

MASTER

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Wind-Load Analysis

For

COLLECTOR SUBSYSTEM
FOR THE 10-MW_e SOLAR-THERMAL
CENTRAL-RECEIVER PILOT PLANT

PHASE 1

December 1978

AC03-79ET21007

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Summary

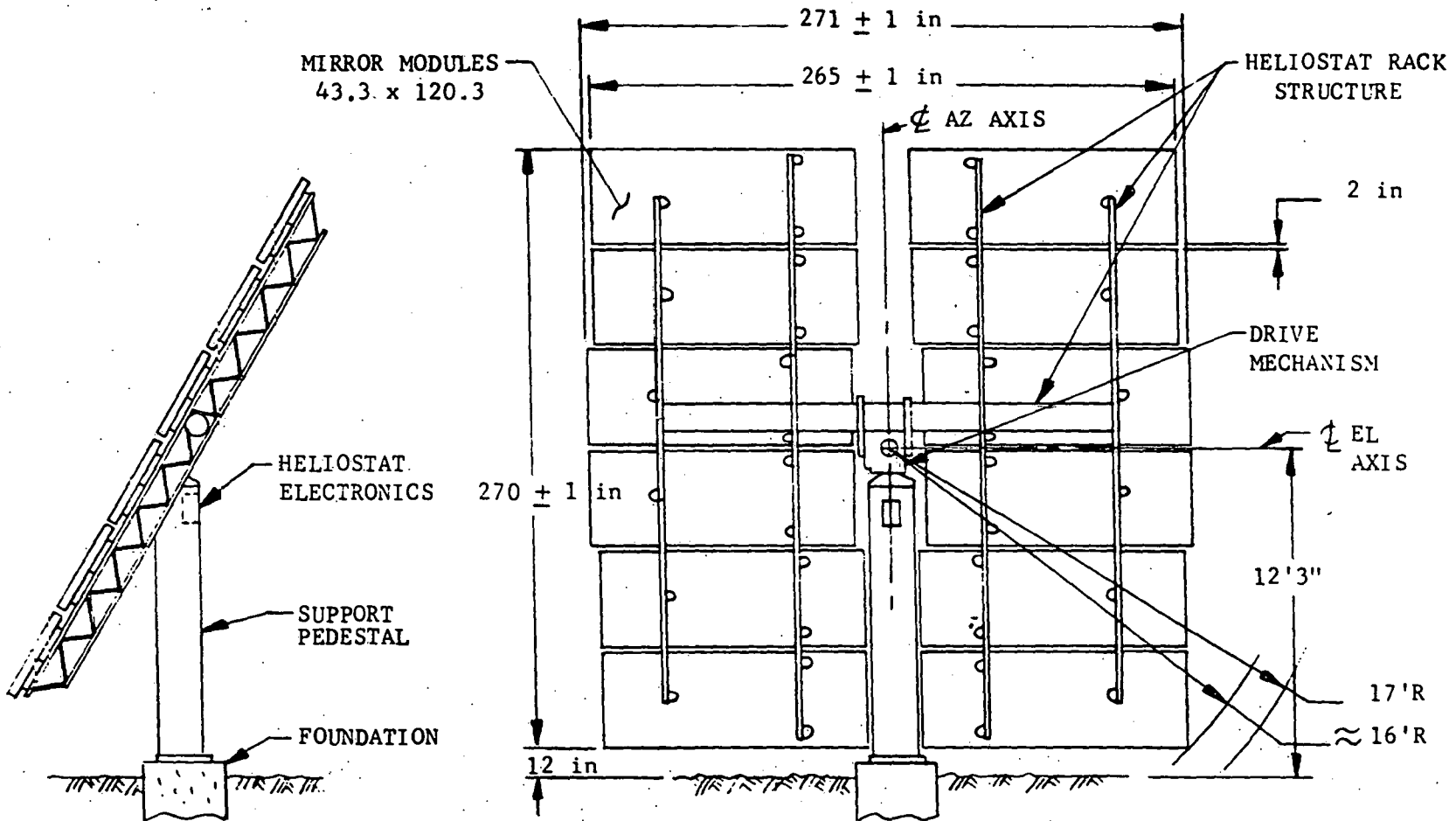
This "Wind Load Analysis" report is being submitted to give the basis for the wind loads and a summary of the effects of the resultant loads.

Our heliostat design is based on wind loading data taken from "Wind Forces on Structures," ASCE Paper No. 3269, Transactions, ASCE, Volume 126, PT2, 1961. The wind loads on the heliostat structure were derived using the force coefficients data in Figure 5 of ASCE Paper No. 3269. The aspect ratio of the baseline heliostat is 1. The solidarity ratio is 0.875. In deriving wind loads, we have assumed a solidarity ratio of 1, and therefore based the loads on the total enclosed area rather than the actual mirror area.

A computer model with 61 grid points and 85 members was used to predict the structural deformations of all the heliostat structural components from the pedestal/foundation interface to the mirror reflective surfaces. The mirror surface rotations are tabulated. The results indicate the current structural configuration will meet requirements of 1.62 mrad standard deviation for structural deflections of the heliostat subject to 27 mph wind and gravity. These values will be optimized with adjustments that compensate for gravity.

Stress analyses are in process on all the heliostat structural components and mechanisms. These are based on the maximum loads (90 mph winds at 10° angle of attack and 50 mph winds with the heliostat in any orientation). The initial calculations on the bar joists and gear drive mechanism components show acceptable safety factors.

10 MW_e COLLECTOR SYSTEM HELIOSTAT



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Figure 1

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Wind Load Analysis

The wind loads and center of pressure on the heliostat are taken from "Wind Forces on Structure," ASCE Paper No. 3269, Transactions, ASCE, Vol. 126, PT2, 1961.

The wind load distribution on the heliostat is assumed to be uniform across the width but vary along the height as indicated in Fig. 2 and Table I.

The wind reduction factor vs elevation is derived from equation 1,

$$V_H = V_{Ref} \left(\frac{H}{H_{Ref}} \right)^{0.15} \frac{1}{\dots}$$

in which

V_H = Wind velocity at H feet elevation.

V_{Ref} = Wind velocity at 30 feet elevation.

H = Elevation in feet.

H_{Ref} = 30 feet of elevation.

The wind reduction factor curve is plotted on Fig. 3. It is then applied to the wind load distribution on Fig. 2 and Table I. The resulting wind load distributions are shown in Table II. They are in terms of a normal load plus two moments for each mirror module for each loading case with 27 mph wind.

