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STRUCTURAL CALCULATIONS

for

HELIODYNE SOLAR COLLECTOR RACK STRUCTURES

GOBI 408 AT 35 DEGREES

FOR HELIODYNE, INC.

REGISTERED PROFESSIONAL ENGINEER
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Heliodyne Rack Structure with Gobi 408 Collector at 35 degrees - Summary of Results:

The following analysis and design are based on the 2009 International Building Code (IBC) and referenced standards:

- ASCE Minimum Design Loads for Buildings and Other Structures (ASCE7-05)
- 2005 National Design Specification for Wood Construction (NDS)
- 2005 Aluminum Design Manual (ADM)

The analysis includes load effects on the structure from the collector due to gravity loads, wind loads, snow loads and seismic loads. The results, presented in Table 1, represent the capacity of the rack structure for three combinations of site specific conditions (Conditions 1-3) with the following stipulations:

- One rack is provided on each of the long sides of the collector, i.e. racks spaced at 4' max.
- The strength of the collectors is beyond the scope of this report.
- The Engineer of Record for each specific installation shall be responsible for analyzing the design forces on the unit at that location and verifying that they are within the limits shown in Table 1.
- The Engineer of Record for each specific installation shall be responsible for the design of fasteners from the pedestal foot to the structure. Design for fasteners has been included, however due to the limitless possibilities of site conditions, only one design has been provided, and all conditions shown must be met for the design to be valid.
- The Engineer of Record for each specific installation shall be responsible for resolving the reactions into the structure to which the collector rack will be attached.
- Atmospheric Ice loading and flood loading are beyond the scope of this report.
- The rack structure analyzed in this report is defined in a drawing package prepared by Heliodyne, Inc, titled, *Heliodyne Rack Installation Guide*, dated 12/15/2010.

Based on the calculations that follow, the Heliodyne rack structure with a Gobi 408 collector angled at 35 degrees is capable of withstanding the demands prescribed by the IBC for the following site specific conditions:

Table 1. Summary of allowable site conditions for Gobi 408 at 35 degrees

Site Condition	Wind Load Variable (1) Maximum q_h (psf)	Snow Load Variable (2) Maximum Total Snow Pressure (including drift) (psf)	Seismic Load Variable (3)(4) Maximum S_{DS}
Condition 1	13.4	0	2.6
Condition 2	13.4	31	1.9
Condition 3	9.7	33	1.8

(1) q_h is determined from ASCE 7-05 Section 6.5.10.
(2) Maximum Total Snow Pressure is P_f (determined from ASCE 7-05 Section 7.3.) plus the effects of drift (from ASCE 7-05 Section 7.7).
(3) Where P_f is less than 30 psf, the S_{DS} from Condition 1 may be used.
(4) S_{DS} is determined from ASCE 7-05 Section 11.4.4.

In all conditions listed in Table 1, (2) 3/8" diameter lag bolts with a minimum 3" effective thread length (not including tapered end) into a Douglas Fir-Larch (N) member is sufficient provided the edge distance is greater than 1-1/2" and the end distance is greater than 2-5/8", both measured from the centerline of the lag bolt.

Wind Loading Only

Wind loads on collectors are limited by maximum allowable normal pressure on the glass for each collector, as reported by Heliodyne or the maximum wind load that the rack system can transfer to the supporting structure.

Pressure is calculated as: $p_w = q_h GC_N = 0.00256 K_z K_{zt} K_d V^2 I(GC_N)$

The rack structure was analyzed to determine a maximum factor q_h for each collector and angle of inclination. This variable allows all site specific variables to be included. The site specific variables are:

- Basic wind speed: V
- Velocity pressure exposure coefficient, evaluated at height z: K_z
- Topographic factor: K_{zt}

Variables for determining wind load that are not site specific are:

- Wind directionality factor: $K_d = 0.85$.
- Importance factor for wind: I = 1.0 (Unless Engineer of Record determines otherwise).
- Gust effect factor: G = 0.85.

The net pressure coefficient C_N is determined as an open building using ASCE 7 Monosloped Roof per Figure 6-18A and varies with angle of inclination. All pertinent data is included on each wind loading sheet. The load combinations with 1.2DL and DL include the full weight of collector, while cases with 0.9DL and 0.6DL use only the empty weight. The wind cases per ASCE 7-05 Figure 6-18A and the loading sheets to follow are represented in the load combinations as: W1= Case 1-A, W2 = Case 1-B, W3 = Case 2-A and W4 = Case 2-B. See Table 2.3.

