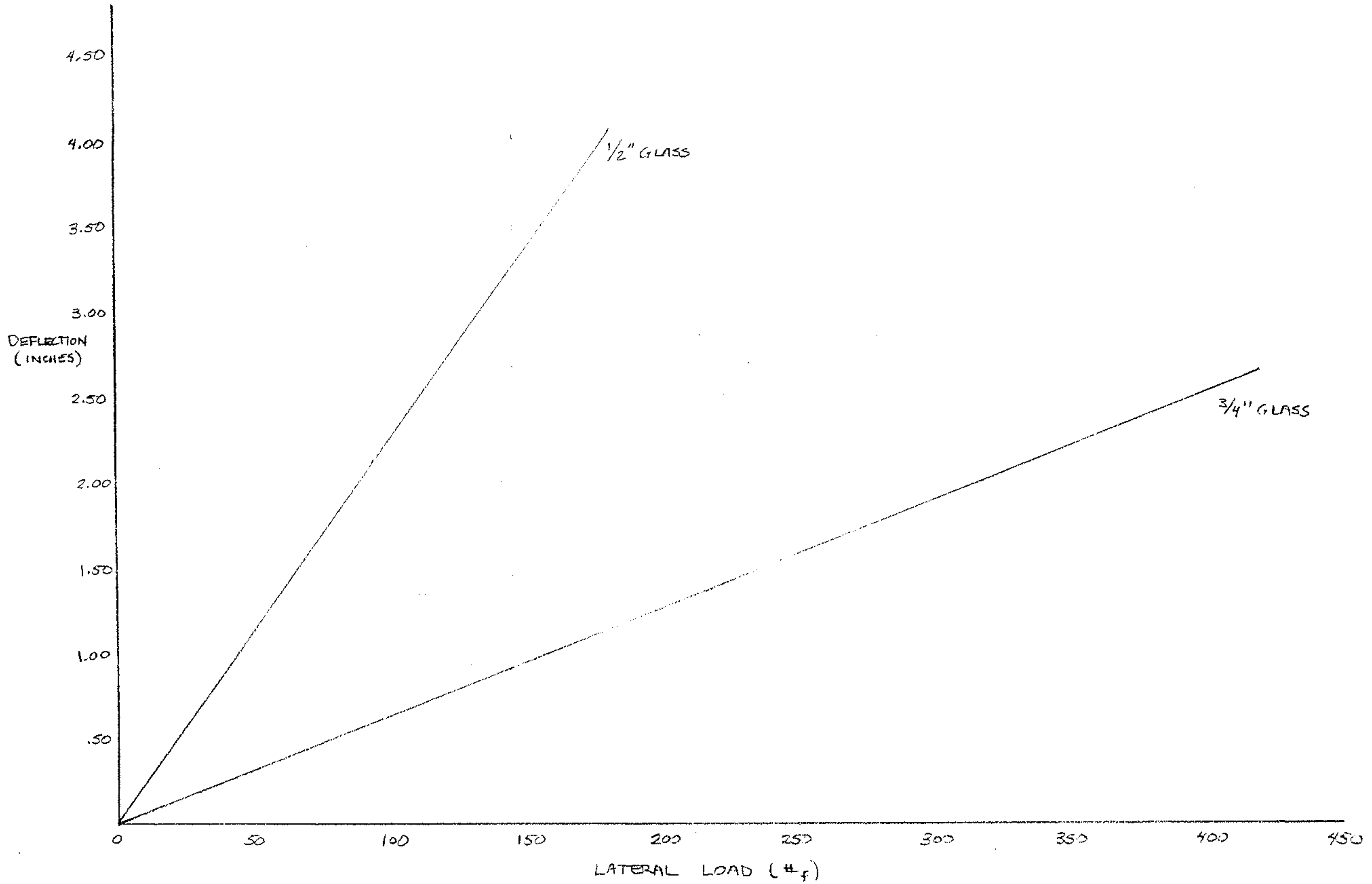
= 279 #/ft 1.5 safety factor

= 167 #/ft 2.5 safety factor

STRESS VS. LATERAL LOAD FOR 42" HIGH HANDRAIL



DEFLECTION VS LATERAL LOAD FOR 42" HIGH HANDRAIL



CALCULATIONS OF BASE STRESSES AND DEFLECTIONS

Design loads are as given in the glass calculations.