Computer Model

The heliostat in Fig. 1 is idealized into a structural model as in Fig. 4. The geometry of the structural model on Table III reflects the current configuration.

The NASTRAN computer program is used to calculate the deflections and rotations of the mirror modules. The heliostat is rotated in 10° increments for 10 positions. Three different wind directions are used for each position. Three deflections and three rotations are calculated for each mirror module. However, as far as point accuracy is concerned, the three deflections and the x rotation are not of any importance. Only the y and z rotations are listed in Table IV. The resultant rotations are computed by taking the root sum squares of the two rotations. The average rotation of the twelve mirrors are calculated for each case. The rotations are due to gravity plus 27 mph wind.

Comparing the deflection values with the 1.62 mrad standard deviation for the heliostat structural deformations, the current structural configuration is satisfactory to meet the specification requirements. Total structural deflections will be much better than what is shown in this analysis because the analysis does not account for mirror module interalignment and the final field pointing adjustment which will eliminate part of the deadweight deflection.

Wind Load Distribution on Heliostat
(Wind Reduction Factor not included)

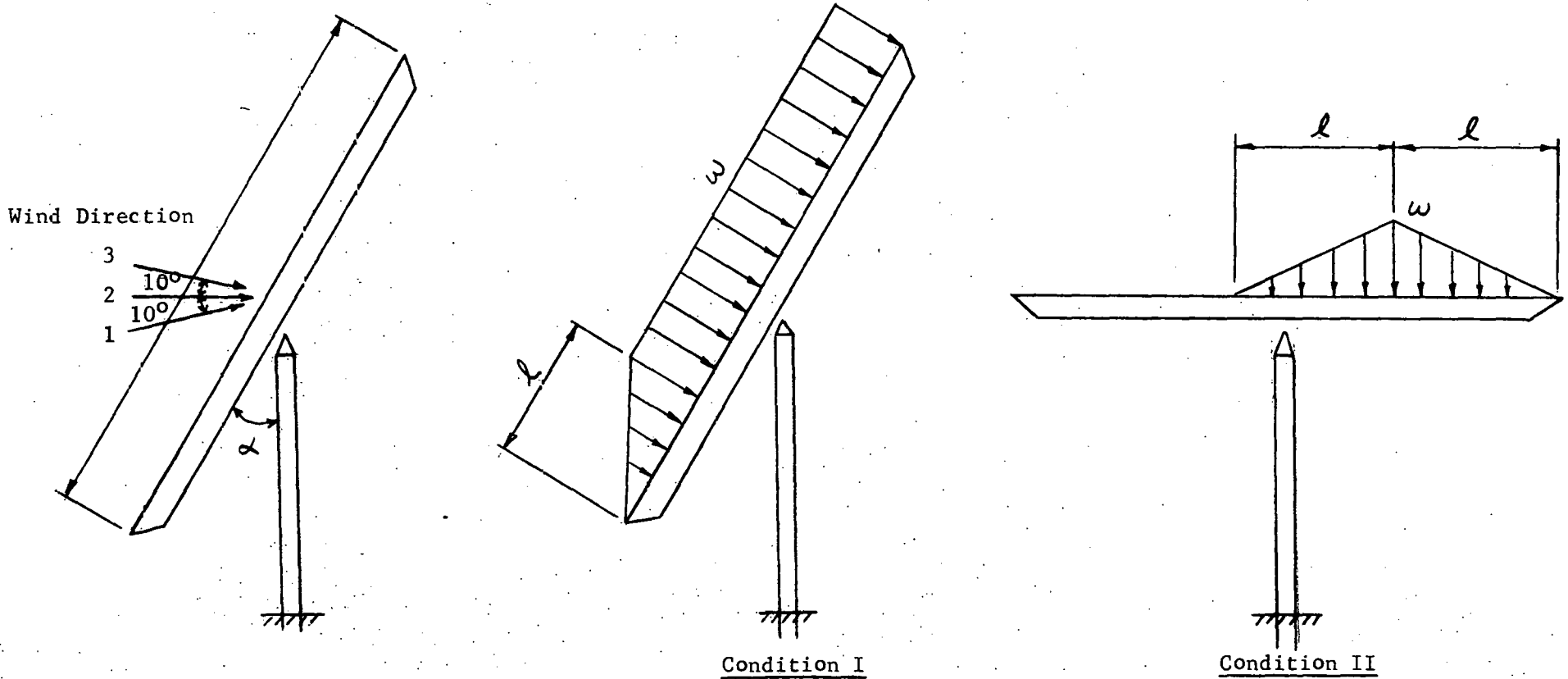


Fig. 2

Table I - Wind Load Distribution on Heliostat
(27 mph wind)

Heliostat Attitude	Wind Direction	Distributed Load W along Heliostat (lbs/in)	Length l (in)	Loading Condition (Fig. 3)	
0°	1	4.099	33.1	I	
	2	3.848	0		
	3	4.099	33.1		
10°	1	4.295	56.2		
	2	4.099	33.1		
	3	3.848	0		
20°	1	4.519	80.3		
	2	4.295	56.2		
	3	4.099	33.1		
30°	1	4.598	80.3		
	2	4.519	80.3		
	3	4.295	56.2		
40°	1	4.727	92.8		
	2	4.598	80.3		
	3	4.519	80.3		
50°	1	4.672	119.3		
	2	4.727	92.8		
	3	4.598	80.3		
60°	1	5.068	229.0		
	2	4.672	119.3		
	3	4.727	92.8		
70°	1	4.829	72.9		II
	2	5.068	229.0		I
	3	4.672	119.3		
80°	1	0	0	II	
	2	4.829	72.9	I	
	3	5.068	229.0		
90°	1	-4.829	72.9	II	
	2	0	0		
	3	4.829	72.9		

