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PROJECT:	HELIODYNE RACK				
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STRUCTURAL CALCULATIONS

for

HELIODYNE SOLAR COLLECTOR RACK STRUCTURES

GOBI 408 AT 45 DEGREES

FOR HELIODYNE, INC.

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Heliodyne Rack Structure with Gobi 408 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 408 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 408 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	14.3	0	2.6
Condition 2	14.3	19.0	2.4
Condition 3	9.7	23.8	2.2

(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 408 at 45 degrees

Building Type	Monosloped Roof				ASCE 7-05 Reference
Roof angle =	45	degrees			
Frame Tributary	4.2	ft			
	q_h(design) =	14.3	psf	(Based on rack component capacities)	
Wind Pressure p_w =	$q_h GC_N$ =	23.1	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
$P_{NL}1$	-21.9	-14.6
$P_{NW}1$	-15.8	-23.1
$P_{NL}2$	-10.9	4.9
$P_{NW}2$	9.7	25.5

(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}	-65.0	-43.3	28.9	75.8
P_{XH}	-46.9	-68.6	-32.5	14.4
P_{YL}	-65.0	-43.3	28.9	75.8
P_{YR}	-46.9	-68.6	-32.5	14.4

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 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	-414	414	225	571	YES
D2	0	-440	440	225	571	YES
D3	0	-529	529	225	571	YES
D4	0	-555	555	225	571	YES
D5	0	-85	85	225	571	YES
D6	0	-111	111	225	571	YES
D7	0	371	371	45	721	YES
D8	0	345	345	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	515	60	519	-38	600	YES
D2	515	36	517	-41	600	YES
D3	520	170	547	-27	600	YES
D4	520	146	540	-29	600	YES
D5	17	229	230	41	690	YES
D6	17	206	206	40	690	YES
D7	-415	205	463	109	530	YES
D8	-415	182	454	111	530	YES

Collector 408 - 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	94	0.21	515	0.11	0	0.00	63	0.00	0.19	0.22	0.21	0.23
D2	94	0.21	514	0.11	0	0.00	39	0.00	0.18	0.22	0.21	0.23
D3	95	0.22	519	0.11	0	0.00	174	0.01	0.19	0.23	0.22	0.24
D4	95	0.22	519	0.11	0	0.00	149	0.01	0.19	0.23	0.22	0.24
D5	3	0.01	17	0.00	0	0.00	234	0.02	0.02	0.02	0.01	0.02
D6	3	0.01	17	0.00	0	0.00	209	0.01	0.02	0.02	0.01	0.02
D7	76	0.17	415	0.09	0	0.00	210	0.01	0.16	0.19	0.17	0.19
D8	76	0.17	415	0.09	0	0.00	185	0.01	0.16	0.18	0.17	0.19
										Max Ratio =		0.24

Collector 408 - 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	418	0.02	0	0.00	0.00	0.00	0.02	0.00
D2	0	0.00	0	0.00	443	0.02	0	0.00	0.00	0.00	0.02	0.00
D3	0	0.00	0	0.00	533	0.02	0	0.00	0.00	0.00	0.02	0.00
D4	0	0.00	0	0.00	557	0.02	0	0.00	0.00	0.00	0.02	0.00
D5	0	0.00	0	0.00	89	0.00	0	0.00	0.00	0.00	0.00	0.00
D6	0	0.00	0	0.00	114	0.00	0	0.00	0.00	0.00	0.00	0.00
D7	0	0.00	0	0.00	0	0.00	366	0.06	0.06	0.06	0.00	0.06
D8	0	0.00	0	0.00	0	0.00	341	0.06	0.06	0.06	0.00	0.06
										Max Ratio =		0.06

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	410.8	161	68.6	441	YES	169	YES
S2	431.1	161	69.5	460	YES	189	YES
S3	367.6	162	66.2	402	YES	217	YES
S4	387.9	162	67.3	420	YES	237	YES
S5	0	5.22	0.0	5.22	YES	26	YES
S6	0	5.21	0.0	5.21	YES	46	YES
S7	316.4	-130	67.7	342	YES	0	YES
S8	325.6	-130	68.3	350	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 408 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	14.3 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	100.0	23.8
S2	75	14.3	25.5	85.7	507	80.0	19.0

Clip/Rail/Mounting Foot Anaylsis Results

Collector 408
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	-100	100	225	571	YES
F2	0	400	400	45	721	YES
F3	0	-178	178	225	571	YES
F4	0	361	361	45	721	YES
F5	0	122	122	45	721	YES
F6	0	512	512	45	721	YES
F7	0	430	430	45	721	YES
F8	0	667	667	45	721	YES
E1	0	-293	293	225	571	YES
E2	0	224	224	45	721	YES
E3	0	-408	408	225	571	YES
E4	0	166	166	45	721	YES
E5	0	36	36	45	721	YES
E6	0	388	388	45	721	YES
E7	0	492	492	45	721	YES
E8	0	616	616	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	348	201	402	-15	600	YES
F2	175	505	535	26	600	YES
F3	351	275	446	-7	600	YES
F4	177	543	571	27	600	YES
F5	11	315	315	43	690	YES
F6	6	563	563	44	690	YES
F7	-280	299	410	88	1300	YES
F8	-141	555	572	59	690	YES
E1	515	168	542	-27	600	YES
E2	258	415	489	13	600	YES
E3	520	279	590	-17	600	YES
E4	260	471	538	16	600	YES
E5	17	338	338	42	690	YES
E6	8	500	500	44	690	YES
E7	-415	314	521	98	530	YES
E8	-208	488	531	68	690	YES

