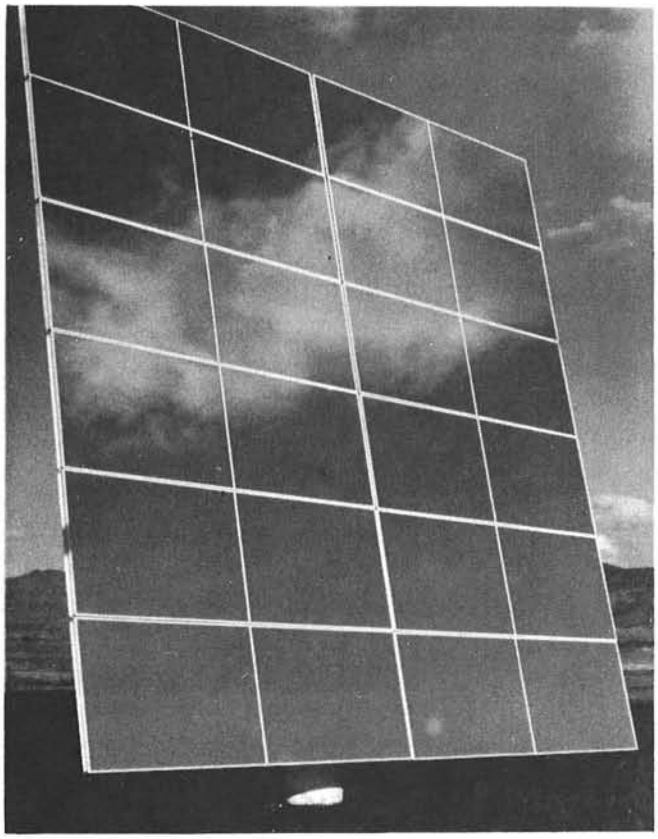
UNLIMITED RELEASE

MARCH 1981

SAND 81-8178
SANDIA CONTRACT
83-2729E

SECOND GENERATION HELIOSTAT DEVELOPMENT FOR SOLAR CENTRAL RECEIVER SYSTEMS

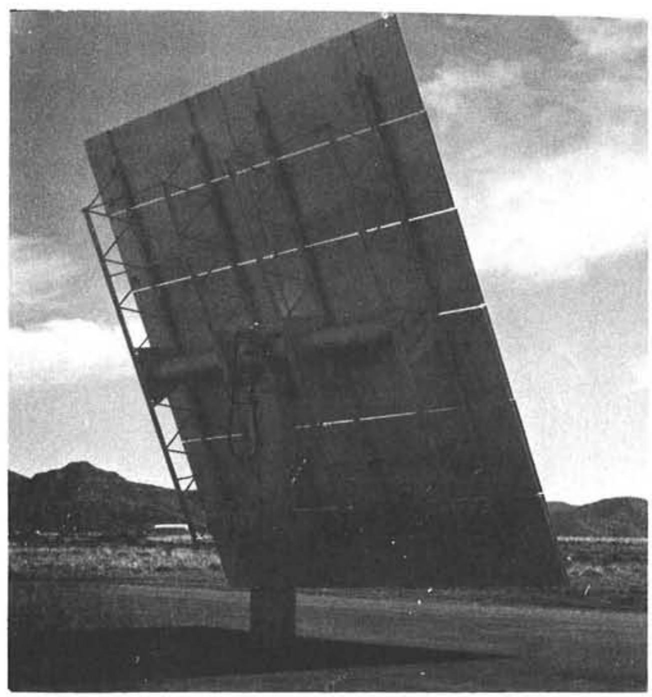


FINAL REPORT

VOLUME IV

APPENDICES F-J

CONTROL SOFTWARE
TEST RESULTS
MANUFACTURING
PILE INSTALLATION
PILE COATINGS



PREPARED BY

NORTHRUP, INCORPORATED

A SUBSIDIARY OF
ATLANTIC RICHFIELD CO.

AND

BECHTEL NATIONAL, INC. AND **BOOZ-ALLEN AND HAMILTON, INC.**

SECOND GENERATION HELIOSTAT DEVELOPMENT

FINAL REPORT

VOLUME IV

Appendices F - J

Sandia Contract No. 83-2729E
Sandia Requestor - C. L. Mavis/8451
Contracting Representative - R. C. Christman

Work performed during the period
July 16, 1979 through March 31, 1981

by

Northrup, Incorporated
302 Nichols Drive
Hutchins, Tx. 75141

and Subcontractors:

Bechtel National, Inc.
50 Beale St.
San Francisco, California 94119
and
Booz-Allen and Hamilton, Inc.
8801 E. Pleasant Valley Rd.
Cleveland, Ohio 44131

This report is presented in 4 Volumes. The content of these volumes is as follows:

9.6 Control Software (Appendix F)

The control software for the Northrup II heliostats consists of two packages, one handling the external data processing, communication, and control and one handling the internal data processing, communication and direct motor control.

The Heliostat Controller specification, Figure F-1 defines the word structure used to communicate control information and status information between the two software systems.

An overview flow diagram of the "Mini HAC" software package to be implemented in the Hewlett Packard 9825 desk-top computer system is shown in Figure F-2.

The detailed software flow being implemented in the Northrup Heliostat Control Electronics is described on pages F-8 to F-11. The flow chart for the Heliostat Controller is included in pages F-12 to F-29. The text margins are annotated with the applicable flow chart step numbers.

FIGURE F-1 (Sheet 1 of 4)
HELIOSTAT CONTROLLER (HC) SPECIFICATION

3.1 Data Format

The data format between the heliostat and the controlled shall be per the following table:

WORD	FUNCTION
1	Address
2	Azimuth(ms byte)
3	Azimuth(ls byte)
4	Elevation(ms byte)
5	Elevation(ls byte)
6	Mode

3.1.1 Bit Configuration

The data word shall consist of one start bit, two stop bits, 8 data bits, and no parity bits.

3.1.1.1 Time Out

The HC shall receive 6 words per paragraph 3.1. The words shall be separated only by the normal two stop bits. If communications is lost during transmission, the HC shall time out after 1.5 bytes(word length) and continue its previous operation until a new instruction is received.

3.1.2 Address

Two Address shall be used for prototype design.
Heliostat 1 shall be address 01
heliostat 2 shall be address 02

3.1.3 Azimuth and Elevation postion

Position shall consist of two 8 bit words. A position command shall be an absolute quantity with the least significant bit being equal to 125 motor steps.

The heliostat processor shall subtract the commanded position from the accumulated position and command the stepper motor to move the differential steps.

Figure F-1 (Sheet 2 of 4)

3.1.4 The Mode byte

The Mode byte is defined by the format shown below.

If Bit 2 = 1

Bit 0	AZ = 1	cw
Bit 0	AZ = 0	ccw
Bit 1	EL = 1	cw
Bit 1	EL = 0	ccw

If Bit 2 = 0

Bit 0 = 1 AZ Stop
Bit 0 = 0 Continue previous operation
Bit 1 = 1 El Stop
Bit 1 = 0 Continue previous operation

Bit 2 = Mode indication for bits 0 and 1

Bit 3 = 1 Slew AZ
Bit 3 = 0 Track AZ

Bit 4 = 1 Slew El to Stow
Bit 4 = 0 Track El

Bit 5 = 1 Request Status

Bit 6 = 1 Set position

Bit 7 = 1 Clear malfunction status

3.2 Wake Up

The wake up mode defines the logic used to power up the heliostat in the morning. The heliostat conroller shall upon power up check limit switch status and if the stow limit switch is in the normal mode shall execute the commanded position. It shall check the limit swich status after 2 steps and continue if the limit switch is open. If the limit swich is closed it shall stop all motor operation and set a status bit.