Wind Reduction Factor vs Elevation

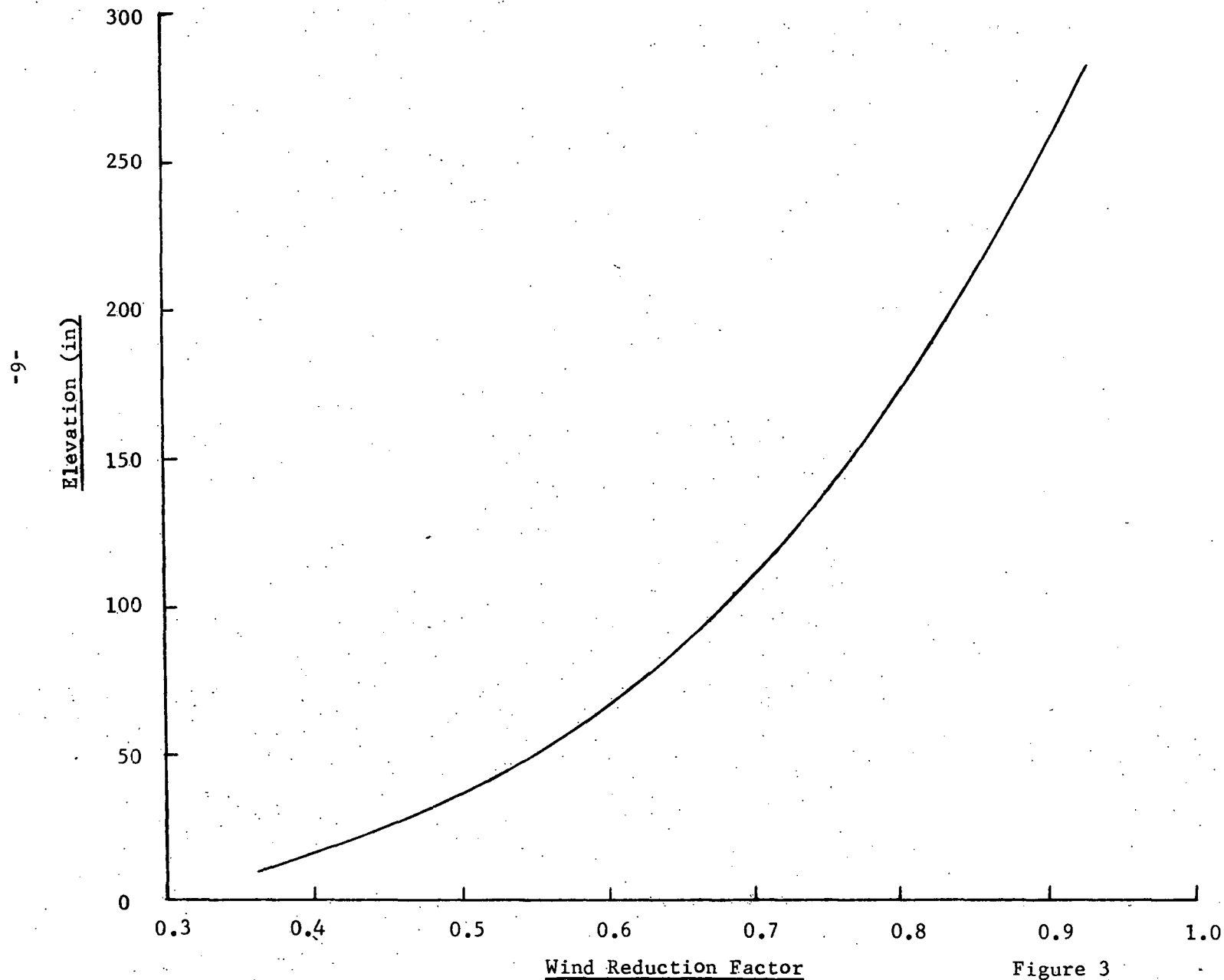
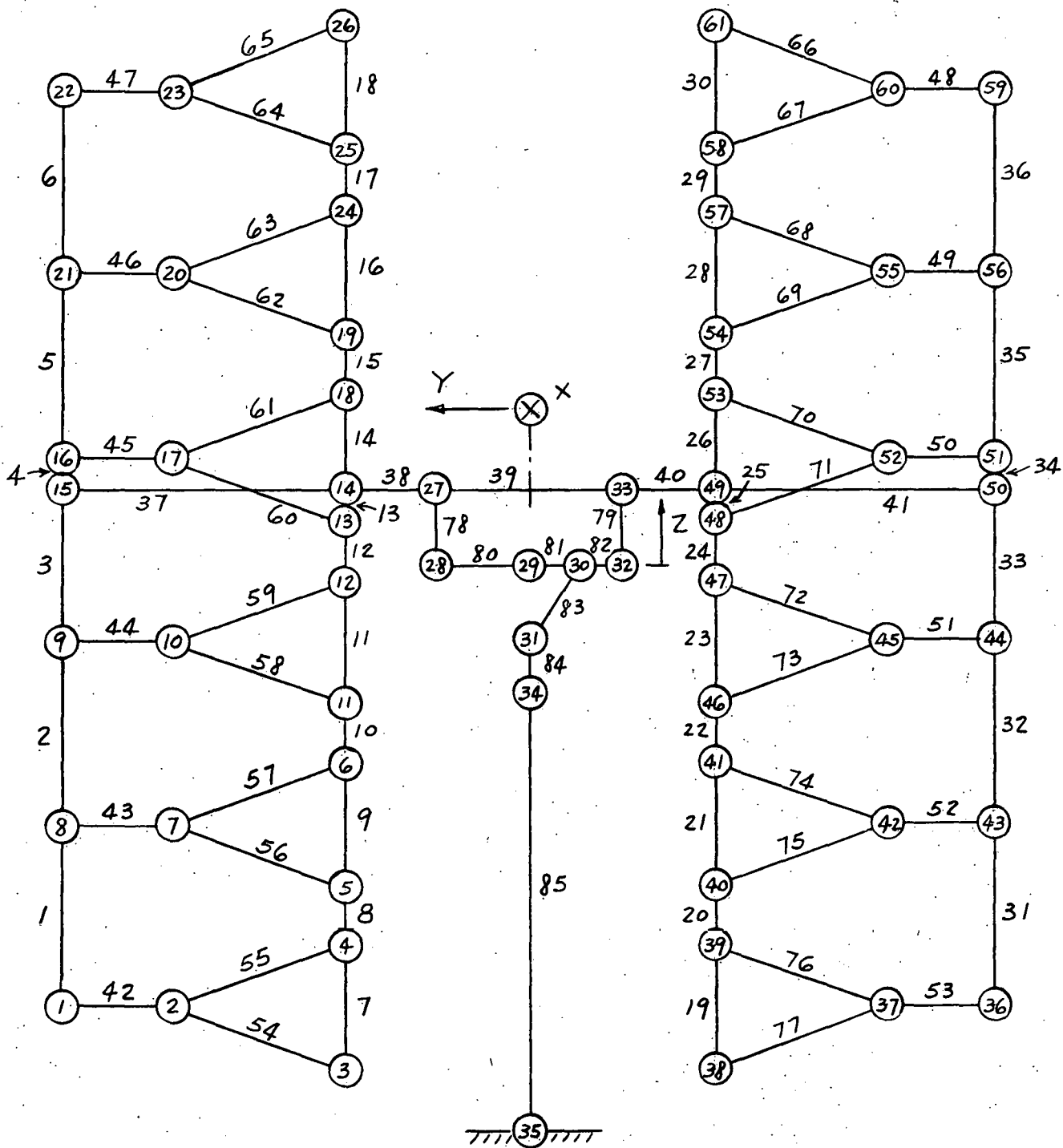