Blumcraft's assembly to the base makes the base and glass act as a rigid assembly so that the base adds to the stiffness of the glass. Thus, the calculations given for the glass are conservative. However, for conservatism and simplicity in the calculations below, the glass will be assumed to be simply supported by a rigidly mounted base. Thus, only one side of the base channel will be assumed to give support.

VI) SECTION PROPERTIES (MINIMUM SECTIONS ONLY)

Since the maximum bending stress will occur at the base of the leg and the section properties are minimum for the 1/2" glass section, these are the properties which will be calculated.

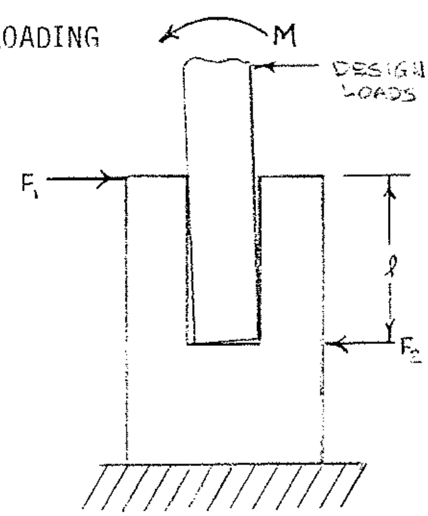
t = .75 in.
l = 1.75 in. RG-100S
= 2.50 in. RG-105S

$$I = \frac{bt^3}{12} = (12 \text{ in/ft})\frac{(.75 \text{ in})^3}{12} = .4219 \text{ in}^4/\text{ft}$$

$$Z = \frac{bt^2}{6} = (12 \text{ in/ft})\frac{(.75 \text{ in})^2}{6} = 1.125 \text{ in}^4/\text{ft}$$

Yield stress = 21000 psi for 6063T5 aluminum

VII) LOADING



The maximum moment M as given in the glass calculations is

$$M = 5250 \frac{\text{in-\#}}{\text{ft}} + 705.8 \text{ in\#/ft} = 5956 \text{ in\#/}$$

VII) Continued

The sum of the moments about F_2 equal zero

$F_1 l = M \quad F = \frac{M}{l} = \frac{5956 \text{ in\#/ft}}{1.75 \text{ in}} = 3403 \text{ \#/ft}$ for RG-100S

$= \frac{5956 \text{ in\#/ft}}{2.50 \text{ in}} = 2382 \text{ \#/ft}$ for RG-105S

The maximum applied force (250% design load) adds to F_1

$F_1 = 3403\#/ft + 125\ \#/ft = 3528\ \#/ft$ for RG-100S

$= 2382\#/ft + 125\ \#/ft = 2507\ \#/ft$ for RG-105S

Moments at base of leg

$M = Fl = (3528\ \#/ft)(1.75\ in) = 6174\ in\#/ft$ for RG-100S

$= (2507\ \#/ft)(2.50\ in) = 6268\ in\#/ft$ for RG-105S

VIII) STRESSES IN BASE

$\sigma = M/Z = (6174\ in\ \#/ft)(1.125\ in^3/ft) = 5488\ psi$ for RG-100S

$= (6268\ in\ \#/ft)(1.125\ in^3/ft) = 5571\ psi$ for RG-105S

IX) DEFLECTIONS IN BASE

$$\Delta = \frac{Fl^3}{3EI} = \frac{(3528\ \#/ft)(1.75\ in)^3}{3(10.3 \times 10^6 \#/in^2)(.4219\ in^4/ft)} = .0015\ in \text{ for RG-100S}$$

$$= \frac{(2507\ \#/ft)(2.50\ in)^3}{3(10.3 \times 10^6\ \#/in^2)(.4219\ in\ \#/ft)} = .0030\ in. \text{ for RG-105S}$$