3.3 Status Words

The heliostat status shall be sent upon request from the controller. The status shall consist of the following:

WORD	FUNCTION
1	Azimuth(ms byte)
2	Azimuth(ls byte)
3	Elevation(ms byte)
4	Elevation(ls byte)
5	Status

Figure F-1 (Sheet 3 of 4)

3.3.1 Position

The heliostat controller shall keep track of its acculumated position. It shall send this position upon request from the master controller.

3.3.2 Status

The heliostat status word shall be defined by the following.

Bit	Function
0	AZ cw limit sw
1	AZ ccw limit sw
2	El cw limit sw
3	El ccw limit sw
4	Motor movement AZ
5	Motor Movement EL
6	Wake up malfunction
7	Power drop out

Bits 0 and 1 shall indicate AZ limit switch activation if Bit 4 = 0 and shall indicate motor movement if Bit 4 = 1.

Bits 2 and 3 shall indicate EL limit switch activation if Bit 5 = 0 and shall indicate motor movement if Bit 5 = 1

3.3.2.1 Wake Up Malfunction

A wake up malfunction shall be defined as the inability of the heliostat to drive off of the limit switches.

3.3.2.2 Power drop out is defined as power up with the limit switches open.

3.4 Heliostat Error Conditions

3.4.1 Malfunction Conditions

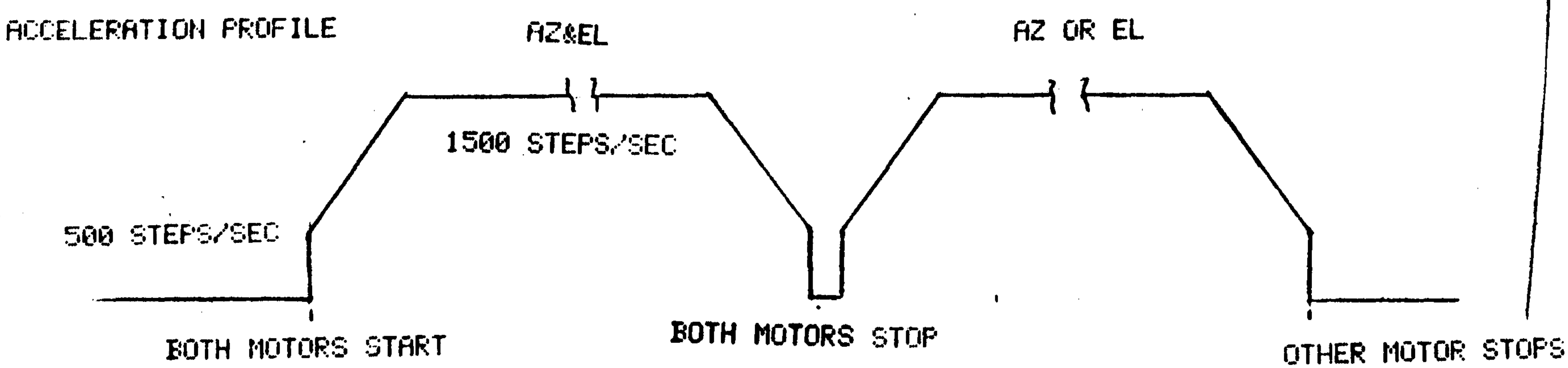
Heliostat motors shall remain off after a malfunction condition(will not execute commands)

3.4.1.1 Bit seven of the mode shall reset the heliostat to normal operation (allow the controller to move the heliostat).

3.5 Motor Operation

3.5.1 Acceleration If two motors are required to move to a position simultaneously they shall accelerate in parallel and both shall deaccelerate when either motor is required to stop. After both motors stop the motor requiring additional position movement shall resume normal operation (see figure F-1).

HELIOSTAT SOFTWARE



- ACCELERATION/DEACCELERATION NEEDED
- NEED TO COUNT CYCLES
- DELAY ADJUSTMENT REQUIRED FOR DIFFERENT BRANCHES

Figure F-1 (Sheet 4 of 4)

FIGURE F-2 (Sheet 1 of 2)