Figure 3



Notes:

1. Reflective Assembly pivots about Grid Point 29.
2. Model is looking at the back of the Reflective Assembly.

Fig. 4 - Computer Model

Table II - Wind Loads on Mirror Module Due to 27 MPH Wind

- Applicable to:
1. Heliostat Attitude $\alpha = 0^\circ$, Wind Direction 1 .
 2. Heliostat Attitude $\alpha = 10^\circ$, Wind Direction 2 .
 3. Heliostat Attitude $\alpha = 20^\circ$, Wind Direction 3 .
 4. Heliostat Attitude $\alpha =$, Wind Direction .

Mirror Location (Grid Point)	Normal Load P (lbs)	Moment, M_y (in-lbs)	Moment, M_z (in-lbs)
2	-31.3	-230.5	-190.9
7	-58.5	-37.9	-356.9
10	-66.9	-28.9	-508.4
17	-73.8	-24.1	-560.9
20	-79.4	-13.9	-484.3
23	-82.4	27.7	-502.6
37	-31.3	-230.5	190.9
42	-58.5	-37.9	356.9
45	-66.9	-28.9	508.4
52	-73.8	-24.1	560.9
55	-79.4	-13.9	484.3
60	-82.4	27.7	502.6

Table II - Wind Loads on Mirror Module Due to 27 MPH Wind

- Applicable to:
1. Heliostat Attitude $\alpha = 0^\circ$, Wind Direction 2 .
 2. Heliostat Attitude $\alpha = 10^\circ$, Wind Direction 3 .
 3. Heliostat Attitude $\alpha =$; Wind Direction .
 4. Heliostat Attitude $\alpha =$, Wind Direction .

Mirror Location (Grid Point)	Normal Load P (lbs)	Moment, M_y (in-lbs)	Moment, M_z (in-lbs)
2	-40.1	-84.3	-244.6
7	-54.5	-39.8	-332.5
10	-62.8	-27.0	-477.3
17	-69.3	-23.4	-526.7
20	-74.5	-12.3	-454.5
23	-77.3	27.1	-471.5
37	-40.1	-84.3	244.6
42	-54.5	-39.8	332.5
45	-62.8	-27.0	477.3
52	-69.3	-23.4	526.7
55	-74.5	-12.3	454.5
60	-77.3	27.1	471.5

Table II - Wind Loads on Mirror Module Due to 27 MPH Wind

- Applicable to:
1. Heliostat Attitude $\alpha = 0^\circ$, Wind Direction 3 .
 2. Heliostat Attitude $\alpha =$, Wind Direction .
 3. Heliostat Attitude $\alpha =$, Wind Direction .
 4. Heliostat Attitude $\alpha =$, Wind Direction .

Mirror Location (Grid Point)	Normal Load P (lbs)	Moment, M_y (in-lbs)	Moment, M_z (in-lbs)
2	-30.7	-226.0	-187.3
7	-58.0	-40.9	-353.8
10	-66.9	-28.9	-508.4
17	-73.8	-24.1	-560.9
20	-79.4	-13.9	-484.3
23	-82.4	27.7	-502.6
37	-30.7	-226.0	187.3
42	-58.0	-40.9	353.8
45	-66.9	-28.9	508.4
52	-73.8	-24.1	560.9
55	-79.4	-13.9	484.3
60	-82.4	27.7	502.6

Table II - Wind Loads on Mirror Module Due to 27 MPH Wind

- Applicable to:
1. Heliostat Attitude $\alpha = 10^\circ$, Wind Direction 1 .
 2. Heliostat Attitude $\alpha = 20^\circ$, Wind Direction 2 .
 3. Heliostat Attitude $\alpha = 30^\circ$, Wind Direction 3 .
 4. Heliostat Attitude $\alpha =$, Wind Direction .

Mirror Location (Grid Point)	Normal Load P (lbs)	Moment, M_y (in-lbs)	Moment, M_z (in-lbs)
2	-22.2	-164.3	-135.4
7	-60.9	-68.5	-371.5
10	-70.5	-24.9	-535.8
17	-76.9	-23.2	-584.4
20	-82.7	-18.0	-504.5
23	-85.8	33.6	-523.4
37	-22.2	-164.3	135.4
42	-60.9	-68.5	371.5
45	-70.5	-24.9	535.8
52	-76.9	-23.2	584.4
55	-82.7	-18.0	504.5
60	-85.8	33.6	523.4

Table II - Wind Loads on Mirror Module Due to 27 MPH Wind

- Applicable to:
1. Heliostat Attitude $\alpha = 20^\circ$, Wind Direction 1.
 2. Heliostat Attitude $\alpha = 30^\circ$, Wind Direction 2.
 3. Heliostat Attitude $\alpha = 40^\circ$, Wind Direction 3.
 4. Heliostat Attitude $\alpha =$, Wind Direction .

Mirror Location (Grid Point)	Normal Load P (lbs)	Moment, M_y (in-lbs)	Moment, M_z (in-lbs)
2	-16.9	-125.1	-103.1
7	-55.9	-154.9	-341.0
10	-74.7	-22.6	-567.7
17	-80.9	-24.2	-614.8
20	-86.5	-15.0	-527.7
23	-89.3	34.1	-544.7
37	-16.9	-125.1	103.1
42	-55.9	-154.9	341.0
45	-74.7	-22.6	567.7
52	-80.9	-24.2	614.8
55	-86.5	-15.0	527.7
60	-89.3	34.1	544.7

Table II - Wind Loads on Mirror Module Due to 27 MPH Wind

- Applicable to:
1. Heliostat Attitude $\alpha = 30^\circ$, Wind Direction 1.
 2. Heliostat Attitude $\alpha = 40^\circ$, Wind Direction 2.
 3. Heliostat Attitude $\alpha = 50^\circ$, Wind Direction 3.
 4. Heliostat Attitude $\alpha =$, Wind Direction .