Load Combinations:

Strength Level Combinations for aluminum member design per IBC 1605.2.1:

D1.	1.2DL + 1.6W1	D5.	1.2DL + 1.6W3
D2.	0.9DL + 1.6W1	D6.	0.9DL + 1.6W3
D3.	1.2DL + 1.6W2	D7.	1.2DL + 1.6W4
D4.	0.9DL + 1.6W2	D8.	0.9DL + 1.6W4

Allowable Stress Combinations for anchorage design per IBC 1605.3.1

S1.	DL + W1	S5	DL + W3
S2.	0.6DL+ W1	S6.	0.6DL+ W3
S3.	DL + W2	S7.	DL + W4
S4.	0.6DL+ W2	S8.	0.6DL+ W4

Code Analysis Model for Wind

A 2-d frame model was created to analyze the distribution of forces to the rack. Reactions and member forces were calculated for all load combinations. The reactions at the base of the collector are transferred to the legs through the clip, rail and rail mounting foot. Forces in the legs and reactions at the feet were determined from the model.

The reactions at the rear leg are purely axial due to the relative stiffness between the front and rear leg; the front leg takes all of the lateral load. To determine the adequacy of the clip/rail/mounting foot assembly to transfer the forces from the collector to the legs a Solidworks FEM model was created. Loads were applied to the model and adjusted to a force level that corresponds to a factored limit state stress (FLSS) per Aluminum Design Manual (ADM 2005). The rear leg connection reactions were compared to loads corresponding to the FLSS for a tension case and a compression case. The angles at which the reactions in the front leg are resolved vary on a case by case basis. To accommodate this, an array of loads corresponding to the FLSS was created. The reactions in the front leg connection were compared to the array.

Capacities of each leg were calculated according to ADM 2005. Forces in each leg from the analysis were tabulated and compared to the capacities according the interaction requirements of ADM 2005.

The reactions at the foot were tabulated to determine the corresponding anchorage demands. These reactions were compared with the allowable loads on a wood structural panel in compression and a 3/8" diameter lag screw with a 3" embedment in a Douglas Fir-Larch (N) member, SG = 0.49.

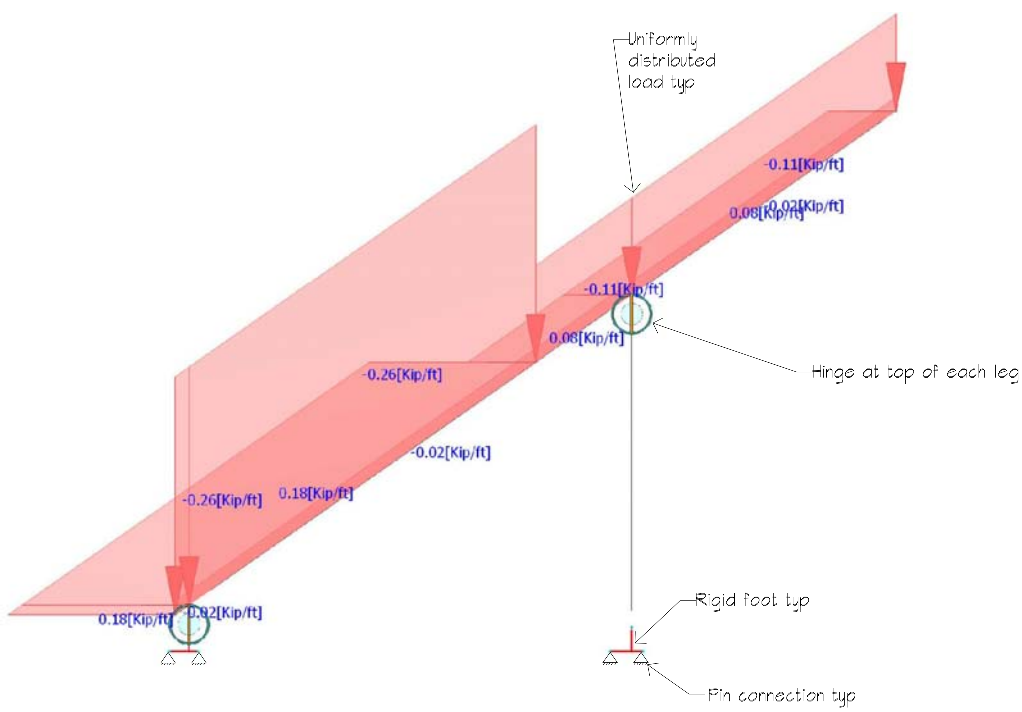


Figure 1. Typical Code Analysis Model

Summaries of capacities of the components follow. Tables 4.1-4.2, on page 6, show and compare the demand and capacity of the clip/rail/mounting foot assembly. Tables 5.1-5.3, on page 7, show and compare the demand and capacity of the rack's legs and fasteners, including interaction. Detailed calculations of FLSS and capacities can be found in the document "Heliodyne Rack Supplemental Calculations" available upon request to Heliodyne, Inc.

