MATRIX CONSULTING ENGINEERS
1170 PACIFIC STREET
SAN LUIS OBISPO, CA 93401
PH. 805.786.4802 FX. 805.786.4817

STRUCTURAL CALCULATIONS

for

HELIODYNE SOLAR COLLECTOR RACK STRUCTURES

GOBI 410 AT 35 DEGREES

FOR HELIODYNE, INC.

WISCONSIN
KEVIN T.
DEVANEY
E-41637
SAN LUIS OBISPO
CA
PROFESSIONAL ENGINEER

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Heliodyne Rack Structure with Gobi 410 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 410 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 410 at 35 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	12.9	0	2.3
Condition 2	12.9	14.3	2.1
Condition 3	9.7	18.6	1.9

(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 35 degrees

Building Type	Monosloped Roof				ASCE 7-05 Reference
Roof angle =	35	degrees			
Frame Tributary	4.2	ft			
	q_h(design) =	12.9	psf	(Based on rack component capacities)	
Wind Pressure p_w =	$q_h GC_N$ =	24.5	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
$P_{NL}1$	-19.7	-12.1
$P_{NW}1$	-16.4	-24.5
$P_{NL}2$	-10.2	2.6
$P_{NW}2$	7.3	19.7

(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}	-47.5	-29.1	17.6	47.5
P_{XH}	-39.6	-59.0	-24.7	6.2
P_{YL}	-67.9	-41.5	25.1	67.9
P_{YR}	-56.6	-84.3	-35.2	8.8

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 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	-461	461	235	630	YES
D2	0	-494	494	235	630	YES
D3	0	-595	595	235	630	YES
D4	0	-628	628	235	630	YES
D5	0	-94	94	235	630	YES
D6	0	-127	127	235	630	YES
D7	0	324	324	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	406	-167	439	303	600	YES
D2	406	-196	450	299	600	YES
D3	408	-37	410	320	600	YES
D4	408	-66	413	316	600	YES
D5	37	219	222	45	690	YES
D6	37	190	194	44	690	YES
D7	-246	378	451	88	1300	YES
D8	-246	349	427	90	1300	YES

Collector 410 - 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	74	0.17	405	0.09	168	0.01	0	0.00	0.14	0.17	0.18	0.18
D2	74	0.17	405	0.09	198	0.01	0	0.00	0.14	0.17	0.18	0.18
D3	74	0.17	407	0.09	38	0.00	0	0.00	0.14	0.17	0.17	0.18
D4	74	0.17	407	0.09	68	0.00	0	0.00	0.14	0.17	0.17	0.18
D5	7	0.02	37	0.01	0	0.00	222	0.01	0.03	0.03	0.02	0.03
D6	7	0.02	37	0.01	0	0.00	192	0.01	0.03	0.03	0.02	0.03
D7	45	0.10	245	0.05	0	0.00	384	0.02	0.11	0.13	0.10	0.13
D8	45	0.10	245	0.05	0	0.00	354	0.02	0.11	0.12	0.10	0.13
										Max Ratio =		0.18

Collector 410- 35 degrees
Member Rear Leg
Loading Wind

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

ϕC_e = 6.2 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	459	0.02	0	0.00	0.00	0.00	0.02	0.00
D2	0	0.00	0	0.00	491	0.02	0	0.00	0.00	0.00	0.02	0.00
D3	0	0.00	0	0.00	593	0.02	0	0.00	0.00	0.00	0.02	0.00
D4	0	0.00	0	0.00	625	0.03	0	0.00	0.00	0.00	0.03	0.00
D5	0	0.00	0	0.00	97	0.00	0	0.00	0.00	0.00	0.00	0.00
D6	0	0.00	0	0.00	129	0.01	0	0.00	0.00	0.00	0.01	0.00
D7	0	0.00	0	0.00	0	0.00	319	0.05	0.05	0.05	0.00	0.05
D8	0	0.00	0	0.00	0	0.00	286	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	370.9	127	71.2	392	YES	183	YES
S2	394.3	127	72.2	414	YES	209	YES
S3	318.4	127	68.2	343	YES	239	YES
S4	341.9	127	69.6	365	YES	265	YES
S5	0	11.6	0.0	11.6	YES	26	YES
S6	0	11.6	0.0	11.6	YES	52	YES
S7	103.7	-76.7	53.5	129	YES	0	YES
S8	115.5	-76.7	56.4	139	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 410 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 $q_h = 0.00256 K_z K_{zt} K_d V^2 I$ =		9.7	12.9	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 =	2.7		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	78.0	18.6
S2	75	12.9	29.6	87.1	446	60.0	14.3

Clip/Rail/Mounting Foot Anaylsis Results

Collector 410
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	-145	145	235	630	YES
F2	0	449	449	55	1274	YES
F3	0	-246	246	235	630	YES
F4	0	399	399	55	1274	YES
F5	0	130	130	55	1274	YES
F6	0	586	586	55	1274	YES
F7	0	443	443	55	1274	YES
F8	0	743	743	55	1274	YES
E1	0	-327	327	235	630	YES
E2	0	250	250	55	1274	YES
E3	0	-461	461	235	630	YES
E4	0	183	183	55	1274	YES
E5	0	39	39	55	1274	YES
E6	0	433	433	55	1274	YES
E7	0	458	458	55	1274	YES
E8	0	642	642	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	304	49	308	-26	600	YES
F2	152	477	500	37	600	YES
F3	306	146	339	-9	600	YES
F4	153	526	547	39	600	YES
F5	28	338	339	50	690	YES
F6	14	621	622	54	690	YES
F7	-184	457	493	77	690	YES
F8	-92	681	687	63	690	YES
E1	406	-51	409	318	600	YES
E2	203	333	390	24	600	YES
E3	408	79	416	-24	600	YES
E4	204	398	447	28	600	YES
E5	37	335	337	49	690	YES
E6	19	526	526	53	690	YES
E7	-246	493	551	81	690	YES
E8	-123	606	618	66	690	YES