X) ADDITIONAL DEFLECTIONS IN HANDRAIL DUE TO BENDING OF BASE

The slope of the leg at the end of the leg is

$$m = \frac{Fl^2}{2\ EI} = \frac{(3528\ \#/ft)(1.75\ in)^2}{2(10.3 \times 10^6\ \#/in^2)(.4219\ in^4/ft)} = .00124\ in/in \text{ for RG-100S}$$

$$= \frac{(2507\ \#/ft)(2.50\ in)^2}{2(10.3 \times 10^6\ \#/in^2)(.4219\ in\ \#/ft)} = .00180\ in/in \text{ for RG-105S}$$

X) Continued

The additional deflection at the top of the handrail is

Δ = mL = (.00124 in/in)(42 in) = .052 in. for RG-100S

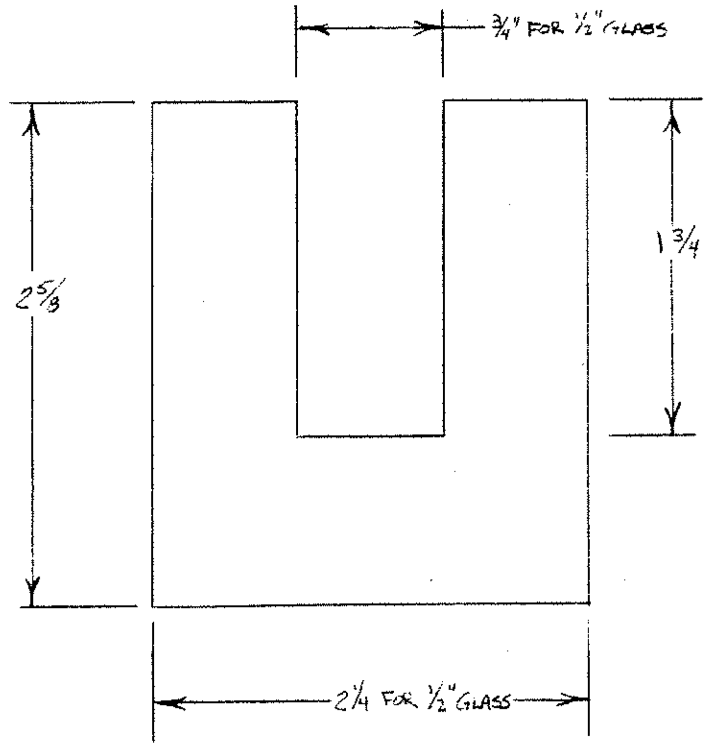
= (.00180 in/in)(42 in) = .076 in for RG-105S