MINI HAC SOFTWARE SCHEMATIC-INITIALIZING SEGMENT

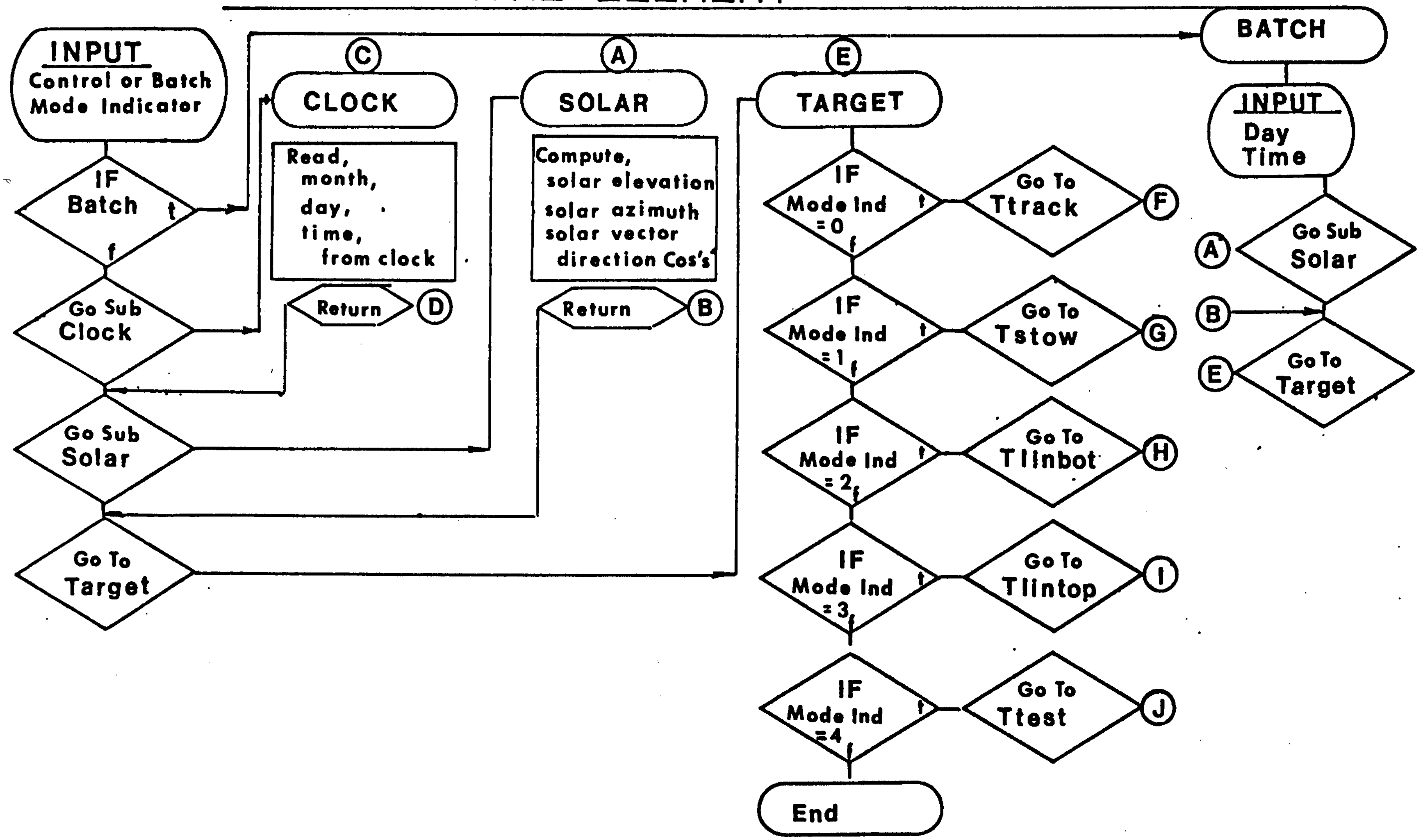
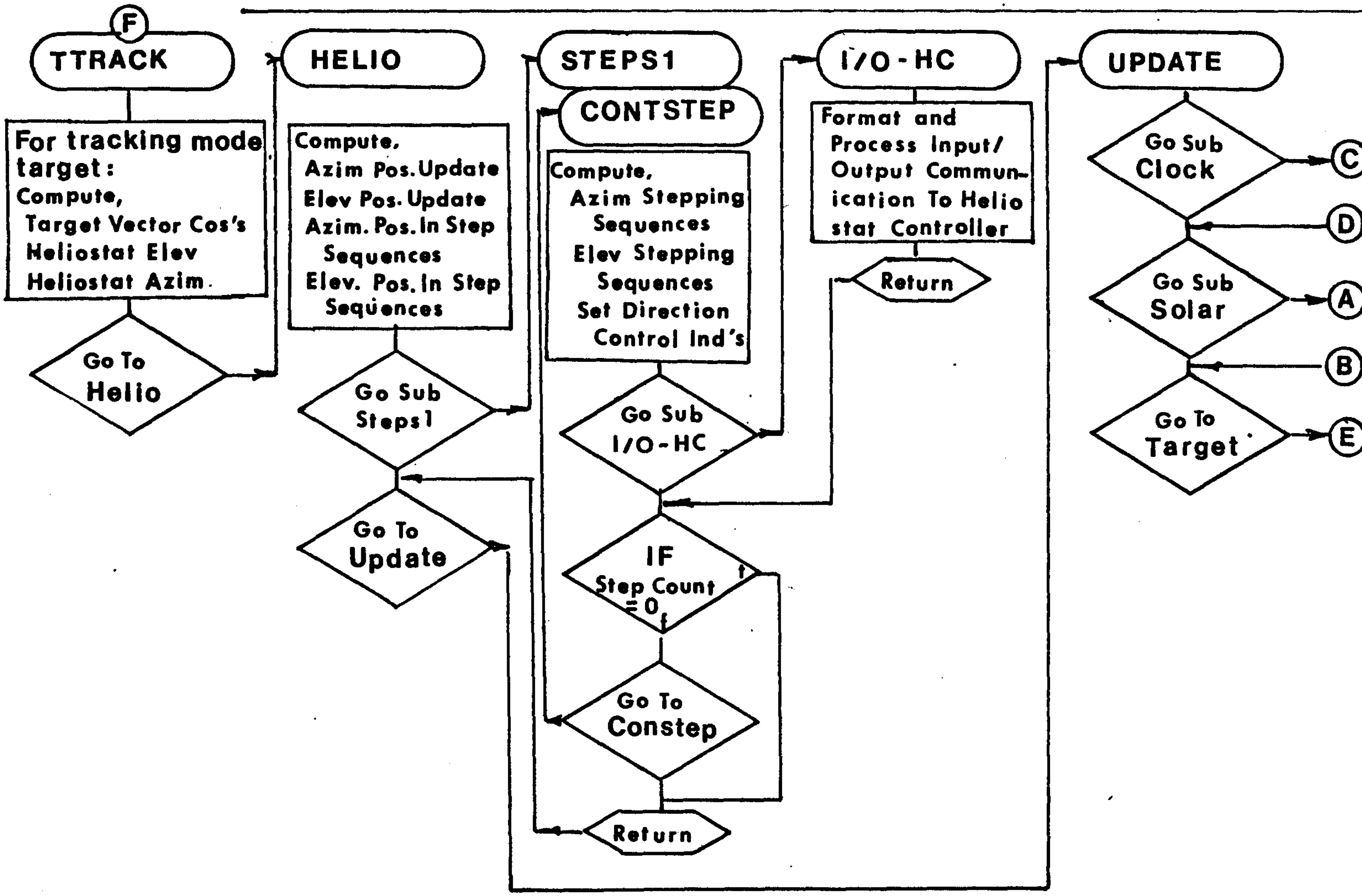


Figure F-2 (Sheet 2 of 2)

MINI HAC SOFTWARE SCHEMATIC–OPERATING SEGMENT



Heliostat Controller Software Performance

After power-on reset the processor will vector to the start of the
program. The first task is to initialize the programmable hardware, 1-7
internal position, and status control bytes.

After initialization the program will test the home limit switches
to see if the mirror was stowed at the home position. If the limits are
open then it will be assumed that power has been lost at some time
during mirror control. If this case has been detected then the power 8-10
drop out bit will be set in the status byte.

If the mirror is at the home position, then the program will try
to move the mirror two positions off the limit switches. This will
test the motor operation and limit switches for malfunction. If the 11-15
limits don't open then the wake-up malfunction bit will be set in the
status register.

If a malfunction has occurred then the program will allow commands
to be received but will only recognize a request for status or a reset 16-25
of the malfunction status or both. A reset of the malfunction status
shall transfer the program control to normal command operation.

In normal command processing the program shall wait for a command
to be fully received before decoding takes place. After a command is
received the first test is for proper device address. If the address 26-31
is incorrect, then it will clear the command ready and return and wait
for the next command to be received. If the address is ok then the
status will reflect the current status of the limit switches.

The next operation will clear the command ready and then test for
high speed operation. If high speed is requested then a bit will 32-38
be set in the direction register. Set position is the next command to
be decoded. If this is requested then the absolute position will reflect
the command position.

If status is requested then the transmitter interupt will be
enabled and the current position and machine status will be transmitted. 39-41
After this operation the program will transfer back to the wait for
command routine.

If the stop motors bit is set then the program will transfer back
to wait for the next command. This is performed because slew direction 42-49
could not be calculated properly. Slew motor is the next test, and if
set then the motor direction is tested and the Slew motor and direction
bits are set in the direction register.

If tracking is requested then the absolute position is subtracted
from the command position and the result is stored in the Step registers 50-54
and the direction register will be set for clockwise. If the result
is negative then the step registers are complemented and the direction
register is set for counter-clockwise. This operation is performed
for both azimuth and elevation.

The status register is set with the limit switch status and then
the program will call the motor movement routine, and then will return 55-66
the wait for command routine.

At the start of the motor routine it will initialize the acceleration
step register with the number of acceleration/deceleration steps.
Both motors will be turned on and home position zeroing will be turned 67-80
off for that motor. The next test will check if the motor is moving 81-88
into a limit switch. If it is then that motor is turned off. 89-91

The program will now test to see if there are any steps to be
performed. If there are none then the motors are turned off. If only 92-105
one step is to be performed then the step motor bit is set in the
stop register. If the motor is slewing then this step is omitted.
If both motors are turned off at this time then the program will return to
where it was called from.