Wind Loading - Gobi 408 at 35 degrees

Building Type	Monosloped Roof				ASCE 7-05 Reference
Roof angle =	35	degrees			
Frame Tributary	4.2	ft			
	q_h(design) =	13.4	psf	(Based on rack component capacities)	
Wind Pressure p_w =	q_hGC_N =	25.4	psf max		EQ 6-25

Table 2.1. Pressure Coefficient(1)

	Case A	Case B
$C_{NL}1$	-1.8	-1.1
$C_{NW}1$	-1.5	-2.2
$C_{NL}2$	-0.9	0.2
$C_{NW}2$	0.7	1.8

(1) Linear interpolation used for Coefficient - Minus sign indicates pressure acting away from roof structure

Figure 6-18A

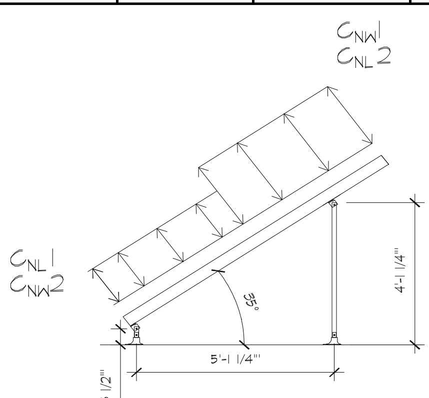
Table 2.2. Net Design Wind Pressure (psf)(1)

	Case A	Case B
$P_{NL}1$	-20.5	-12.5
$P_{NW}1$	-17.1	-25.4
$P_{NL}2$	-10.6	2.7
$P_{NW}2$	7.6	20.5

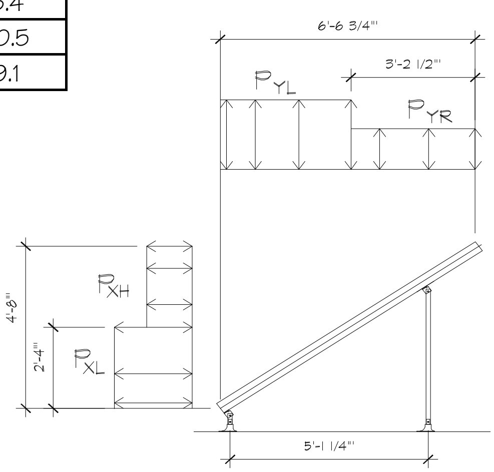
(1) Pressures shown correspond to coefficients in Table 2.1

Table 2.3. Component Wind Pressure Over Tributary (plf)

	Case 1-A	Case 1-B	Case 2-A	Case 2-B
P_{XL}	-49.4	-30.2	18.3	49.4
P_{XH}	-41.2	-61.3	-25.6	6.4
P_{YL}	-70.5	-43.1	26.1	70.5
P_{YR}	-58.8	-87.5	-36.6	9.1



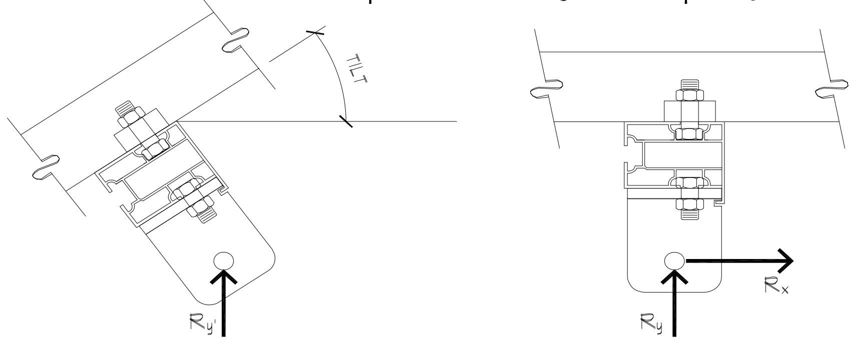
a) Pressure coefficients per ASCE 7-05 Figure 6-18A



b) Corresponding collector wind pressures

Figure 2. Loading Diagrams

Clip/Rail/Mounting Foot Capacity Summary

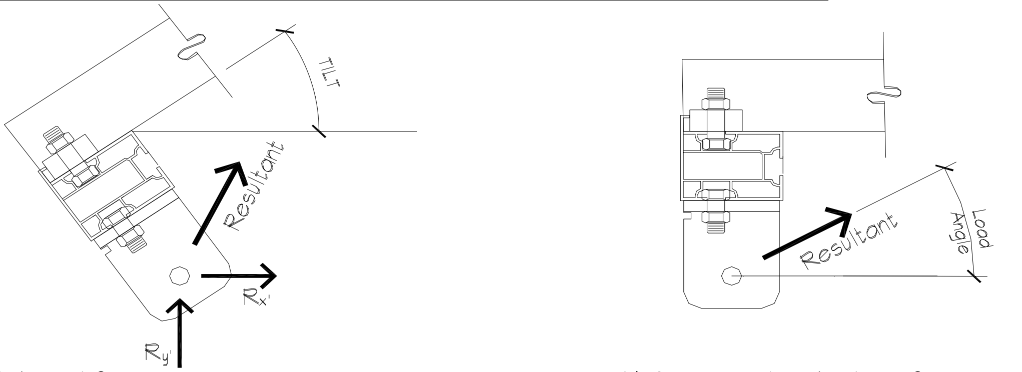


a) Actual Orientation   b) Corresponding Analysis Orientation

Figure 3. Rear Leg Assembly loading

Table 3.1. Rear Assembly Capacity

Tilt (degrees)	Load Direction	$R_{y'}$ (lb)	R_x (lb)	R_y (lb)
35	Tension	-630	-361	-516
35	Comp.	1274	731	1044
45	Tension	-571	-404	-404
45	Comp.	721	510	510



