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STRUCTURAL CALCULATIONS

for

HELIODYNE SOLAR COLLECTOR RACK STRUCTURES

GOBI 410 AT 45 DEGREES

FOR HELIODYNE, INC.

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Heliodyne Rack Structure with Gobi 410 Collector at 45 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 410 collector angled at 45 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 410 at 45 degrees

	Wind Load Variable (1)	Snow Load Variable (2)	Seismic Load Variable (3)(4)
Site Condition	Maximum q_h (psf)	Maximum Total Snow Pressure (including drift) (psf)	Maximum S_{DS}
Condition 1	10.0	0	2.2
Condition 2	9.7	11.9	2.2
Condition 3	9.7	13.6	2.1

(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: $p_w = q_h G C_N = 0.00256 K_z K_{zt} K_d V^2 I (GC_N)$

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 410 at 45 degrees

Building Type	Monosloped Roof				ASCE 7-05 Reference
Roof angle =	45	degrees			
Frame Tributary	4.2	ft			
	q_h(design) =	10.0	psf	(Based on rack component capacities)	
Wind Pressure p_w =	$q_h GC_N$ =	16.2	psf max		EQ 6-25

Table 2.1. Pressure Coefficient[1]

	Case A	Case B
$C_{NL}1$	-1.8	-1.2
$C_{NW}1$	-1.3	-1.9
$C_{NL}2$	-0.9	0.4
$C_{NW}2$	0.8	2.1

(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
$P_{NL}1$	-15.3	-10.2
$P_{NW}1$	-11.1	-16.2
$P_{NL}2$	-7.7	3.4
$P_{NW}2$	6.8	17.9

(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}	-45.4	-30.3	20.2	53.0
P_{XH}	-32.8	-48.0	-22.7	10.1
P_{YL}	-45.4	-30.3	20.2	53.0
P_{YR}	-32.8	-48.0	-22.7	10.1

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 410
Tilt 45 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	-407	407	225	571	YES
D2	0	-448	448	225	571	YES
D3	0	-524	524	225	571	YES
D4	0	-565	565	225	571	YES
D5	0	-52	52	225	571	YES
D6	0	-92	92	225	571	YES
D7	0	444	444	45	721	YES
D8	0	403	403	45	721	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	445	163	474	-25	600	YES
D2	445	142	467	-27	600	YES
D3	446	279	526	-13	600	YES
D4	446	258	515	-15	600	YES
D5	15	237	238	41	690	YES
D6	15	216	217	41	690	YES
D7	-360	117	379	117	530	YES
D8	-360	96	373	120	530	YES

Collector 410 - 45 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	53	0.12	291	0.06	0	0.00	135	0.01	0.11	0.13	0.12	0.13
D2	53	0.12	291	0.06	0	0.00	112	0.01	0.11	0.13	0.12	0.13
D3	81	0.18	446	0.10	0	0.00	284	0.02	0.18	0.20	0.18	0.21
D4	81	0.18	445	0.10	0	0.00	261	0.02	0.17	0.20	0.18	0.21
D5	2	0.00	10	0.00	0	0.00	184	0.01	0.02	0.02	0.00	0.02
D6	2	0.00	10	0.00	0	0.00	162	0.01	0.01	0.01	0.00	0.01
D7	43	0.10	235	0.05	0	0.00	106	0.01	0.09	0.10	0.10	0.11
D8	43	0.10	235	0.05	0	0.00	83	0.01	0.09	0.10	0.10	0.11
										Max Ratio =		0.21

Collector 410 - 45 degrees
Member Rear Leg
Loading Wind

ϕM_n = 700 ft-#
ϕV_n = 7200 #
ϕT_n = 24400 #
ϕC_n = 6200 #

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	226	0.01	0	0.00	0.00	0.00	0.01	0.00
D2	0	0.00	0	0.00	265	0.01	0	0.00	0.00	0.00	0.01	0.00
D3	0	0.00	0	0.00	530	0.02	0	0.00	0.00	0.00	0.02	0.00
D4	0	0.00	0	0.00	569	0.02	0	0.00	0.00	0.00	0.02	0.00
D5	0	0.00	0	0.00	0	0.00	7	0.00	0.00	0.00	0.00	0.00
D6	0	0.00	0	0.00	33	0.00	0	0.00	0.00	0.00	0.00	0.00
D7	0	0.00	0	0.00	0	0.00	330	0.05	0.05	0.05	0.00	0.05
D8	0	0.00	0	0.00	0	0.00	291	0.05	0.05	0.05	0.00	0.05
										Max Ratio =		0.05