For 1/2" glass at 250% design load, the total deflection is

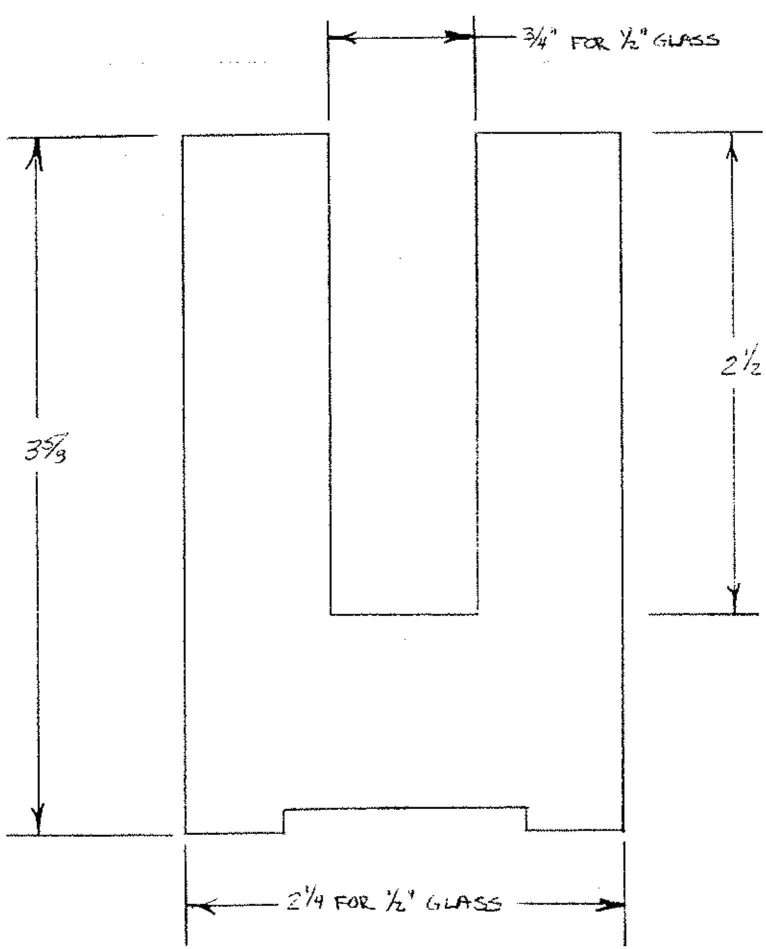
Δ = 3.392 in + .052 in. = 3.444 in. for RG-100S base