a) Actual Orientation   b) Corresponding Analysis Orientation

Figure 4. Front Leg Assembly loading

Table 3.2. Front Assembly Capacity

Load Angle	Resultant (lb)
0-40	600
40-85	690
85-95	1300
95-140	529
140-180	260
180-265	245
265-275	454
275-325	640
325-360	600

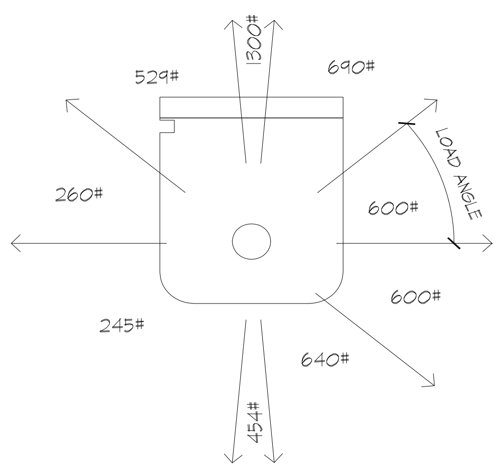


Figure 5. Front Assembly Capacity Array

Clip/Rail/Mounting Foot Anaylsis Results

Collector 408
Tilt 35 degrees
Loading Wind

Table 4.1. Rear Assembly Reactions

Load Case	$R_{x'}$ (lb)	$R_{y'}$ (lb)	Resultant (lb)	Load Angle (degrees)	Max Resultant (lb)	Resultant < Max?
D1	0	-460	460	235	630	YES
D2	0	-491	491	235	630	YES
D3	0	-596	596	235	630	YES
D4	0	-628	628	235	630	YES
D5	0	-92	92	235	630	YES
D6	0	-123	123	235	630	YES
D7	0	323	323	55	1274	YES
D8	0	291	291	55	1274	YES

Table 4.2. Front Assembly Reactions

Load Case	$R_{x'}$ (lb)	$R_{y'}$ (lb)	Resultant (lb)	Load Angle (degrees)	Max Resultant (lb)	Resultant < Max?
D1	338	-68	345	314	600	YES
D2	338	-86	349	311	600	YES
D3	341	61	347	-25	600	YES
D4	341	43	344	-28	600	YES
D5	28	197	199	47	690	YES
D6	28	179	181	46	690	YES
D7	-208	263	335	93	1300	YES
D8	-208	245	321	95	530	YES

Collector 408 - 35 degrees
Member Front Leg
Loading Wind

ϕM_n = 440 ft-#
ϕV_n = 4600 #
ϕT_n = 15500 #
ϕC_n = 15500 #

ϕC_e = 599 k
C_m = 0.85

Table 5.1. Front Leg Analysis Results

Load Combo	M_u (k-ft)	$M_u/\phi M_n$	V_u (k)	$V_u/\phi V_n$	T_u (k)	$T_u/\phi T_n$	C_u (k)	$C_u/\phi C_n$	Comb 1	Comb 2	Comb 3	Comb 4
D1	62	0.14	337	0.07	70	0.00	0	0.00	0.12	0.14	0.14	0.15
D2	62	0.14	337	0.07	89	0.01	0	0.00	0.12	0.14	0.15	0.15
D3	62	0.14	340	0.07	0	0.00	60	0.00	0.12	0.15	0.14	0.15
D4	62	0.14	340	0.07	0	0.00	41	0.00	0.12	0.14	0.14	0.15
D5	5	0.01	29	0.01	0	0.00	201	0.01	0.02	0.03	0.01	0.03
D6	5	0.01	29	0.01	0	0.00	182	0.01	0.02	0.02	0.01	0.02
D7	38	0.09	208	0.05	0	0.00	270	0.02	0.09	0.10	0.09	0.11
D8	38	0.09	208	0.05	0	0.00	250	0.02	0.09	0.10	0.09	0.10
									Max Ratio =			0.15