Mirror Location (Grid Point)	Normal Load P (lbs)	Moment, M_y (in-lbs)	Moment, M_z (in-lbs)
2	-17.8	-131.7	-108.6
7	-58.0	-157.8	-353.8
10	-76.6	-20.5	-582.2
17	-82.5	-25.5	-627.0
20	-87.7	-9.6	-535.0
23	-89.8	34.7	-547.8
37	-17.8	-131.7	108.6
42	-58.0	-157.8	353.8
45	-76.6	-20.5	582.2
52	-82.5	-25.5	627.0
55	-87.7	-9.6	535.0
60	-89.8	34.7	547.8

Table II - Wind Loads on Mirror Module Due to 27 MPH Wind

- Applicable to:
1. Heliostat Attitude $\alpha = 40^\circ$, Wind Direction 1.
 2. Heliostat Attitude $\alpha = 50^\circ$, Wind Direction 2.
 3. Heliostat Attitude $\alpha = 60^\circ$, Wind Direction 3.
 4. Heliostat Attitude $\alpha =$, Wind Direction .

Mirror Location (Grid Point)	Normal Load P (lbs)	Moment, M_y (in-lbs)	Moment, M_z (in-lbs)
2	-16.6	-122.8	-101.3
7	-54.2	-156.8	-330.6
10	-79.0	-18.7	-600.4
17	-84.1	-20.7	-639.2
20	-88.9	-12.1	-542.3
23	-90.8	37.7	-553.9
37	-16.6	-122.8	101.3
42	-54.2	-156.8	330.6
45	-79.0	-18.7	600.4
52	-84.1	-20.7	639.2
55	-88.9	-12.1	542.3
60	-90.8	37.7	553.9

Table II - Wind Loads on Mirror Module Due to 27 MPH Wind

- Applicable to:
1. Heliostat Attitude $\alpha = 50^\circ$, Wind Direction 1.
 2. Heliostat Attitude $\alpha = 60^\circ$, Wind Direction 2.
 3. Heliostat Attitude $\alpha = 70^\circ$, Wind Direction 3.
 4. Heliostat Attitude $\alpha = \quad$, Wind Direction .

Mirror Location (Grid Point)	Normal Load P (lbs)	Moment, M_y (in-lbs)	Moment, M_z (in-lbs)
2	-13.3	-98.4	-81.1
7	-42.6	-118.1	-259.9
10	-73.3	-96.1	-557.1
17	-83.1	-12.4	-631.6
20	-86.3	-8.8	-526.4
23	-87.6	37.7	-534.4
37	-13.3	-98.4	81.1
42	-42.6	-118.1	259.9
45	-73.3	-96.1	557.1
52	-83.1	-12.4	631.6
55	-86.3	-8.8	526.4
60	-87.6	37.7	534.4

Table II - Wind Loads on Mirror Module Due to 27 MPH Wind

- Applicable to:
1. Heliostat Attitude $\alpha = 60^\circ$, Wind Direction 1 .
 2. Heliostat Attitude $\alpha = 70^\circ$, Wind Direction 2 .
 3. Heliostat Attitude $\alpha = 80^\circ$, Wind Direction 3 .
 4. Heliostat Attitude $\alpha =$, Wind Direction .

Mirror Location (Grid Point)	Normal Load P (lbs)	Moment, M_y (in-lbs)	Moment, M_z (in-lbs)
2	-7.8	-57.7	-47.6
7	-24.7	-67.2	-150.7
10	-42.7	-70.4	-324.5
17	-61.8	-72.8	-469.7
20	-81.5	-72.3	-497.2
23	-92.1	41.4	-561.8
37	-7.8	-57.7	47.6
42	-24.7	-67.2	150.7
45	-42.7	-70.4	324.5
52	-61.8	-72.8	469.7
55	-81.5	-72.3	497.2
60	-92.1	41.4	561.8

Table II - Wind Loads on Mirror Module Due to 27 MPH Wind

- Applicable to:
1. Heliostat Attitude $\alpha = 70^\circ$, Wind Direction 1.
 2. Heliostat Attitude $\alpha = 80^\circ$, Wind Direction 2.
 3. Heliostat Attitude $\alpha = 90^\circ$, Wind Direction 3.
 4. Heliostat Attitude $\alpha = \quad$, Wind Direction 4.

Mirror Location (Grid Point)	Normal Load P (lbs)	Moment, M_y (in-lbs)	Moment, M_z (in-lbs)
2	0	0	0
7	0	0	0
10	-1.5	-28.6	-11.4
17	-39.1	-201.2	-297.2
20	-71.4	76.6	-435.5
23	-25.8	190.9	-157.4
37	0	0	0
42	0	0	0
45	-1.5	-28.6	11.4
52	-39.1	-201.2	297.2
55	-71.4	76.6	435.5
60	-25.8	190.9	157.4

Table II - Wind Loads on Mirror Module Due to 27 MPH Wind

- Applicable to:
1. Heliostat Attitude $\alpha = 90^\circ$, Wind Direction / .
 2. Heliostat Attitude $\alpha =$, Wind Direction .
 3. Heliostat Attitude $\alpha =$, Wind Direction .
 4. Heliostat Attitude $\alpha =$, Wind Direction .

Mirror Location (Grid Point)	Normal Load P (lbs)	Moment, M_y (in-lbs)	Moment, M_z (in-lbs)
2	0	0	0
7	0	0	0
10	1.5	28.6	11.4
17	38.7	198.3	294.1
20	70.3	-77.6	428.8
23	25.2	-186.5	153.7
37	0	0	0
42	0	0	0
45	1.5	28.6	-11.4
52	38.7	198.3	-294.1
55	70.3	-77.6	-428.8
60	25.2	-186.5	-153.7