The next operation will test the motor to see if it is on and if it 106-115
is then it will set the status register to indicate operation and
the direction it is moving.

The number of steps per position will be set at the start of the
motor movement loop. At the start of the loop the program will delay 116-117
30 μs for each acceleration step.

A test will be made to see if a command was received during

motor movement. If there was then it will test for proper address, 118-128
status request and stop motor command. If stop motor command is
received then stop motor bits will be set in the stop register and the
command ready bit will be reset.

The next test is for high speed. If this bit is set then the
program will skip a 500μs delay for 1000 step per second timing to 129-132
an adjustment for 2000 steps per second maximum speed.

If the motor is on then it will test the direction register and 133-144
will pulse either the clockwise or counter-clockwise line for 10μs.
After the step a test will be made to check if the motor hit a limit
switch. If it did then the stop bit for that motor will be set. 145-152

The number of steps left will be decremented. If there are 153-163
more steps left then it will test to see if any motors are stopping.
If so then it tests to see if there are enough steps left to decelerate
the motor. If there are it sets the decelerate bit. If the decelerate
bit is set then the delay steps are incremented.

If no motors are stopping then it tests to see if it is at maximum
speed. If not then the number of delay steps are decremented.

After 125 steps have been performed then the absolute position 164-168
will be incremented or decremented depending upon the motor direction.
If the motor is not slewing then the number of position steps are
decremented. If the stop bit is set then it tests the deceleration
bit. If it is also set then the motor is turned off and status is 169-178
set to reflect the status of the limit switches. If the step bit is 179-193
not set and the number of position steps left is one, then the stop
bit is set.

If the motor is slewing then a test is made on the stop bit.
If set it makes the same test on the deceleration bit. If it is
not set the program continues.

A test is made at this point to see if either motor is on. If 194-198
they are then the deceleration bit and the stop bits are reset if a

motor was stopped. Then the program transfers back to the start of the motor step loop.

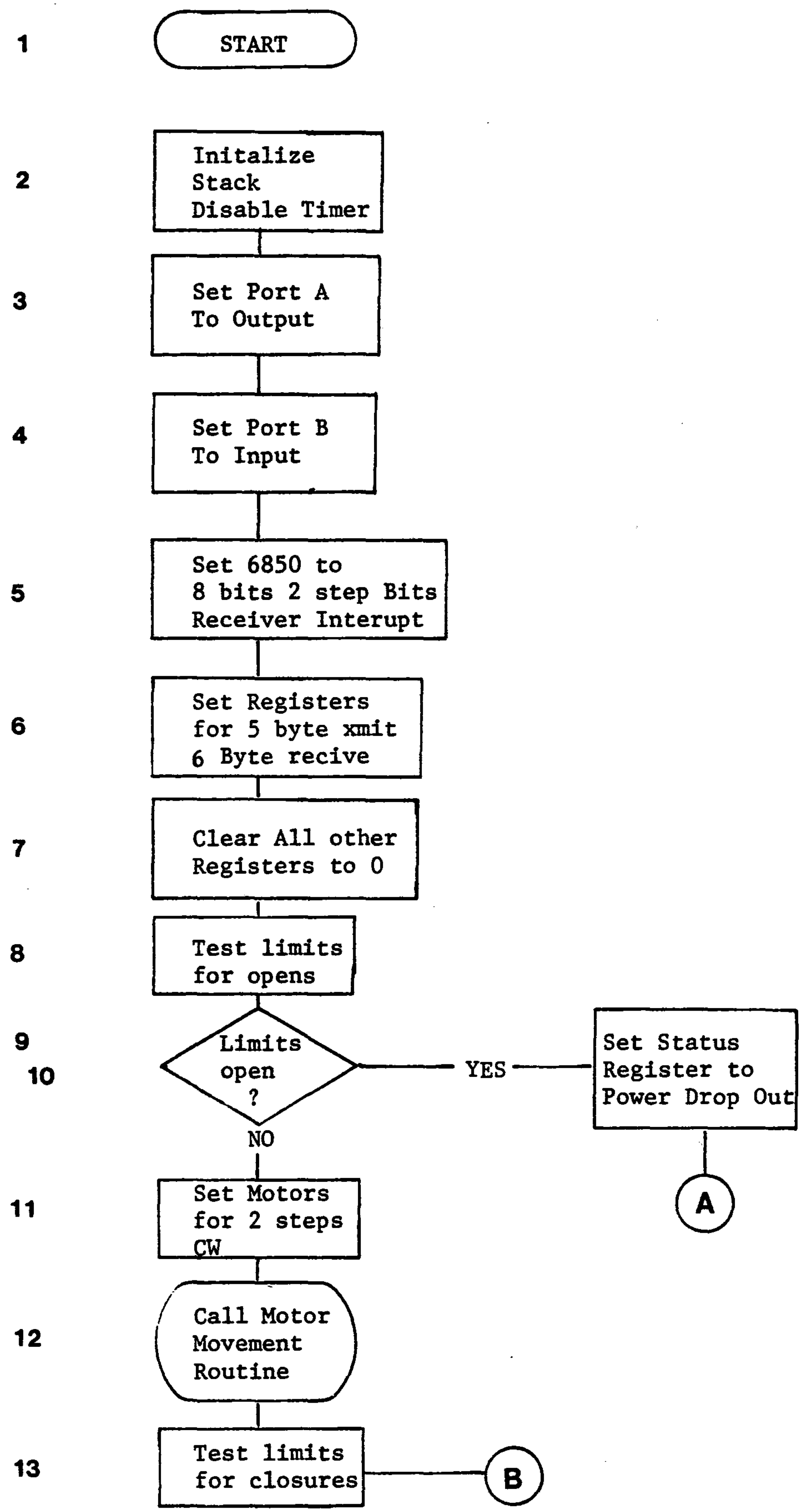
If both motors are stopped, a test is made to see if a home limit switch is on. If it is then the zero position bit is on. If it is also on then the motor is stepped back onto the limit switch and the 199-213
absolute position is set to zero. After this program transfers back to the place from which it was called.

After an interrupt the processor vectors program control to the interrupt service routine. The internal registers are saved and a test is made to see if the serial I/O device caused the interrupt. If 214-216
not then it assumes that it was the timer. A timer interrupt will reset the byte counter in the receiver. A timer interupt will be caused if thereis a transmission failure. After the interrupt was serviced then the internal registers will be restored and will return to where it was called from.