Collector	410 - 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	55	0.13	304	0.07	151	0.01	0	0.00	0.11	0.13	0.14	0.13
F2	28	0.06	152	0.03	0	0.00	430	0.03	0.08	0.09	0.06	0.09
F3	56	0.13	306	0.07	251	0.02	0	0.00	0.11	0.13	0.14	0.13
F4	28	0.06	153	0.03	0	0.00	380	0.02	0.08	0.09	0.06	0.09
F5	5	0.01	28	0.01	0	0.00	122	0.01	0.02	0.02	0.01	0.02
F6	3	0.01	14	0.00	0	0.00	567	0.04	0.04	0.04	0.01	0.04
F7	34	0.08	184	0.04	0	0.00	433	0.03	0.09	0.10	0.08	0.11
F8	17	0.04	92	0.02	0	0.00	723	0.05	0.08	0.08	0.04	0.09
E1	74	0.17	405	0.09	330	0.02	0	0.00	0.14	0.17	0.19	0.18
E2	37	0.08	203	0.04	0	0.00	236	0.02	0.09	0.10	0.08	0.10
E3	74	0.17	407	0.09	464	0.03	0	0.00	0.14	0.17	0.20	0.18
E4	37	0.08	204	0.04	0	0.00	169	0.01	0.08	0.10	0.08	0.10
E5	7	0.02	37	0.01	0	0.00	33	0.00	0.02	0.02	0.02	0.02
E6	3	0.01	19	0.00	0	0.00	417	0.03	0.03	0.03	0.01	0.03
E7	45	0.10	245	0.05	0	0.00	448	0.03	0.12	0.13	0.10	0.13
E8	22	0.05	123	0.03	0	0.00	625	0.04	0.08	0.09	0.05	0.09
										Max Ratio =		0.20

Collector 410 - 35 degrees
Member Rear Leg
Loading Wind + Snow

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

ϕC_e = 6.2 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	151	0	0	0.00	0.00	0.00	0.02	0.00
F2	0	0	0	0	0	0	430	0.02	0.02	0.02	0.00	0.02
F3	0	0	0	0	251	0	0	0.00	0.00	0.00	0.03	0.00
F4	0	0	0	0	0	0	380	0.01	0.01	0.01	0.00	0.01
F5	0	0	0	0	0	0	122	0.00	0.00	0.00	0.00	0.00
F6	0	0	0	0	0	0	567	0.03	0.03	0.03	0.00	0.03
F7	0	0	0	0	0	0	433	0.03	0.03	0.03	0.00	0.03
F8	0	0	0	0	0	0	723	0.04	0.04	0.04	0.00	0.04
E1	0	0	0	0	330	0.01	0	0.00	0.00	0.00	0.01	0.00
E2	0	0	0	0	0	0.00	236	0.04	0.04	0.04	0.00	0.04
E3	0	0	0	0	464	0.02	0	0.00	0.00	0.00	0.02	0.00
E4	0	0	0	0	0	0.00	169	0.03	0.03	0.03	0.00	0.03
E5	0	0	0	0	0	0.00	33	0.01	0.01	0.01	0.00	0.01
E6	0	0	0	0	0	0.00	417	0.07	0.07	0.07	0.00	0.07
E7	0	0	0	0	0	0.00	448	0.07	0.07	0.07	0.00	0.07
E8	0	0	0	0	0	0.00	625	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

$SF_y = 0 \rightarrow E = 2*R_y \rightarrow R_y = E/2$

$SM_A = 0 \rightarrow Ee = 4*R_x \rightarrow R_x = Ee/4$

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	78	1.9	141	4.2	71	149	517
2	60	2.1	141	4.2	70	148	565
3	0	2.3	128	4.2	64	135	658

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	77	222	64.8	561	YES	86	71	126	74	64	235
2	77	171	53.7	594	YES	110	70	139	74	68	269
3	77	0	16.7	666	YES	177	64	171	67	75	360

(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	297	22.6	333	25.3
2	0.145	1.5	277	259	268	38.9	279	40.4	312	45.3
3	0.201	1.4	259	241	250	50.2	260	52.3	292	58.7
4	0.253	1.3	241	223	232	58.6	242	61.2	271	68.6
5	0.277	1.2	223	204	213	59.1	224	62.0	251	69.5
6	0.256	1.1	204	186	195	50.0	206	52.6	230	59.0
7	0.27	1	186	168	177	47.8	187	50.6	210	56.7
8	0.293	0.9	168	150	159	46.6	169	49.5	189	55.5
9	0.316	0.8	150	132	141	44.5	151	47.6	169	53.4
10	0.33	0.7	132	114	123	40.5	132	43.7	148	49.0
11	0.34	0.6	114	95	104	35.5	114	38.8	128	43.5
12	0.348	0.5	95	77	86	30.0	96	33.4	108	37.4
13	0.355	0.4	77	59	68	24.2	78	27.6	87	30.9
14	0.355	0.3	59	41	50	17.7	59	21.1	67	23.6
15	0.328	0.2	41	23	32	10.4	41	13.5	46	15.1
16	0.289	0.1	23	5	14	3.9	23	6.6	26	7.4
17	0.074	0	5	0	2	0.2	5	0.3	5	0.4
					F (#) =	580	F (#) =	624	F (#) =	699
					A (in) =	0.968	A (in) =	0.952	A (in) =	0.952

Figure 8. Stress Distribution @ Foot