Table III - Grid Point Geometry

<u>Grid Point</u>	<u>x (in)</u>	<u>y (in)</u>	<u>z (in)</u>
1	-6.58	108.30	-113.25
2	13.80	72.15	-113.25
3	-6.58	36.00	-129.49
4	-6.58	36.00	-97.01
5	-6.58	36.00	-84.19
6	-6.58	36.00	-51.71
7	13.80	72.15	-67.95
8	-6.58	108.30	-67.95
9	-6.58	108.30	-22.65
10	13.80	75.15	-22.65
11	-6.58	36.00	-38.89
12	-6.58	36.00	-6.41
13	-6.58	36.00	6.41
14	-6.58	36.00	12.52
15	-6.58	108.30	12.64
16	-6.58	108.30	22.65
17	13.80	75.15	22.65
18	-6.58	36.00	38.89
19	-6.58	36.00	51.71
20	13.80	72.15	67.95
21	-6.58	108.30	67.95
22	-6.58	108.30	113.25
23	13.80	72.15	113.25
24	-6.58	36.00	84.19
25	-6.58	36.00	97.01
26	-6.58	36.00	129.49
27	-6.58	8.75	12.64
28	0	8.75	0
29	0	0	0
30	0	-6.90	0
31	0	0	-6.88
32	0	-12.38	0
33	-6.58	-12.38	12.64
34	0	0	-16.30
35	0	0	-147.00
36	-6.58	-108.30	-113.25
37	13.80	-72.15	-113.25
38	-6.58	-36.00	-129.49
39	-6.58	-36.00	-97.01
40	-6.58	-36.00	-84.19
41	-6.58	-36.00	-51.71
42	13.80	-72.15	-67.95
43	-6.58	-108.30	-67.95
44	-6.58	-108.30	-22.65
45	13.80	-75.15	-22.65
46	-6.58	-36.00	-38.89
47	-6.58	-36.00	-6.61
48	-6.58	-36.00	6.61
49	-6.58	-36.00	12.64

Table III - Grid Point Geometry - Cont'd

<u>Grid Point</u>	<u>x (in)</u>	<u>y (in)</u>	<u>z (in)</u>
50	-6.58	-108.30	12.64
51	-6.58	-108.30	22.65
52	13.80	-75.15	22.65
53	-6.58	-36.00	38.89
54	-6.58	-36.00	51.71
55	13.80	-72.15	67.95
56	-6.58	-108.30	67.95
57	-6.58	-36.00	84.19
58	-6.58	-36.00	97.01
59	-6.58	-108.30	113.25
60	13.80	-72.15	113.25
61	-6.58	-36.00	129.49

Table IV - Mirror Module Rotations Due to 27 MPH Wind and Gravity Loads

Heliostat Attitude $\alpha = 0^\circ$

Wind Direction	Mirror Location (Grid Point)	θ_y (Mrad)	θ_z (mrad)	Resultant θ (mrad)
1	2	-.5426	-.0286	.5434
	7	-.5849	.1103	.5952
	10	-.7060	.2128	.7374
	17	-.9046	.2576	.9406
	20	-.9671	.2897	1.0096
	23	-.9693	.3352	1.0256
	37	-.5301	.0952	.5386
	42	-.5724	-.0440	.5741
	45	-.6931	-.1470	.7085
	52	-.8927	-.1920	.9131
	55	-.9548	-.2241	.9807
	60	-.9571	-.2698	.9944
2	2	-.3826	-.0275	.3836
	7	-.4322	.1099	.4460
	10	-.5657	.2075	.6026
	17	-.7724	.2443	.8101
	20	-.8273	.2673	.8694
	23	-.8273	.3047	.8816
	37	-.3746	.0892	.3851
	42	-.4243	-.0486	.4271
	45	-.5573	-.1466	.5763
	52	-.7652	-.1837	.7869
	55	-.8198	-.2067	.8455
	60	-.8198	-.2443	.8554
3	2	-.5501	-.0309	.5510
	7	-.5923	.1086	.6022
	10	-.7125	.2117	.7433
	17	-.9099	.2571	.9455
	20	-.9724	.2900	1.0147
	23	-.9746	.3364	1.0310
	37	-.5373	.0976	.5461
	42	-.5795	-.0422	.5810
	45	-.6993	-.1458	.7143
	52	-.8977	-.1915	.9179
	55	-.9599	-.2244	.9858
	60	-.9621	-.2709	.9995

Table IV - Mirror Module Rotations Due to 27 MPH Wind and Gravity Loads

Heliostat Attitude $\alpha = 10^\circ$

Wind Direction	Mirror Location (Grid Point)	θ_y (Mrad)	θ_z (mrad)	Resultant θ (mrad)
1	2	-.5533	.1456	.5721
	7	-.6036	.2774	.6643
	10	-.7541	.3709	.8404
	17	-1.0179	.4061	1.0959
	20	-1.1251	.4276	1.2036
	23	-1.1398	.4588	1.2287
	37	-.5376	-.0710	.5423
	42	-.5879	-.2032	.6220
	45	-.7378	-.2972	.7954
	52	-1.0030	-.3327	1.0567
	55	-1.1098	-.3543	1.1650
	60	-1.1244	-.3858	1.1887
2	2	-.4362	.1621	.4653
	7	-.4885	.2859	.5660
	10	-.6471	.3713	.7461
	17	-.9178	.3980	1.0004
	20	-1.0201	.4106	1.0996
	23	-1.0333	.4336	1.1206
	37	-.4242	-.0909	.5204
	42	-.4765	-.2153	.5229
	45	-.6345	-.3012	.7024
	52	-.9067	-.3282	.9643
	55	-1.0085	-.3409	1.0646
	60	-1.0218	-.3640	1.0847
3	2	-.2764	.1632	.3210
	7	-.3360	.2856	.4410
	10	-.5070	.3660	.6253
	17	-.7859	.3847	.8750
	20	-.8805	.3883	.9623
	23	-.8916	.4031	.9785
	37	-.2690	-.0969	.2859
	42	-.3287	-.2198	.3954
	45	-.4990	-.3008	.5827
	52	-.7794	-.3199	.8425
	55	-.8736	-.3235	.9316
	60	-.8847	-.3385	.9472

Table IV - Mirror Module Rotations Due to 27 MPH Wind and Gravity Loads

Heliostat Attitude $\alpha = 20^\circ$

Wind Direction	Mirror Location (Grid Point)	θ_y (Mrad)	θ_z (mrad)	Resultant θ (mrad)
1	2	-.5732	.3220	.6575
	7	-.6307	.4423	.7703
	10	-.8064	.5244	.9619
	17	-1.1295	.5502	1.2564
	20	-1.2825	.5616	1.4001
	23	-1.3104	.5782	1.4323
	37	-.5537	-.2398	.6034
	42	-.6112	-.3606	.7096
	45	-.7862	-.4433	.9026
	52	-1.1109	-.4694	1.2060
	55	-1.2633	-.4810	1.3518
	60	-1.2912	-.4978	1.3838
2	2	-.4416	.3369	.5554
	7	-.5006	.4511	.6739
	10	-.6854	.5258	.8639
	17	-1.0176	.5427	1.1533
	20	-1.1654	.5443	1.2862
	23	-1.1917	.5517	1.3132
	37	-.4264	-.2585	.4986
	42	-.4854	-.3731	.6122
	45	-.6694	-.4485	.8058
	52	-1.0033	-.4658	1.1062
	55	-1.1505	-.4675	1.2419
	60	-1.1768	-.4751	1.2691
3	2	-.3248	.3534	.4800
	7	-.3858	.4597	.6001
	10	-.5787	.5263	.7822
	17	-.9178	.5347	1.0622
	20	-1.0606	.5274	1.1845
	23	-1.0857	.5265	1.2066
	37	-.3133	-.2784	.4191
	42	-.3743	-.3852	.5371
	45	-.5665	-.4524	.7250
	52	-.9073	-.4612	1.0178
	55	-1.0495	-.4540	1.1435
	60	-1.0745	-.4533	1.1662