Collector 408 - 35 degrees
Member Rear Leg
Loading Wind

ϕM_n = 440 ft-#
ϕV_n = 4600 #
ϕT_n = 15500 #
ϕC_n = 6700 #

ϕC_e = 7.9 k
C_m = 0.85

Table 5.2. Rear Leg Analysis Results

Load Combo	M_u (k-ft)	$M_u/\phi M_n$	V_u (k)	$V_u/\phi V_n$	T_u (k)	$T_u/\phi T_n$	C_u (k)	$C_u/\phi C_n$	Comb 1	Comb 2	Comb 3	Comb 4
D1	0	0.00	0	0.00	458	0.03	0	0.00	0.00	0.00	0.03	0.00
D2	0	0.00	0	0.00	488	0.03	0	0.00	0.00	0.00	0.03	0.00
D3	0	0.00	0	0.00	594	0.04	0	0.00	0.00	0.00	0.04	0.00
D4	0	0.00	0	0.00	625	0.04	0	0.00	0.00	0.00	0.04	0.00
D5	0	0.00	0	0.00	96	0.01	0	0.00	0.00	0.00	0.01	0.00
D6	0	0.00	0	0.00	126	0.01	0	0.00	0.00	0.00	0.01	0.00
D7	0	0.00	0	0.00	0	0.00	315	0.05	0.05	0.05	0.00	0.05
D8	0	0.00	0	0.00	0	0.00	285	0.04	0.04	0.04	0.00	0.04
									Max Ratio =			0.05

Table 5.3. ASD Wind Anchorage Demands

Load Combination	Front Foot T (K)	V (K)	Angle (deg)	z_α (#)	z_α < Z'α?	Rear Foot T (#)	T < W'p?
S1	282.1	105	69.5	301	YES	181	YES
S2	297.2	105	70.5	315	YES	205	YES
S3	230.7	106	65.2	254	YES	238	YES
S4	245.8	106	66.6	268	YES	262	YES
S5	0	9.09	0.0	9.09	YES	26	YES
S6	0	9.08	0.0	9.08	YES	50	YES
S7	100.7	-64.9	57.2	120	YES	0	YES
S8	108.4	-64.9	59.1	126	YES	0	YES

Combined Wind and Snow Loading

Snow loading, or a combination of snow and wind on collectors is limited by the maximum allowable normal pressure on the collector's glass or the maximum load that the racks can transfer to the supporting structure. Using the load combination of the IBC 1605.3.1 EQ 16-13, the maximum allowable snow pressure limited by the collector's glass is found by:

$$S = \left(\frac{Allowable\ Pressure - 0.75W}{0.75}\right) / \cos 35^\circ$$

Three cases for snow are used. The first case, S1, is a low baseline wind load corresponding to a structure at 15 feet above the ground, therefore maximizing the allowable snow load on the glass and racking. The second case, S2, is a wind load corresponding to roughly 85%-100% (100% if the q_{hmax} is low) of the maximum allowable wind load, as discussed in the previous section, and a corresponding snow load. Load combinations F1-F8 (below) correspond to S1 and E1-E8 to S2.

The allowable snow pressure on the collectors includes any effects of drift due to aerodynamic shade. Snow load, including drift, is to be determined on a site by site basis per Chapter 7 of ASCE 7-05 and any local provisions.

Load Combinations:

Strength Level Combinations for aluminum member design per IBC 1605.2.1:

F1	1.2DL + 1.6W1 + 0.5S1	E1	1.2DL + 1.6W1 + 0.5S2
F2	1.2DL + 0.8W1 + 1.6S1	E2	1.2DL + 0.8W1 + 1.6S2
F3	1.2DL + 1.6W2 + 0.5S1	E3	1.2DL + 1.6W2 + 0.5S2
F4	1.2DL + 0.8W2 + 1.6S1	E4	1.2DL + 0.8W2 + 1.6S2
F5	1.2DL + 1.6W2 + 0.5S1	E5	1.2DL + 1.6W2 + 0.5S2
F6	1.2DL + 0.8W2 + 1.6S1	E6	1.2DL + 0.8W2 + 1.6S2
F7	1.2DL + 1.6W2 + 0.5S1	E7	1.2DL + 1.6W2 + 0.5S2
F8	1.2DL + 0.8W2 + 1.6S1	E8	1.2DL + 0.8W2 + 1.6S2

Allowable Stress Combinations for anchorage design per IBC 1605.3.1

R1	DL + 0.75W1 + 0.75S2
R2	DL + 0.75W2 + 0.75S2
R3	DL + 0.75W3 + 0.75S2
R4	DL + 0.75W4 + 0.75S2

Code Analysis Model

The same model used for wind was utilized for analysis of the combination of wind and snow loading, see Figure 1. Loading variables are presented on the following page. Results from the code analysis model are shown and compared with component capacities on Tables 7.1 and 7.2 which follow.