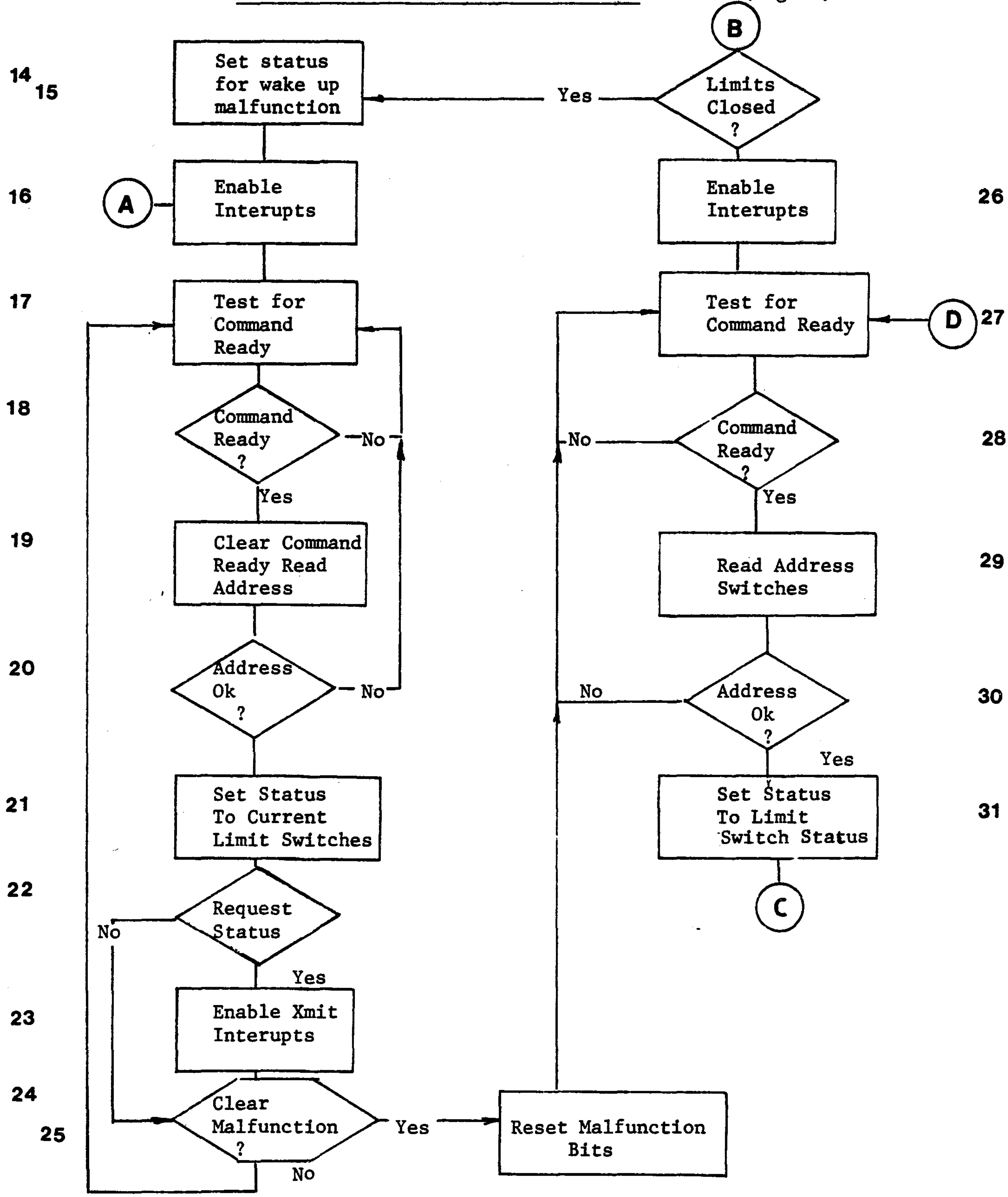
If the serial I/O device interupted then a test is made to see if it was the transmitter or receiver section. If it was the 217-226
receiver, data is read from the device and saved in a table. Then the timer is set for a byte and a half time out, the registers are restored, and the program returns. If it was the last byte to be received then the command ready bits are set and the Timer is disabled.

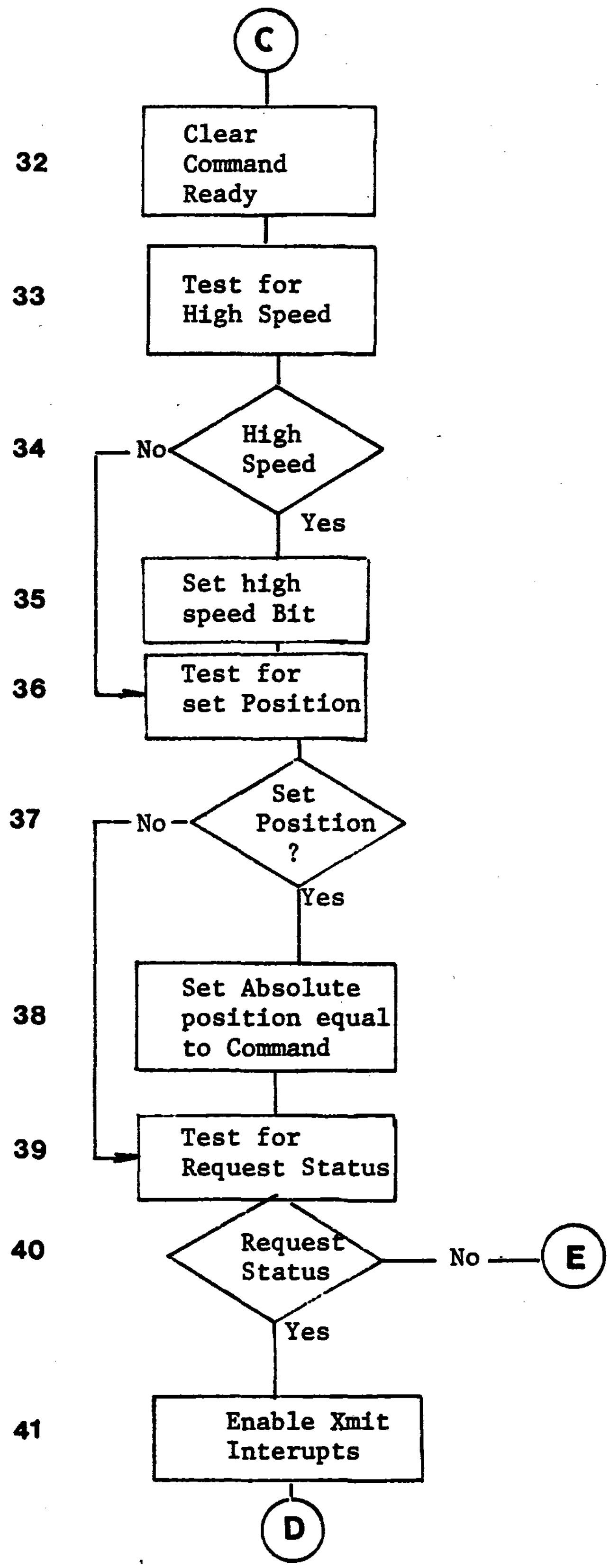
When the transmitter interrupts the data is read from a table and it is transformed to the data register. If it's the last byte, 227-233
the transmitter is disabled from interrupt and the number of bytes to be sent is reset. Registers are restored and the program returns.