Table 5.3. ASD Wind Anchorage Demands

Load Combination	Front Foot					Rear Foot	
	T (K)	V (K)	Angle (deg)	z_α (#)	z_α < Z'α?	T (#)	T < W'p?
S1	159.2	90.9	60.3	183	YES	79	YES
S2	177.2	90.9	62.9	199	YES	110	YES
S3	217.5	139	57.4	258	YES	208	YES
S4	235.5	139	59.4	274	YES	239	YES
S5	0	3.06	0.0	3.06	YES	0	YES
S6	0	3.05	0.0	3.05	YES	10	YES
S7	155.4	-73.5	64.7	172	YES	0	YES
S8	164.5	-73.5	65.9	180	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:

$$S = \left(\frac{Allowable\ Pressure - 0.75W}{0.75}\right) / \cos 45^{\circ}$$

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 410 at 45 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 $q_h = 0.00256 K_z K_{zt} K_d V^2 I$ =	9.7	10.0	psf	EQ 6-15
Snow Case	1	2		
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 =	2.1			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	17.4	90.3	534	57.0	13.6
S2	75	10.0	17.9	90.0	532	50.0	11.9

Clip/Rail/Mounting Foot Anaylsis Results

Collector 410
Tilt 45 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	-256	256	225	571	YES
F2	0	304	304	45	721	YES
F3	0	-369	369	225	571	YES
F4	0	248	248	45	721	YES
F5	0	89	89	45	721	YES
F6	0	475	475	45	721	YES
F7	0	569	569	45	721	YES
F8	0	714	714	45	721	YES
E1	0	-289	289	225	571	YES
E2	0	241	241	45	721	YES
E3	0	-406	406	225	571	YES
E4	0	182	182	45	721	YES
E5	0	67	67	45	721	YES
E6	0	419	419	45	721	YES
E7	0	562	562	45	721	YES
E8	0	666	666	45	721	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	431	229	488	-17	600	YES
F2	214	336	398	12	600	YES
F3	432	342	551	-7	600	YES
F4	215	392	447	16	600	YES
F5	14	301	302	42	690	YES
F6	7	372	372	44	690	YES
F7	-349	185	395	107	530	YES
F8	-173	314	358	74	690	YES
E1	445	223	498	-18	600	YES
E2	223	310	382	9	600	YES
E3	446	340	561	-8	600	YES
E4	223	368	431	14	600	YES
E5	15	298	298	42	690	YES
E6	7	347	348	44	690	YES
E7	-360	178	402	109	530	YES
E8	-180	287	339	77	690	YES

Collector	410 - 45 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	51	0.12	282	0.06	86	0.01	0	0.00	0.10	0.12	0.12	0.12
F2	26	0.06	140	0.03	0	0.00	370	0.02	0.07	0.08	0.06	0.08
F3	79	0.18	432	0.09	380	0.02	0	0.00	0.15	0.18	0.20	0.19
F4	39	0.09	215	0.05	0	0.00	224	0.01	0.09	0.10	0.09	0.11
F5	2	0.00	10	0.00	0	0.00	139	0.01	0.01	0.01	0.00	0.01
F6	1	0.00	5	0.00	0	0.00	482	0.03	0.03	0.03	0.00	0.03
F7	42	0.09	228	0.05	0	0.00	453	0.03	0.11	0.12	0.09	0.13
F8	21	0.05	113	0.02	0	0.00	637	0.04	0.08	0.09	0.05	0.09
E1	53	0.12	291	0.06	113	0.01	0	0.00	0.10	0.12	0.13	0.12
E2	27	0.06	146	0.03	0	0.00	313	0.02	0.07	0.08	0.06	0.08
E3	81	0.19	446	0.10	416	0.03	0	0.00	0.16	0.19	0.21	0.19
E4	41	0.09	223	0.05	0	0.00	161	0.01	0.09	0.10	0.09	0.11
E5	2	0.00	10	0.00	0	0.00	120	0.01	0.01	0.01	0.00	0.01
E6	1	0.00	5	0.00	0	0.00	429	0.03	0.03	0.03	0.00	0.03
E7	43	0.10	235	0.05	0	0.00	443	0.03	0.11	0.13	0.10	0.13
E8	21	0.05	118	0.03	0	0.00	591	0.04	0.08	0.09	0.05	0.09
										Max Ratio =		0.21