Wind + Snow Loading - Gobi 408 at 35 degrees

Building Type	Monosloped Roof		6.5.13
Snow Case	1	2	
Basic Wind Speed (mph)	85		
Wind Exposure	B		

Wind Pressure p_w = $q_h G C_N$ — EQ 6-25

where $q_h = 0.00256 K_z K_{zt} K_d V^2 I$ =

Snow Case	1	2		
q_h	9.7	13.4	psf	EQ 6-15
K_z =	0.62			Table 6-3
K_d =	0.85			Table 6-4
K_{zt} =	1			6.5.7.2
G =	0.85			6.5.8.1
C_N =	2.7			Figure 6-18A
I =	1			Table 6-1

P_s max = (Max Glass Pressure - $0.75P_w$)/0.75

Table 6. Snow and Wind Loading (psf unless noted otherwise)

Snow Case	Maximum Collector Glass Pressure	Design q_h for Snow Case	P_w	P_s Max	Max Snow load per frame (plf)	Snow Load Per Frame Used in Design (plf)	P_s Used for Design
S1	75	9.7	22.4	90.3	462	140.0	33.3
S2	75	13.4	30.8	86.6	444	130.0	31.0

Clip/Rail/Mounting Foot Anaylsis Results

Collector 408
Tilt 35 degrees
Loading Wind + Snow

Table 7.1. Rear Assembly Reactions

Load Case	$R_{x'}$ (lb)	$R_{y'}$ (lb)	Resultant (lb)	Load Angle (degrees)	Max Resultant (lb)	Resultant < Max?
F1	0	-12	12	235	630	YES
F2	0	847	847	55	1274	YES
F3	0	-111	111	235	630	YES
F4	0	797	797	55	1274	YES
F5	0	257	257	55	1274	YES
F6	0	982	982	55	1274	YES
F7	0	560	560	55	1274	YES
F8	0	1133	1133	55	1274	YES
E1	0	-195	195	235	630	YES
E2	0	670	670	55	1274	YES
E3	0	-331	331	235	630	YES
E4	0	601	601	55	1274	YES
E5	0	173	173	55	1274	YES
E6	0	854	854	55	1274	YES
E7	0	588	588	55	1274	YES
E8	0	1061	1061	55	1274	YES

Table 7.2.Front Assembly Reactions

Load Case	$R_{x'}$ (lb)	$R_{y'}$ (lb)	Resultant (lb)	Load Angle (degrees)	Max Resultant (lb)	Resultant < Max?
F1	247	135	282	-6	600	YES
F2	123	554	567	42	690	YES
F3	250	230	339	8	600	YES
F4	125	601	614	43	690	YES
F5	21	329	330	51	690	YES
F6	10	651	651	54	690	YES
F7	-152	377	407	77	690	YES
F8	-76	675	679	61	690	YES
E1	338	89	349	-20	600	YES
E2	169	498	526	36	600	YES
E3	341	219	405	-2	600	YES
E4	171	563	588	38	600	YES
E5	28	354	355	50	690	YES
E6	14	631	631	54	690	YES
E7	-208	420	469	81	690	YES
E8	-104	664	672	64	690	YES

Collector	408 - 35 degrees	ϕM_n =	440 ft-#	ϕC_e =	599 k
Member	Front Leg	ϕV_n =	4600 #	C_m =	0.85
Loading	Wind + Snow	ϕT_n =	15500 #		
		ϕC_n =	15500 #		

Table 8.1. Front Leg Analysis Results

Load Combo	M_u (k-ft)	$\frac{M_u}{\phi M_n}$	V_u (k)	$\frac{V_u}{\phi V_n}$	T_u (k)	$\frac{T_u}{\phi T_n}$	C_u (k)	$\frac{C_u}{\phi C_n}$	Comb 1	Comb 2	Comb 3	Comb 4
F1	45	0.10	247	0.05	23	0.00	0	0.00	0.09	0.10	0.10	0.11
F2	23	0.05	124	0.03	0	0.00	810	0.05	0.10	0.10	0.05	0.10
F3	46	0.10	249	0.05	123	0.01	0	0.00	0.09	0.10	0.11	0.11
F4	23	0.05	125	0.03	0	0.00	760	0.05	0.09	0.10	0.05	0.10
F5	4	0.01	21	0.00	0	0.00	242	0.02	0.02	0.02	0.01	0.02
F6	2	0.00	11	0.00	0	0.00	942	0.06	0.06	0.07	0.00	0.07
F7	28	0.06	152	0.03	0	0.00	543	0.04	0.09	0.10	0.06	0.10
F8	14	0.03	76	0.02	0	0.00	1092	0.07	0.10	0.10	0.03	0.10
E1	62	0.14	337	0.07	193	0.01	0	0.00	0.12	0.14	0.15	0.15
E2	31	0.07	169	0.04	0	0.00	669	0.04	0.10	0.11	0.07	0.11
E3	62	0.14	341	0.07	329	0.02	0	0.00	0.12	0.14	0.16	0.15
E4	31	0.07	171	0.04	0	0.00	601	0.04	0.10	0.11	0.07	0.11
E5	5	0.01	29	0.01	0	0.00	169	0.01	0.02	0.02	0.01	0.02
E6	3	0.01	15	0.00	0	0.00	850	0.05	0.06	0.06	0.01	0.06
E7	38	0.09	208	0.05	0	0.00	581	0.04	0.11	0.12	0.09	0.13
E8	19	0.04	104	0.02	0	0.00	1056	0.07	0.10	0.11	0.04	0.11
										Max Ratio =		0.16