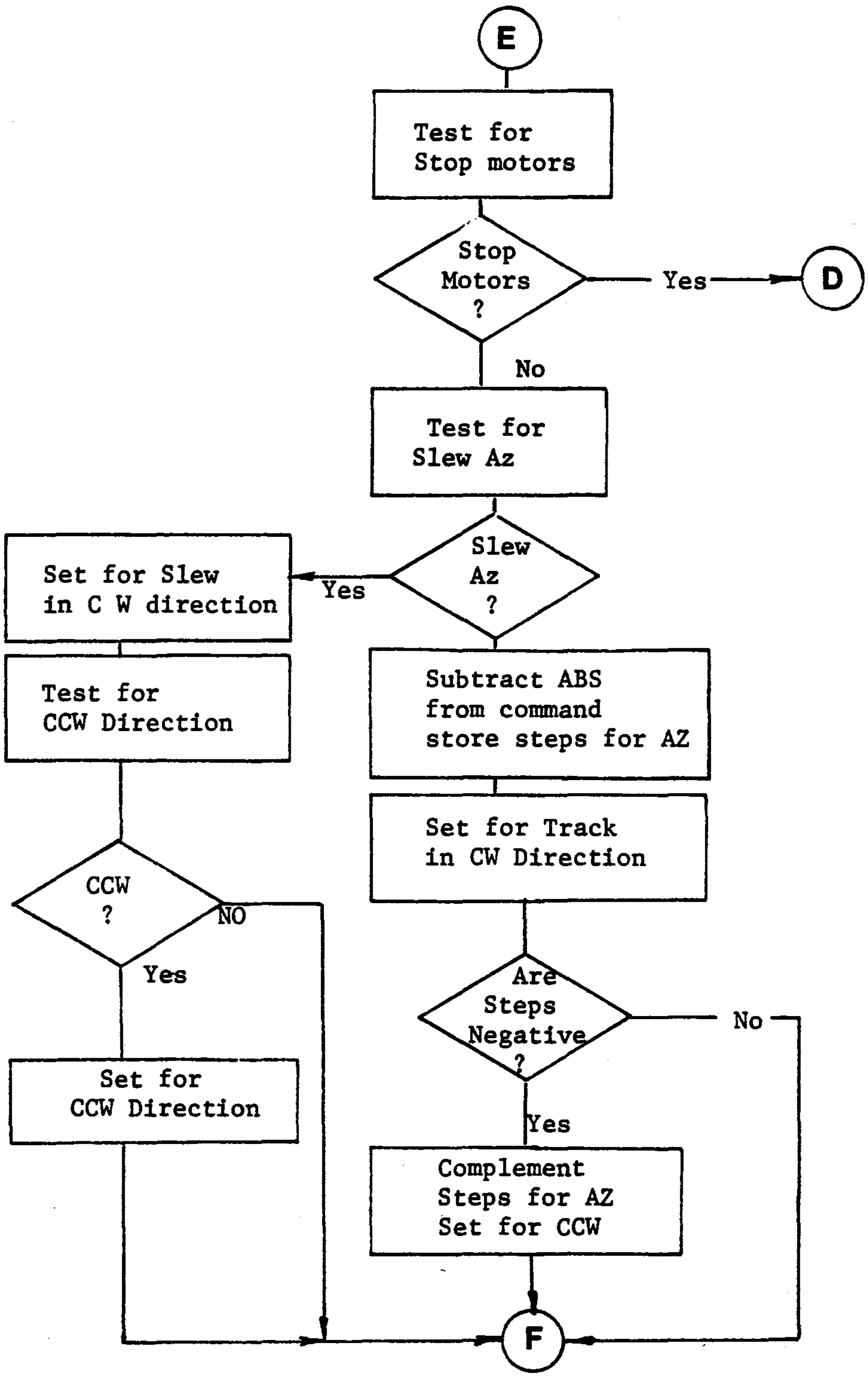
FLOW CHART FOR HELIOSTAT CONTROLLER (Page 1)



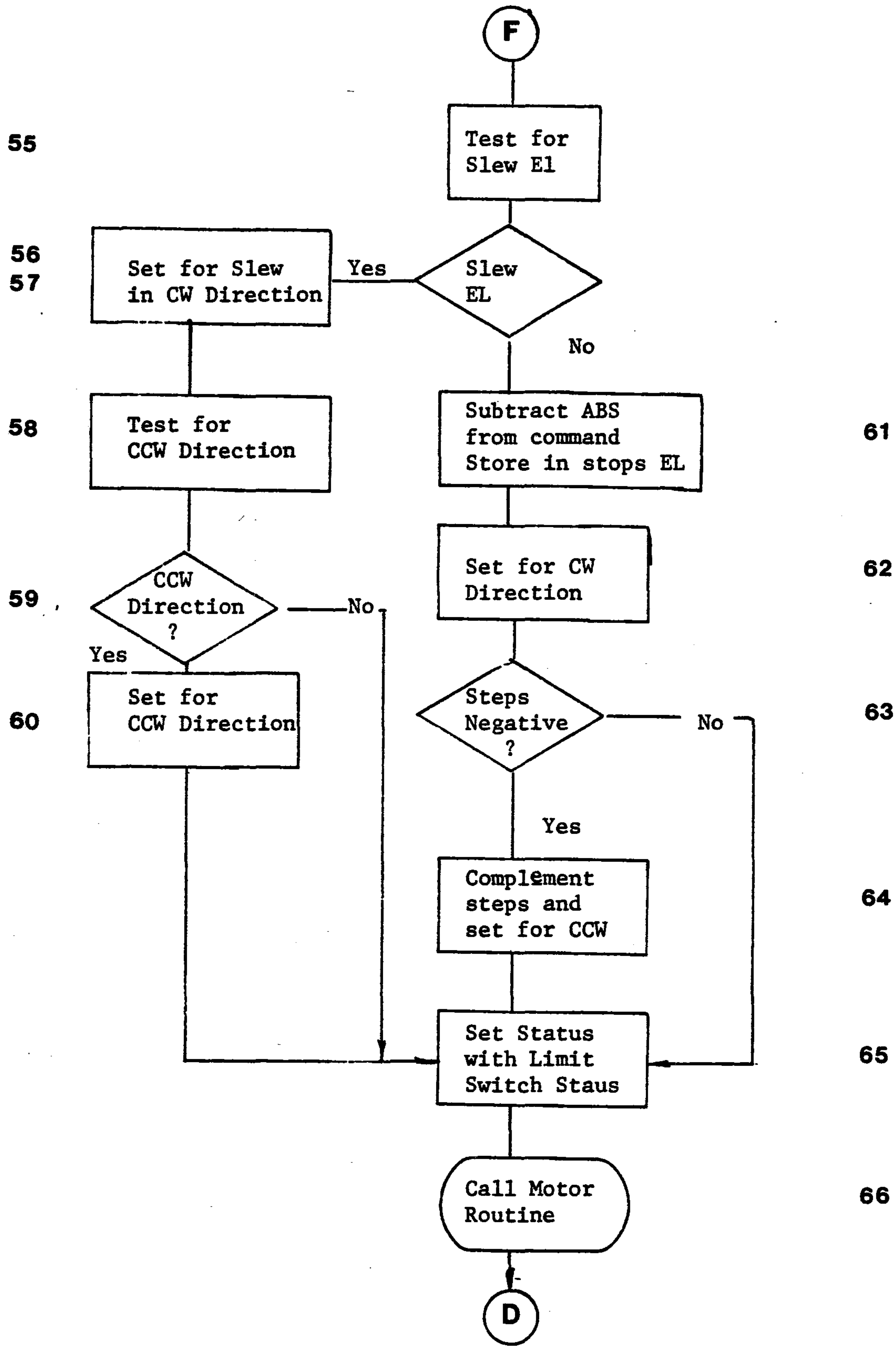
FLOW CHART FOR HELIOSTAT CONTROLLER (Page 2)