Table IV - Mirror Module Rotations Due to 27 MPH Wind and Gravity Loads

Heliostat Attitude $\alpha = 30^\circ$

Wind Direction	Mirror Location (Grid Point)	θ_y (Mrad)	θ_z (mrad)	Resultant θ (mrad)
1	2	-.4543	.5163	.6877
	7	-.5191	.6161	.8056
	10	-.7265	.6775	.9934
	17	-1.1157	.6840	1.3087
	20	-1.3099	.6740	1.4731
	23	-1.3500	.6643	1.5046
	37	-.4354	-.4305	.6123
	42	-.5002	-.5308	.7293
	45	-.7069	-.5929	.9226
	52	-1.0979	-.5998	1.2511
	55	-1.2913	-.5900	1.4197
	60	-1.3314	-.5806	1.4525
2	2	-.4594	.5081	.6850
	7	-.5239	.6087	.8031
	10	-.7297	.6711	.9914
	17	-1.1153	.6788	1.3056
	20	-1.3085	.6705	1.4703
	23	-1.3484	.6626	1.5024
	37	-.4401	-.4229	.6104
	42	-.5047	-.5240	.7275
	45	-.7097	-.5871	.9211
	52	-1.0971	-.5953	1.2482
	55	-1.2895	-.5871	1.4169
	60	-1.3295	-.5795	1.4503
3	2	-.3282	.5231	.6175
	7	-.3943	.6175	.7327
	10	-.6092	.6725	.9074
	17	-1.0038	.6714	1.2076
	20	-1.1918	.6532	1.3591
	23	-1.2302	.6361	1.3849
	37	-.3132	-.4415	.5413
	42	-.3793	-.5365	.6570
	45	-.5934	-.5923	.8384
	52	-.9900	-.5916	1.1533
	55	-1.1771	-.5736	1.3094
	60	-1.2155	-.5567	1.3369

Table IV - Mirror Module Rotations Due to 27 MPH Wind and Gravity Loads

Helioostat Attitude $\alpha = 40^\circ$

Wind Direction	Mirror Location (Grid Point)	θ_y (Mrad)	θ_z (mrad)	Resultant θ (mrad)
1	2	-.3843	.6842	.7847
	7	-.4540	.7658	.8903
	10	-.6839	.8103	1.0603
	17	-1.1245	.8029	1.3817
	20	-1.3586	.7777	1.5654
	23	-1.4112	.7471	1.5968
	37	-.3641	-.5950	.6976
	42	-.4338	-.6772	.8042
	45	-.6628	-.7225	.9805
	52	-1.1055	-.7156	1.3034
	55	-1.3387	-.6905	1.5063
60	-1.3912	-.6603	1.5400	
2	2	-.3411	.6915	.7711
	7	-.4112	.7702	.8731
	10	-.6436	.8115	1.0357
	17	-1.0874	.8007	1.3504
	20	-1.3200	.7718	1.5290
	23	-1.3722	.7378	1.5580
	37	-.3223	-.6036	.6843
	42	-.3924	-.6828	.7875
	45	-.6239	-.7248	.9563
	52	-1.0699	-.7146	1.2866
	55	-1.3015	-.6858	1.4711
60	-1.3537	-.6522	1.5026	
3	2	-.3472	.6833	.7665
	7	-.4170	.7628	.8693
	10	-.6477	.8050	1.0332
	17	-1.0880	.7956	1.3479
	20	-1.3196	.7683	1.5270
	23	-1.3715	.7361	1.5566
	37	-.3280	-.5959	.6802
	42	-.3978	-.6759	.7842
	45	-.6277	-.7190	.9544
	52	-1.0701	-.7100	1.2842
	55	-1.3007	-.6829	1.4691
60	-1.3527	-.6510	1.5012	

Table IV - Mirror Module Rotations Due to 27 MPH Wind and Gravity Loads

Heliostat Attitude $\alpha = 50^\circ$

Wind Direction	Mirror Location (Grid Point)	θ_y (Mrad)	θ_z (mrad)	Resultant θ (mrad)
1	2	-.3296	.8120	.8763
	7	-.4016	.8757	.9634
	10	-.6434	.9050	1.1104
	17	-1.1124	.8881	1.4234
	20	-1.3770	.8535	1.6201
	23	-1.4397	.8087	1.6513
	37	-.3071	-.7229	.7854
	42	-.3791	-.7872	.9994
	45	-.6200	-.8173	1.0259
	52	-1.0911	-.8009	1.3535
	55	-1.3547	-.7664	1.5565
60	-1.4174	-.7220	1.5907	
2	2	-.2758	.8431	.8871
	7	-.3488	.9027	.9677
	10	-.5978	.9274	1.1034
	17	-1.0836	.9042	1.4113
	20	-1.3532	.8612	1.6040
	23	-1.4174	.8073	1.6312
	37	-.2555	-.7527	.7949
	42	-.3285	-.8130	.8769
	45	-.5765	-.8384	1.0175
	52	-1.0646	-.8158	1.3412
	55	-1.3332	-.7730	1.5411
60	-1.3973	-.7196	1.5717	
3	2	-.2328	.8504	.8817
	7	-.3061	.9071	.9574
	10	-.5576	.9285	1.0831
	17	-1.0467	.9019	1.3817
	20	-1.3148	.8554	1.5686
	23	-1.3785	.7980	1.5928
	37	-.2139	-.7612	.7907
	42	-.2872	-.8185	.8674
	45	-.5378	-.8407	.9980
	52	-1.0291	-.8148	1.3126
	55	-1.2962	-.7684	1.5068
60	-1.3599	-.7114	1.5347	