Collector 408 - 35 degrees
Member Rear Leg
Loading Wind + Snow

ϕM_n = 440 ft-#
ϕV_n = 4600 #
ϕT_n = 15500 #
ϕC_n = 6700 #

ϕC_e = 7.9 k
C_m = 0.85

Table 8.2. Rear Leg Analysis Results

Load Combo	M_u (k-ft)	$M_u/\phi M_n$	V_u (k)	$V_u/\phi V_n$	T_u (k)	$T_u/\phi T_n$	C_u (k)	$C_u/\phi C_n$	Comb 1	Comb 2	Comb 3	Comb 4
F1	0	0	0	0	23	0	0	0.00	0.00	0.00	0.01	0.00
F2	0	0	0	0	0	0	810	0.04	0.04	0.04	0.00	0.04
F3	0	0	0	0	123	0	0	0.00	0.00	0.00	0.02	0.00
F4	0	0	0	0	0	0	760	0.04	0.04	0.04	0.00	0.04
F5	0	0	0	0	0	0	242	0.01	0.01	0.01	0.00	0.01
F6	0	0	0	0	0	0	942	0.05	0.05	0.05	0.00	0.05
F7	0	0	0	0	0	0	543	0.04	0.04	0.04	0.00	0.04
F8	0	0	0	0	0	0	1092	0.07	0.07	0.07	0.00	0.07
E1	0	0	0	0	193	0.01	0	0.00	0.00	0.00	0.01	0.00
E2	0	0	0	0	0	0.00	669	0.10	0.10	0.10	0.00	0.10
E3	0	0	0	0	329	0.02	0	0.00	0.00	0.00	0.02	0.00
E4	0	0	0	0	0	0.00	601	0.09	0.09	0.09	0.00	0.09
E5	0	0	0	0	0	0.00	169	0.03	0.03	0.03	0.00	0.03
E6	0	0	0	0	0	0.00	850	0.13	0.13	0.13	0.00	0.13
E7	0	0	0	0	0	0.00	581	0.09	0.09	0.09	0.00	0.09
E8	0	0	0	0	0	0.00	1056	0.16	0.16	0.16	0.00	0.16
										Max Ratio =		0.16

Seismic Loading & Combined Seismic & Snow

Seismic Loading was determined using the provisions of ASCE 7-05 Chapter 13 Seismic Design Requirements for Nonstructural Components. The design force is found from equations 13.3-(1-3):

$$F_p = \frac{0.4 a_p S_{DS} W_p}{\frac{R_p}{I_p}} \left(1 + 2\frac{z}{h}\right)$$

$$0.3 S_{DS} I_p W_p < F_p \leq 1.6 S_{DS} I_p W_p$$

Where:

- S_{DS} = Spectral acceleration, short period, as determined from Section 11.4.4 – A maximum value of 1.55 was assumed.
- a_p = Component amplification factor from Table 13.6-1: 1.0 for "mechanical components constructed of highly deformable materials".
- I_p = Component importance factor: 1.0.
- W_p = Component operating weight & effective weight of snow.
- R_p = Component response modification factor from Table 13.6-1: 2.5 for "mechanical components constructed of highly deformable materials".
- z = Height in structure of point of attachment of component with respect to the base.
- h = Average roof height of structure with respect to the base – for roof mount collectors, z/h = 1.

$$F_p = 0.48 S_{DS} \quad \& \quad F_{p(asd)} = 0.336 S_{DS}$$

Seismic analysis was performed for the three snow cases. Per ASCE 7-05 section 12.7.2 where $P_f > 30$ psf, 20% of snow load is to be included in seismic weight. Where $P_f < 30$ psf snow load is not required to be included in seismic weight.

Wind loading on a light structure such as this will govern perpendicular to the face of the collector. In the direction parallel to the surface of the collector's seismic loading will govern design. A simple approach of statics was used to determine the demand on the legs of the rack structure. An allowable spectral acceleration, S_{DS}, has been determined for each of the three cases. The analysis is based on allowable compression perpendicular to grain for a Hem-Fir support and anchorage of a lag bolt discussed earlier.

Load Combinations:

Allowable Stress Combinations per IBC 1605.3.1

1 DL + 0.7E
2 DL + 0.75(0.7E) + 0.75S

Longitudinal Seismic Loading

$SF_y = 0 \text{ --> } E = 2*R_y \text{ --> } R_y = E/2$

$SM_A = 0 \text{ --> } Ee = 4*R_x \text{ --> } R_x = Ee/4$

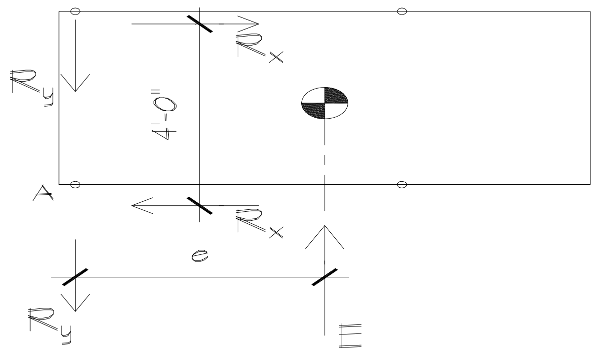


Figure 6. Seismic Loading

Table 9. Seismic Demand (ASD)