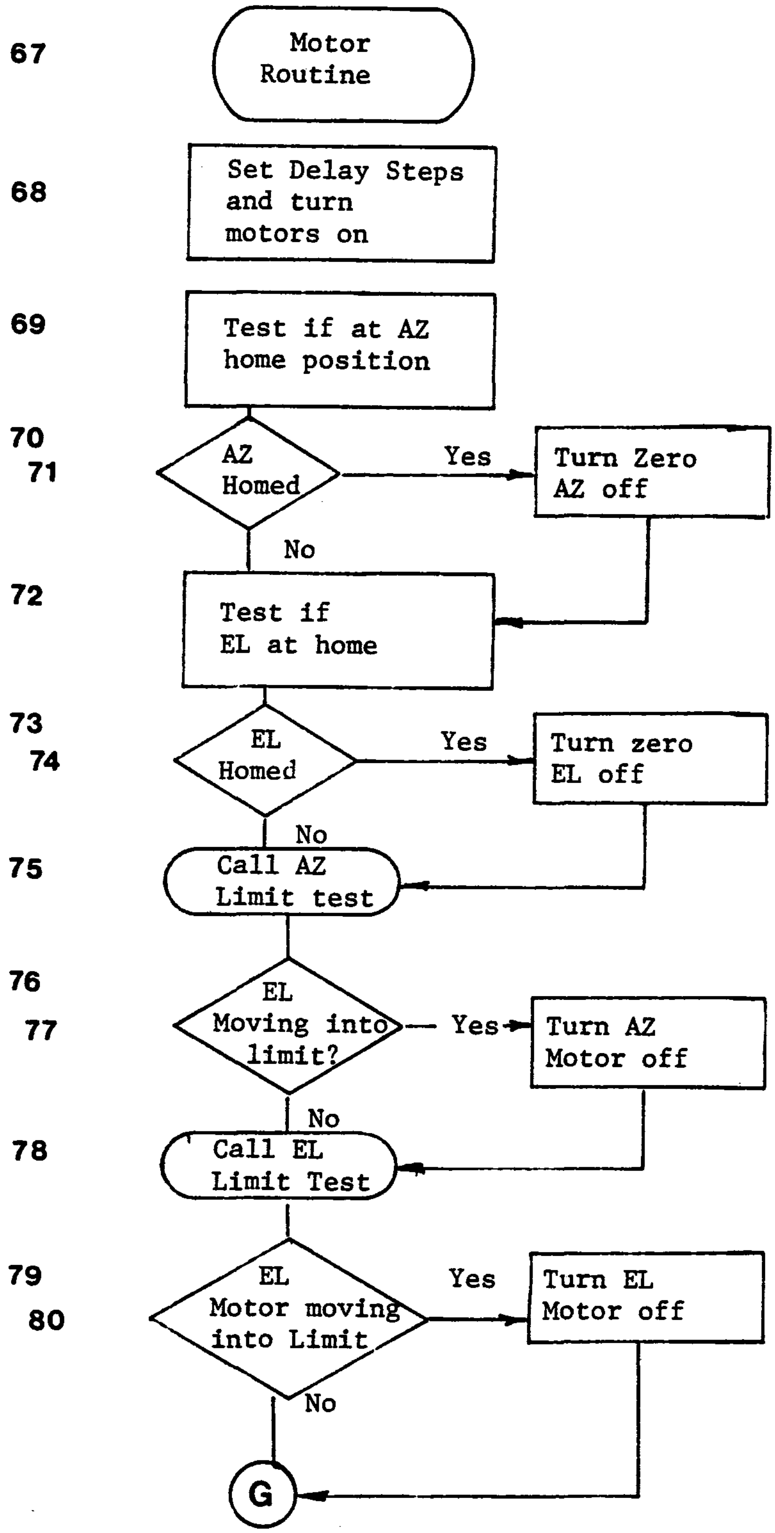

C
32
Clear Command Ready
33
Test for High Speed
34
High Speed
No
Yes
35
Set high speed Bit
36
Test for set Position
37
Set Position ?
No
Yes
38
Set Absolute position equal to Command
39
Test for Request Status
40
Request Status
No
E
Yes
41
Enable Xmit Interupts
D



42 43 44 45 46 47 48 49 50 51 52 53 54

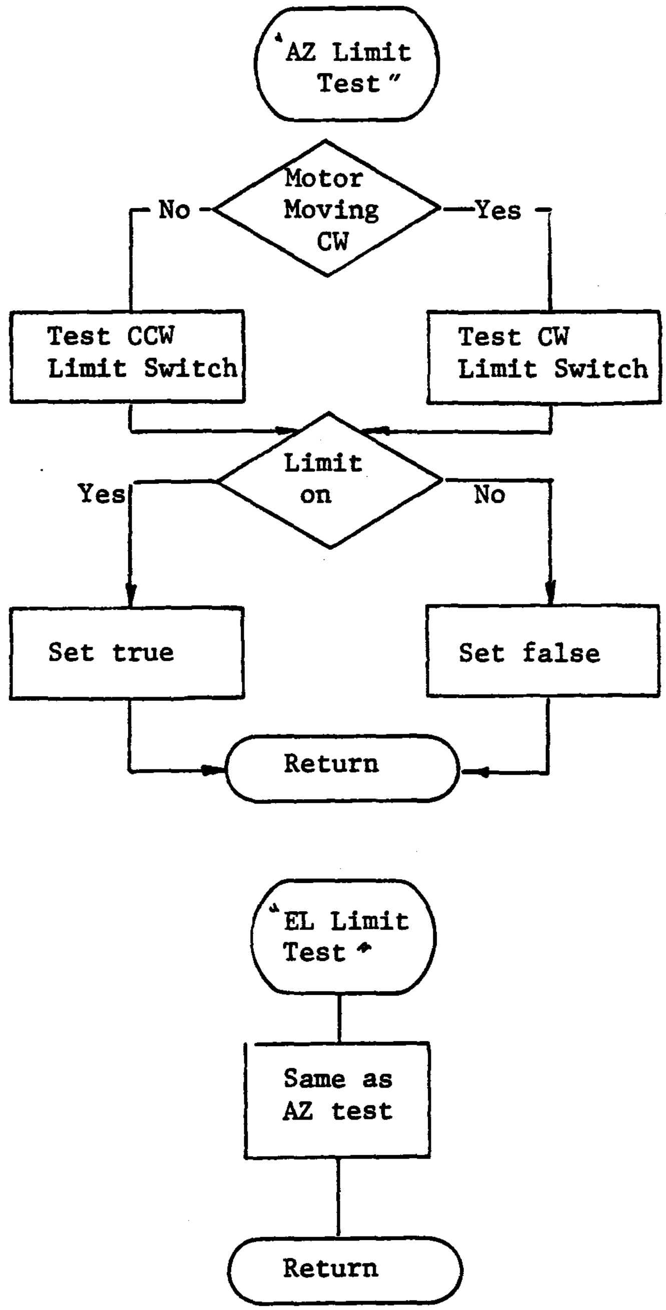

F
55
Test for
Slew El
56
57
Set for Slew
in CW Direction
Yes
Slew
EL
No
58
Test for
CCW Direction
Subtract ABS
from command
Store in stops EL
61
59
CCW
Direction
?
No
Yes
Set for CW
Direction
62
60
Set for
CCW Direction
Steps
Negative
?
No
63
Yes
Complement
steps and
set for CCW
64
Set Status
with Limit
Switch Staus
65
Call Motor
Routine
66
D

FLOW CHART FOR HELIOSTAT CONTROLLER (Page 6)