= 3.392 in + .076 in. = 3.468 in. for RG-105S base

1/2" GLASS BASE SECTIONS

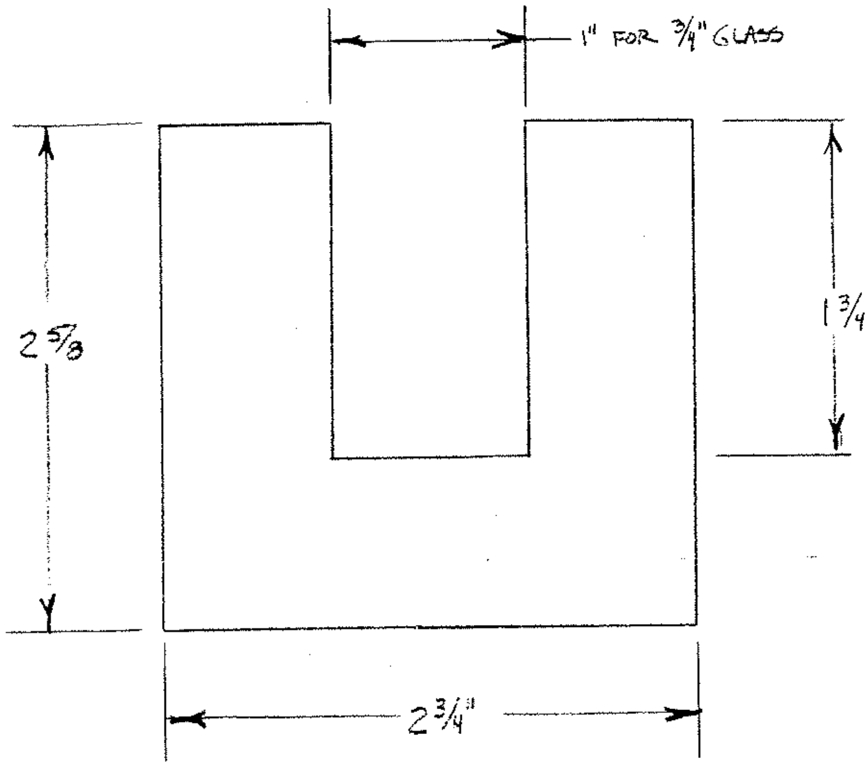


RG-100 S
SECTION

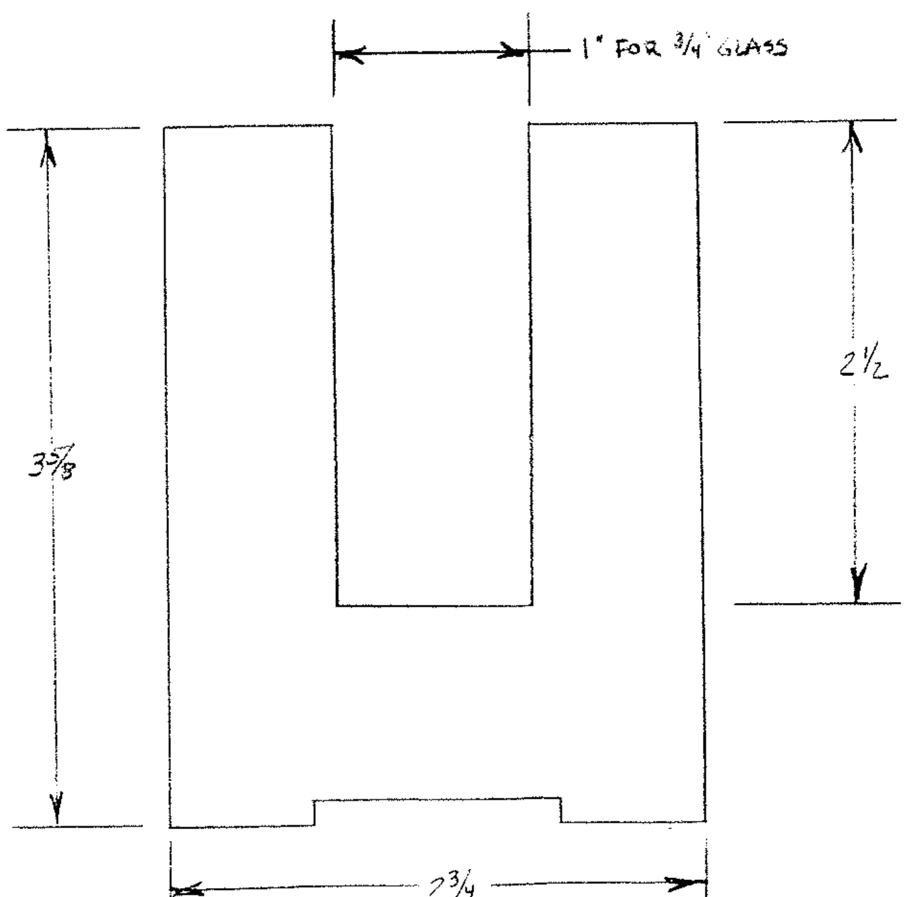


RG-105 S
SECTION

3/4" GLASS BASE SECTIONS



RG-100
FOR 3/4" GLASS



RG-175S

GUARD RAIL CALCULATIONS FOR CONCENTRATED LOAD

Calculations are based on a minimum 4' long section of rail. It is assumed that all railing systems shall have a top rail so that all panels of glass shall bend as one unit, even if the individual panels are less than 4' long. The most conservative case is that where the rail is free standing, with no wall return for the top rail.

Calculations are based on a 42" high glass rail, cantilevered about the base, with an applied load of 200# and 300# at the top of the rail.

I. SECTION PROPERTIES

Minimum glass thickness is 1/32" below nominal

t = .469 in. for 1/2" glass
= .719 in. for 3/4" glass

$$I = bt^3/12 = (48 \text{ in.}) \frac{(.469 \text{ in})^3}{12} = .4126 \text{ in.}^4 \quad \text{For 1/2" glass}$$

$$= (48 \text{ in.}) \frac{(.719 \text{ in})^3}{12} = 1.488 \text{ in.}^4$$

$$Z = \frac{bt^2}{6} = (48 \text{ in.}) \frac{(.469 \text{ in.})^2}{6} = 2.640 \text{ in.}^3 \quad \text{For 1/2" glass}$$

$$= (48 \text{ in.}) \frac{(.719 \text{ in.})^2}{6} = 4.136 \text{ in.}^3 \quad \text{For 3/4" glass}$$