Table IV - Mirror Module Rotations Due to 27 MPH Wind and Gravity Loads

Heliostat Attitude $\alpha = 60^\circ$

Wind Direction	Mirror Location (Grid Point)	θ_y (Mrad)	θ_z (mrad)	Resultant θ (mrad)
1	2	-.3838	.8478	.9306
	7	-.4554	.9070	1.0149
	10	-.6978	.9359	1.1674
	17	-1.1758	.9252	1.4962
	20	-1.4755	.8966	1.7266
	23	-1.5508	.8513	1.7691
	37	-.3544	-.7615	.8399
	42	-.4260	-.8213	.9252
	45	-.6674	-.8509	1.0814
	52	-1.1475	-.8408	1.4225
	55	-1.4462	-.8124	1.6588
	60	-1.5215	-.7675	1.7041
2	2	-.2336	.9499	.9782
	7	-.3468	.9916	1.0505
	10	-.5612	1.0018	1.1483
	17	-1.0646	.9709	1.4408
	20	-1.3609	.9205	1.6430
	23	-1.4344	.8539	1.6693
	37	-.2108	-.8605	.8859
	42	-.2841	-.9028	.9464
	45	-.5375	-.9138	1.0602
	52	-1.0432	-.8835	1.3671
	55	-1.3383	-.8333	1.5765
	60	-1.4119	-.7672	1.6069
3	2	-.1753	.9810	.9965
	7	-.2495	1.0186	1.0487
	10	-.5111	1.0241	1.1446
	17	-1.0313	.9869	1.4274
	20	-1.3326	.9282	1.6240
	23	-1.4075	.8526	1.6456
	37	-.1547	-.8904	.9037
	42	-.2289	-.9286	.9564
	45	-.4895	-.9350	1.0554
	52	-1.0121	-.8984	1.3533
	55	-1.3122	-.8399	1.5580
	60	-1.3872	-.7647	1.5840

Table IV - Mirror Module Rotations Due to 27 MPH Wind and Gravity Loads

Heliostat Attitude $\alpha = 70^\circ$

Wind Direction	Mirror Location (Grid Point)	θ_y (Mrad)	θ_z (mrad)	Resultant θ (mrad)
1	2	.0317	.9106	.9112
	7	-.0366	-.9200	.9207
	10	-.2679	.9046	.9434
	17	-.7042	-.8629	1.1138
	20	-.9434	.8145	1.2464
	23	-.9966	.7573	1.2517
	37	.0484	-.8519	.8533
	42	-.0200	-.8618	.8620
	45	-.2504	-.8470	.8832
	52	-.6887	-.8059	1.0601
	55	-.9270	-.7576	1.1972
	60	-.9801	-.7007	1.2048
2	2	-.3133	.9605	1.0103
	7	-.3840	.9981	1.0694
	10	-.6321	1.0093	1.1909
	17	-1.1326	.9869	1.5022
	20	-1.4591	.9449	1.7383
	23	-1.5442	.8801	1.7774
	37	-.2834	-.8749	.9197
	42	-.3541	-.9132	.9794
	45	-.6013	-.9251	1.1033
	52	-1.1040	-.9033	1.4265
	55	-1.4293	-.8615	1.6689
	60	-1.5144	-.7972	1.7114
3	2	-.1492	1.0626	1.0730
	7	-.2216	1.0827	1.1051
	10	-.4817	1.0753	1.1783
	17	-1.0076	1.0326	1.4427
	20	-1.3306	.9688	1.6459
	23	-1.4138	.8827	1.6667
	37	-.1260	-.9740	.9821
	42	-.1984	-.9947	1.0143
	45	-.4575	-.9881	1.0889
	52	-.9858	-.9460	1.3663
	55	-1.3076	-.8824	1.5775
	60	-1.3909	-.7969	1.6030

Table IV - Mirror Module Rotations Due to 27 MPH Wind and Gravity Loads

Heliostat Attitude $\alpha = 80^\circ$

Wind Direction	Mirror Location (Grid Point)	θ_y (Mrad)	θ_z (mrad)	Resultant θ (mrad)
1	2			
	7			
	10			
	17			
	20			
	23			
	37			
	42			
	45			
	52			
	55			
60				
2	2	.0536	.9947	.9961
	7	-.0119	.9838	.9839
	10	-.2419	.9526	.9828
	17	-.6881	.9019	1.1344
	20	-.9483	.8427	1.2686
	23	-1.0099	.7689	1.2693
	37	.0708	-.9375	.9402
	42	.0053	-.9270	.9270
	45	-.2238	-.8965	.9240
	52	-.6721	-.8463	1.0807
	55	-.9313	-.7873	1.2195
60	-.9928	-.7139	1.2228	
3	2	-.2577	1.0445	1.0758
	7	-.3255	1.0618	1.1106
	10	-.5723	1.0572	1.2022
	17	-1.0828	1.0258	1.4916
	20	-1.4303	.9730	1.7299
	23	-1.5238	.8916	1.7655
	37	-.2273	-.9607	.9872
	42	-.2951	-.9785	1.0220
	45	-.5410	-.9747	1.1148
	52	-1.0536	-.9439	1.4146
	55	-1.3999	-.8914	1.6596
60	-1.4933	-.8105	1.6991	

Table IV - Mirror Module Rotations Due to 27 MPH Wind and Gravity Loads

Heliostat Attitude $\alpha = 90^\circ$

Wind Direction	Mirror Location (Grid Point)	θ_y (Mrad)	θ_z (mrad)	Resultant θ (mrad)
1	2	1.1125	1.1111	1.5723
	7	1.0520	.9855	1.4415
	10	.8303	.8449	1.1846
	17	.4322	.6994	.8222
	20	.2592	.5489	.6070
	23	.2063	.3877	.4392
	37	1.0878	-1.1120	1.5556
	42	1.0273	-.9870	1.4246
	45	.8064	-.8472	1.1696
	52	.4061	-.7021	.8111
	55	.2338	-.5515	.5990
	60	.1808	-.3905	.4303
2	2			
	7			
	10			
	17			
	20			
	23			
	37			
	42			
	45			
	52			
	55			
	60			
Average of 12 Mirrors				
3	2	.0576	1.0476	1.0492
	7	-.0030	1.0182	1.0182
	10	-.2247	.9737	.9993
	17	-.6680	.9167	1.1343
	20	-.9429	.8500	1.2695
	23	-1.0112	.7630	1.2667
	37	.0755	-.9927	.9956
	42	.0150	-.9637	.9638
	45	-.2059	-.9199	.9427
	52	-.6512	-.8634	1.0814
	55	-.9251	-.7969	1.2210
	60	-.9934	-.7103	1.2212