Collector 410 - 45 degrees
Member Rear Leg
Loading Wind + Snow

ϕM_n = 700 ft-#
ϕV_n = 7200 #
ϕT_n = 24400 #
ϕC_n = 6200 #

ϕC_e = 7.9 k
C_m = 0.85

Table 8.2. Rear 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	0	0	0	0	86	0	0	0.00	0.00	0.00	0.01	0.00
F2	0	0	0	0	0	0	370	0.02	0.02	0.02	0.00	0.02
F3	0	0	0	0	380	0	0	0.00	0.00	0.00	0.03	0.00
F4	0	0	0	0	0	0	224	0.01	0.01	0.01	0.00	0.01
F5	0	0	0	0	0	0	139	0.01	0.01	0.01	0.00	0.01
F6	0	0	0	0	0	0	482	0.03	0.03	0.03	0.00	0.03
F7	0	0	0	0	0	0	453	0.03	0.03	0.03	0.00	0.03
F8	0	0	0	0	0	0	637	0.04	0.04	0.04	0.00	0.04
E1	0	0	0	0	113	0.00	0	0.00	0.00	0.00	0.00	0.00
E2	0	0	0	0	0	0.00	313	0.05	0.05	0.05	0.00	0.05
E3	0	0	0	0	416	0.02	0	0.00	0.00	0.00	0.02	0.00
E4	0	0	0	0	0	0.00	161	0.03	0.03	0.03	0.00	0.03
E5	0	0	0	0	0	0.00	120	0.02	0.02	0.02	0.00	0.02
E6	0	0	0	0	0	0.00	429	0.07	0.07	0.07	0.00	0.07
E7	0	0	0	0	0	0.00	443	0.07	0.07	0.07	0.00	0.07
E8	0	0	0	0	0	0.00	591	0.10	0.10	0.10	0.00	0.10
										Max Ratio =		0.10

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

$SF_y = 0$ --> $E = 2*R_y$ --> $R_y = E/2$

$SM_A = 0$ --> $Ee = 4*R_x$ --> $R_x = Ee/4$

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	57	2.1	131	3.7	66	121	598
2	50	2.2	132	3.7	66	122	615
3	0	2.2	123	3.7	61	114	642

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	60	94.1	33.3	621	YES	137	66	127	61	71	279
2	60	82.5	30.8	638	YES	144	66	131	61	72	289
3	60	0	13	673	YES	172	61	144	57	75	326

(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	327	307	317	24.1	319	24.2	336	25.6
2	0.145	1.5	307	286	297	43.0	299	43.4	316	45.8
3	0.201	1.4	286	266	276	55.6	280	56.2	295	59.3
4	0.253	1.3	266	246	256	64.8	260	65.8	274	69.4
5	0.277	1.2	246	226	236	65.4	240	66.6	254	70.2
6	0.256	1.1	226	206	216	55.3	221	56.5	233	59.6
7	0.27	1	206	186	196	52.9	201	54.3	212	57.3
8	0.293	0.9	186	166	176	51.5	182	53.2	191	56.1
9	0.316	0.8	166	146	156	49.2	162	51.2	171	54.0
10	0.33	0.7	146	126	136	44.8	142	47.0	150	49.5
11	0.34	0.6	126	106	116	39.3	123	41.7	129	44.0
12	0.348	0.5	106	85	95	33.2	103	35.9	109	37.8
13	0.355	0.4	85	65	75	26.8	83	29.6	88	31.2
14	0.355	0.3	65	45	55	19.6	64	22.7	67	23.9
15	0.328	0.2	45	25	35	11.5	44	14.5	47	15.3
16	0.289	0.1	25	5	15	4.4	25	7.1	26	7.5
17	0.074	0	5	0	3	0.2	5	0.4	5	0.4
					F (#) =	642	F (#) =	670	F (#) =	707
					A (in) =	0.968	A (in) =	0.952	A (in) =	0.952

Figure 8. Stress Distribution @ Foot