II. LATERAL LOADING

Case 1 load = 200#
Case 2 load = 300#

Moments due to lateral loads

M = Fh = (200#) (42 in.) = 8400 in.# Case 1 loading
= (300#) (42 in.) = 12,600 in.# Case 2 loading

Stresses due to lateral loads - 1/2" glass

$\sigma = M/Z$ = (8400 in.#)/(2.640 in.^{3}) = 3182 psi Case 1 loading
= (12,600 in.#)/(2.640 in.^{3}) = 4773 psi Case 2 loading

Stresses due to lateral loads - 3/4" glass

$\sigma = M/Z$ = (8400 in.#)/(4.136 in.^{3}) = 2031 psi Case 1 loading
= (12,600 in.#)/(4.136 in.^{3}) = 3046 psi Case 2 loading

II. Continued.

Factor of Safety N

Allowable stress for tempered glass (8 breaks/1000) = 17,200 psi

1/2" Glass

N	= (17,200 psi)/(3,182 psi)	=	5.41	Case 1 loading
	= (17,200 psi)/(4,773 psi)	=	3.60	Case 2 loading

3/4" Glass

N	= (17,200 psi)/(2031 psi)	=	8.47	Case 1 loading
	= (17,200 psi)/(3046 psi)	=	5.65	Case 2 loading

Therefore, a minimum 4 foot long railing system will withstand a concentrated load of either 200# or 300# along the top rail with an adequate factor of safety. Since the stress is worst for a load at the top of the rail this also indicates that a requirement of 200# applied to the infill area of the rail is also met.

Deflections due to lateral loads - 1/2" Glass

$$\Delta = \frac{Fh^3}{3EI} = \frac{(200\#)\ (42\ \text{in.})^3}{3\ (10.6 \times 10^6 \#/\text{in.}^2)\ (.4126\ \text{in.}^4)} = 1.129\ \text{in.} \quad \text{Case 1 loading}$$

$$= \frac{(300\#)\ (42\ \text{in.})^3}{3\ (10.6 \times 10^6 \#/\text{in.}^2)\ (.4126\ \text{in.}^4)} = 1.694\ \text{in.} \quad \text{Case 2 loading}$$

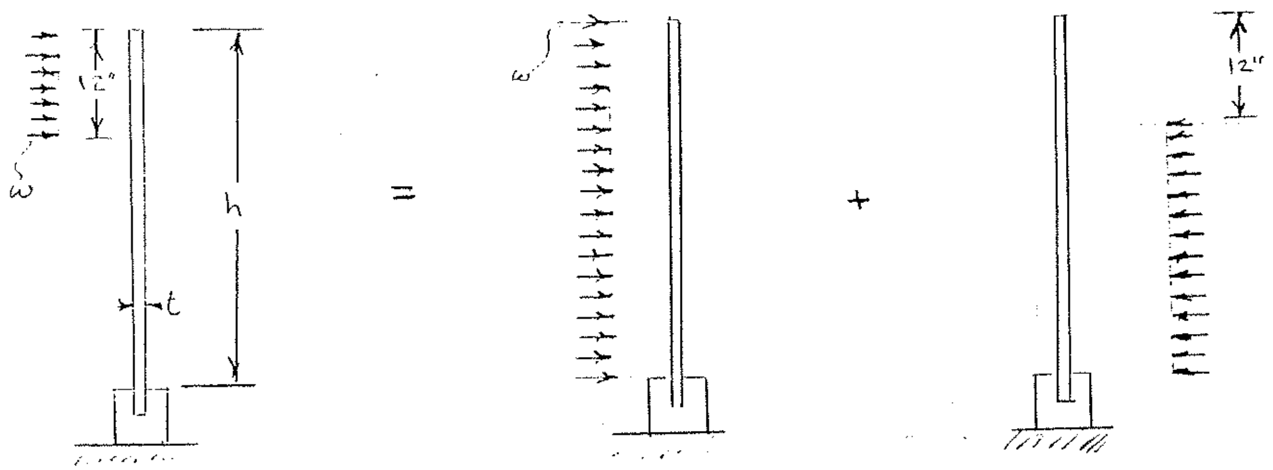
Deflections due to lateral loads - 3/4" Glass