Snow Case	Snow per frame (plf)	S_{DS}	E Horiz (#)	e (ft)	R_y (#)	R_x (#)	$\Sigma M_O = R_y*5.7"$
1	140	1.8	146	3.5	73	128	542
2	130	1.9	148	3.5	74	130	574
3	0	2.6	119	3.5	59	104	630

Table 10. Seismic Analysis Results (1)

Snow Case	D (#)	0.75* S (#)	σ_{vert} (psi)(2)	$\Sigma M_R = F*A$	$\Sigma M_R > \Sigma M_O$?	T_y (#)	V_y (#)	T_x (#)	V_x (#)	Angle (deg)	Z_α (#)
1	50	252	65.4	560	YES	82	73	92	64	61	199
2	50	234	61.5	579	YES	93	74	99	65	63	216
3	50	0	10.8	677	YES	167	59	132	52	75	309

(1) See following page for determination of stress at bottom of foot

(2) σ_{vert} is compressive stress due to dead and snow loads

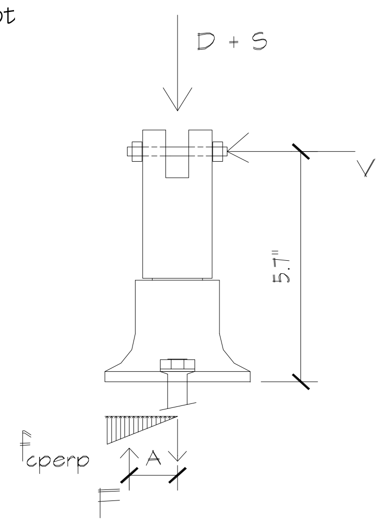


Figure 7. Seismic Loading on Foot

Table 11. Stresses on Foot - Seismic Overturning

Segment	$area_x$ (in^2)	a_x (in)	$f_{cperpx}1$ (psi)	f_{cperpx} 2 (psi)	f_{cperpx} ave (psi)	r_x (#)	f_{cperpx} ave (psi)	r_x (#)	f_{cperpx} ave (psi)	r_x (#)
1	0.076	1.6	295	277	286	21.7	289	22.0	338	25.7
2	0.145	1.5	277	258	267	38.8	272	39.4	318	46.1
3	0.201	1.4	258	240	249	50.1	254	51.0	297	59.7
4	0.253	1.3	240	222	231	58.5	236	59.7	276	69.8
5	0.277	1.2	222	204	213	59.0	218	60.4	255	70.7
6	0.256	1.1	204	186	195	49.9	200	51.3	234	60.0
7	0.27	1	186	168	177	47.7	183	49.3	213	57.6
8	0.293	0.9	168	150	159	46.5	165	48.3	193	56.4
9	0.316	0.8	150	131	141	44.4	147	46.4	172	54.3
10	0.33	0.7	131	113	122	40.4	129	42.6	151	49.8
11	0.34	0.6	113	95	104	35.4	111	37.8	130	44.3
12	0.348	0.5	95	77	86	30.0	93	32.5	109	38.1
13	0.355	0.4	77	59	68	24.1	76	26.9	89	31.4
14	0.355	0.3	59	41	50	17.7	58	20.5	68	24.0
15	0.328	0.2	41	23	32	10.4	40	13.1	47	15.4
16	0.289	0.1	23	5	14	3.9	22	6.4	26	7.5
17	0.074	0	5	0	2	0.2	4	0.3	5	0.4
					F (#) =	579	F (#) =	608	F (#) =	711
					A (in) =	0.968	A (in) =	0.952	A (in) =	0.952

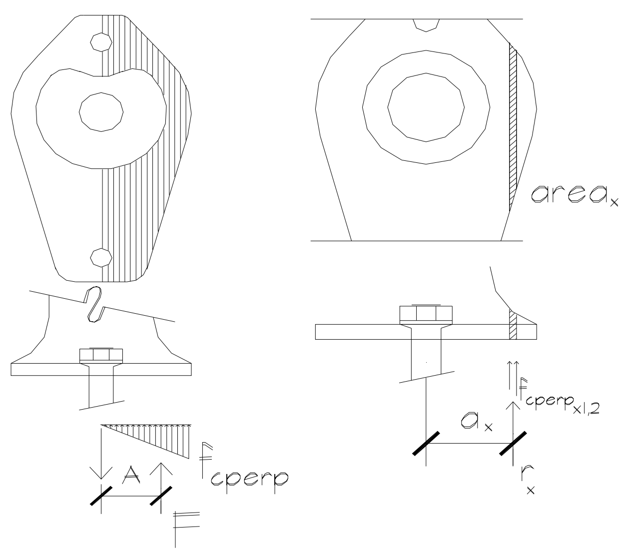


Figure 8. Stress Distribution @ Foot