Collector	408 - 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	63	0.14	348	0.08	113	0.01	0	0.00	0.12	0.14	0.15	0.15
F2	32	0.07	175	0.04	0	0.00	370	0.02	0.09	0.10	0.07	0.10
F3	64	0.15	351	0.08	190	0.01	0	0.00	0.12	0.15	0.16	0.15
F4	32	0.07	177	0.04	0	0.00	331	0.02	0.08	0.09	0.07	0.10
F5	2	0.00	11	0.00	0	0.00	109	0.01	0.01	0.01	0.00	0.01
F6	1	0.00	6	0.00	0	0.00	482	0.03	0.03	0.03	0.00	0.03
F7	51	0.12	280	0.06	0	0.00	417	0.03	0.13	0.14	0.12	0.15
F8	26	0.06	141	0.03	0	0.00	637	0.04	0.09	0.10	0.06	0.10
E1	94	0.21	515	0.11	303	0.02	0	0.00	0.18	0.21	0.23	0.23
E2	47	0.11	258	0.06	0	0.00	198	0.01	0.10	0.12	0.11	0.12
E3	95	0.22	519	0.11	418	0.03	0	0.00	0.18	0.22	0.24	0.23
E4	48	0.11	260	0.06	0	0.00	141	0.01	0.10	0.12	0.11	0.12
E5	3	0.01	17	0.00	0	0.00	25	0.00	0.01	0.01	0.01	0.01
E6	2	0.00	9	0.00	0	0.00	363	0.02	0.03	0.03	0.00	0.03
E7	76	0.17	415	0.09	0	0.00	481	0.03	0.18	0.20	0.17	0.21
E8	38	0.09	207	0.05	0	0.00	591	0.04	0.11	0.12	0.09	0.13
										Max Ratio =		0.24

Collector 408 - 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	113	0	0	0.00	0.00	0.00	0.02	0.00
F2	0	0	0	0	0	0	370	0.01	0.01	0.01	0.00	0.01
F3	0	0	0	0	190	0	0	0.00	0.00	0.00	0.03	0.00
F4	0	0	0	0	0	0	331	0.01	0.01	0.01	0.00	0.01
F5	0	0	0	0	0	0	109	0.00	0.00	0.00	0.00	0.00
F6	0	0	0	0	0	0	482	0.02	0.02	0.02	0.00	0.02
F7	0	0	0	0	0	0	417	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	303	0.01	0	0.00	0.00	0.00	0.01	0.00
E2	0	0	0	0	0	0.00	198	0.03	0.03	0.03	0.00	0.03
E3	0	0	0	0	418	0.02	0	0.00	0.00	0.00	0.02	0.00
E4	0	0	0	0	0	0.00	141	0.02	0.02	0.02	0.00	0.02
E5	0	0	0	0	0	0.00	25	0.00	0.00	0.00	0.00	0.00
E6	0	0	0	0	0	0.00	363	0.06	0.06	0.06	0.00	0.06
E7	0	0	0	0	0	0.00	481	0.08	0.08	0.08	0.00	0.08
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 (#)	ΣM_O = R_y*5.7"
1	100	2.2	139	2.9	70	101	535
2	80	2.4	138	2.9	69	100	571
3	0	2.6	119	2.9	59	86	616

Table 10. Seismic Analysis Results (1)

Snow Case	D (#)	0.75* S (#)	σ_{vert} (psi)(2)	ΣM_R = F*A	ΣM_R > ΣM_O ?	T_y (#)	V_y (#)	T_x (#)	V_x (#)	Angle (deg)	Z_α (#)
1	64	203	57.7	575	YES	94	70	72	50	63	187
2	64	162	48.9	603	YES	112	69	82	50	66	212
3	64	0	13.9	671	YES	165	59	109	43	75	284

(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	302	284	293	22.3	302	22.9	335	25.5
2	0.145	1.5	284	265	274	39.8	283	41.0	315	45.7
3	0.201	1.4	265	247	256	51.4	264	53.1	294	59.1
4	0.253	1.3	247	228	237	60.0	246	62.2	274	69.2
5	0.277	1.2	228	209	219	60.6	227	63.0	253	70.1
6	0.256	1.1	209	191	200	51.2	209	53.4	232	59.5
7	0.27	1	191	172	181	49.0	190	51.3	212	57.1
8	0.293	0.9	172	153	163	47.7	172	50.3	191	56.0
9	0.316	0.8	153	135	144	45.6	153	48.4	170	53.8
10	0.33	0.7	135	116	126	41.4	135	44.4	150	49.4
11	0.34	0.6	116	98	107	36.4	116	39.4	129	43.9
12	0.348	0.5	98	79	88	30.8	97	33.9	108	37.7
13	0.355	0.4	79	60	70	24.8	79	28.0	88	31.1
14	0.355	0.3	60	42	51	18.2	60	21.4	67	23.8
15	0.328	0.2	42	23	33	10.7	42	13.7	46	15.2
16	0.289	0.1	23	5	14	4.0	23	6.7	26	7.5
17	0.074	0	5	0	2	0.2	5	0.3	5	0.4
					F (#) =	594	F (#) =	634	F (#) =	705
					A (in) =	0.968	A (in) =	0.952	A (in) =	0.952

Figure 8. Stress Distribution @ Foot