$$\Delta = \frac{(200\#)\ (42\ \text{in.})^3}{3\ (10.6 \times 10^6\ \#/\text{in.}^2)\ (1.488\ \text{in}^4)} = .313\ \text{in.} \quad \text{Case 1 loading}$$

$$\Delta = \frac{(300\#)\ (42\ \text{in.})^3}{3\ (10.6 \times 10^6\ \#/\text{in.}^2)\ (1.488\ \text{in}^4)} = .470\ \text{in.} \quad \text{Case 2 loading}$$

Therefore, in order to minimize deflection, 3/4" glass should be used for Case 2 loading on short railings.

CALCULATION FOR ALLOWABLE GLASS STRESS DUE TO DISTRIBUTED LOAD ON INFILL AREA



BOCA '96 specified loads per section 4.4 of ASCE7 (1995) "Minimum Design Loads for Buildings and Other Structures" Section 4.4.2A) requires that glass fillers must withstand 50# applied horizontally on an area not to exceed 1 ft.^{2}. Normally, this load will be distributed over a large panel. For conservatism, it will be assumed that this load is applied on a 1 ft. wide panel, applied at the top to maximize bending stress.

The distributed load is $w = 50\#/12 \text{ in.} = 25/6 \ \#/\text{in.}$

The maximum moment is $M = \frac{w}{2} \left[h^2 - (h-12)^2\right] = w(12h-72) = 50h - 300 \text{ in.}\#$

The section modulus is $Z = bt^2/6 = (12 \text{ in.})\ t^2/6 = 2t^2 \text{ in.}^3$

PPG Glass thickness recommendations to meet Architect's specified 1-minute wind load gives typical rupture stress for fully tempered glass of S_R = 23,000 psi.

The code specifies a safety factor of N=4.

The allowable stress is therefore $S_A = S_R = 23{,}000 \text{ psi}/4 = 5750 \text{ psi}$

Tolerance on glass thickness is $\pm$ 1/32". At minimum tolerance, the allowable height is therefoe

$$h = t^2 S_a/25 + 6 = 56.5" \quad \text{for 1/2" glass}$$
$$= 125 \quad \text{for 3/4" glass}$$

ADDENDUM TO BLUMCRAFT TEST REPORT FOR RAILGLASS SYSTEM

COMPARISON TO ASTM E 985

The results in our test report meet or exceed the specifications indicated in ASTM E 985. With regard to the detail requirements, please refer to the applicable specifications as indicated.

1) Our test report is divided into three sections. Design calculations are furnished in Attachment 3 while Attachments 1 and 2 are reports of actual physical tests which corroborate the design calculations.

2) The allowable design stress indicated in the report is given as 17,200 psi. This figure already includes a safety factor because this figure corresponds to a breakage rate of .8 lites per thousand. The published figure for the rupture strength of tempered glass is 23,000 psi so that a safety factor of 4 indicates the design stress is 5750 psi.

3) Since the length or span of the railing is not indicated in the ASTM spec, we assume a four foot (4') rail span. This makes the 200# concentrated load and the 50 plf load equivalent Our practice is to reinforce any rail shorter than this by turning a corner or returning to a wall.

4) The calculations included in the report are based on 50 plf horizontal and 100 plf applied simultaneously so the specification is exceeded. Our report indicates the allowable stress is 5750 psi for a reduced loading condition and the ASTM specification allows a deflection of 42"/24 + 48"/96 = 2.25" based on a 42" rail height.

We hope that you will find that this meets your requirements.