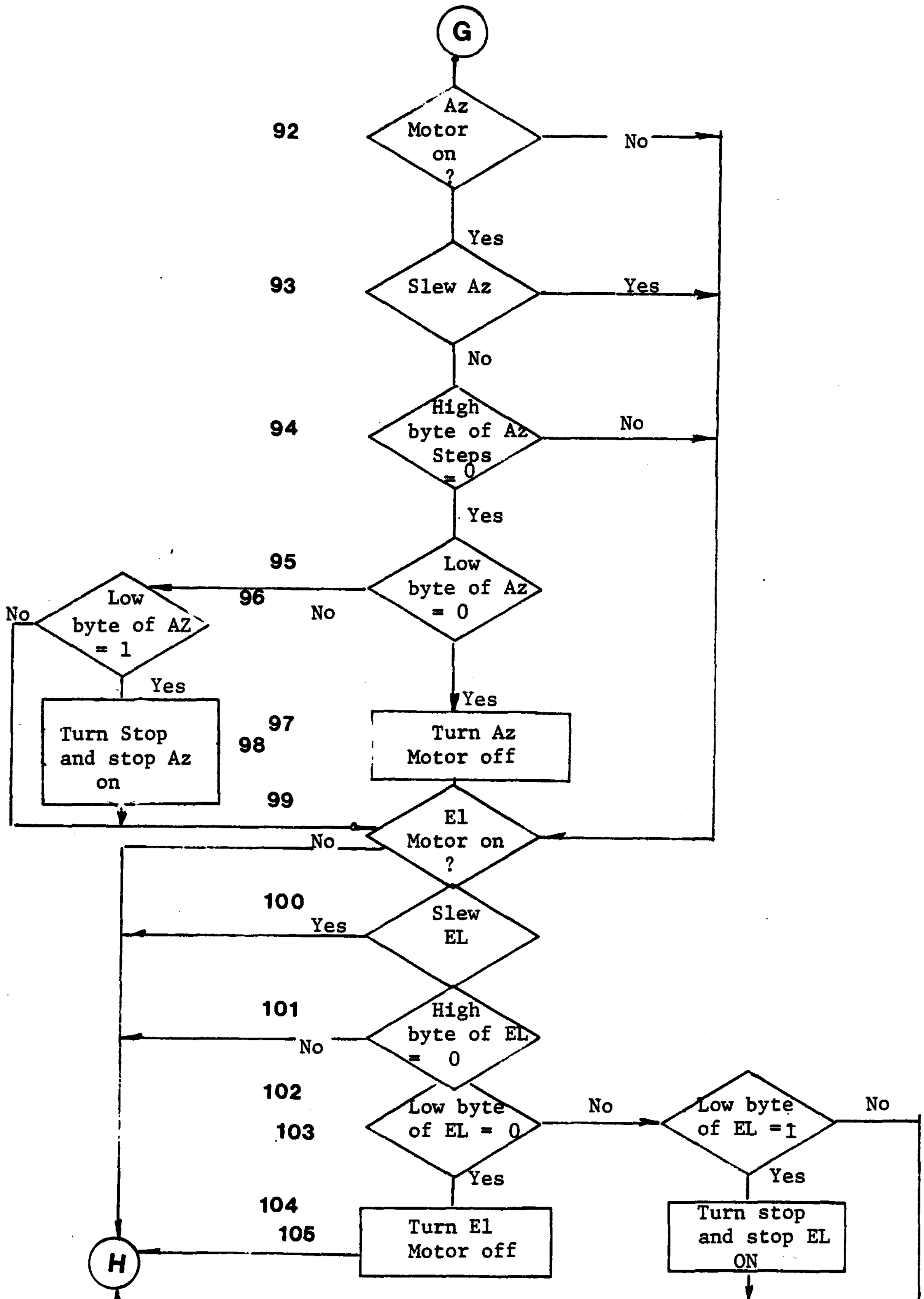


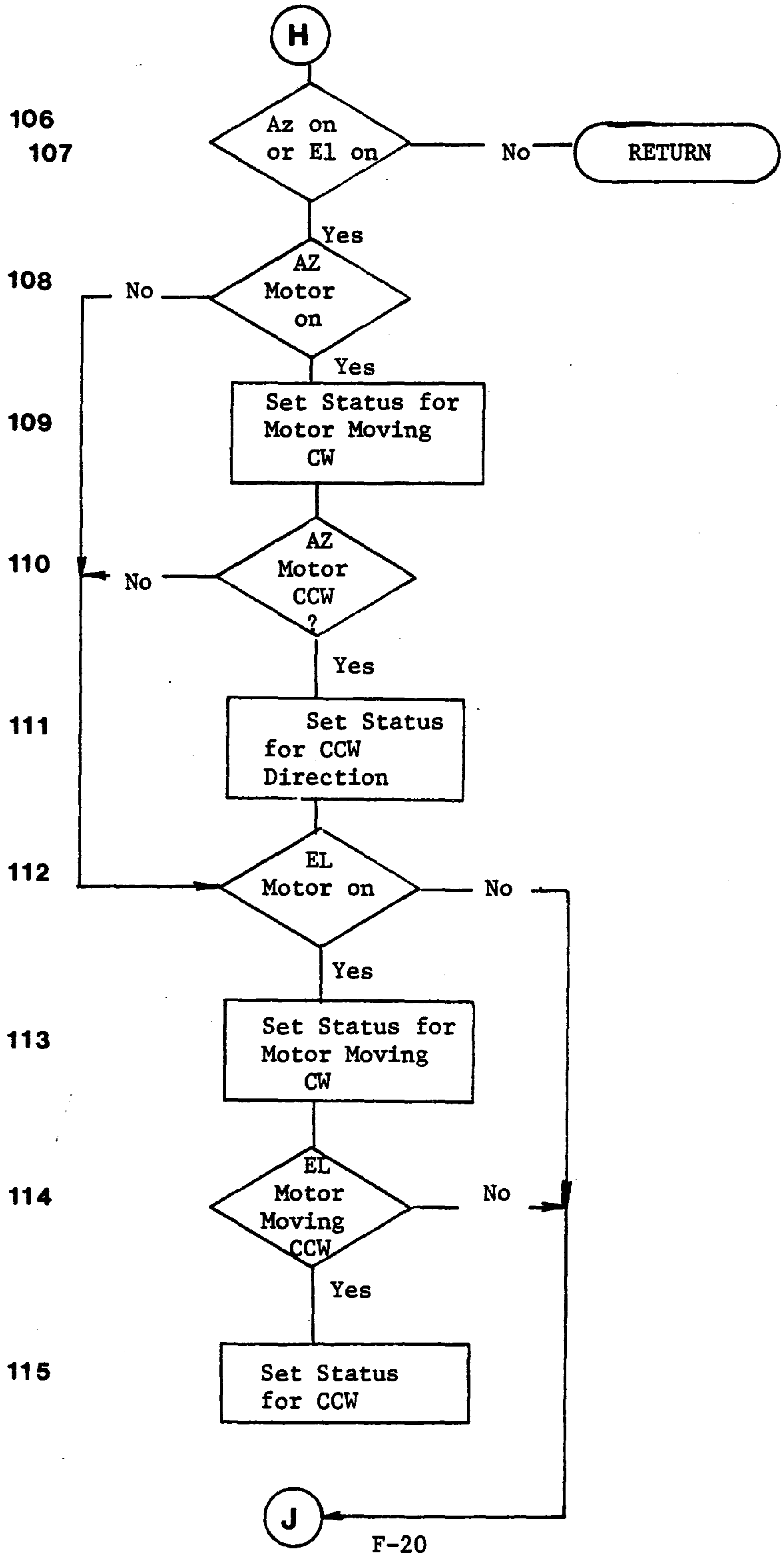
FLOW CHART FOR HELIOSTAT CONTROLLER (Page 6 A)

81
82
83
84
85
86
87
88
89
90
91

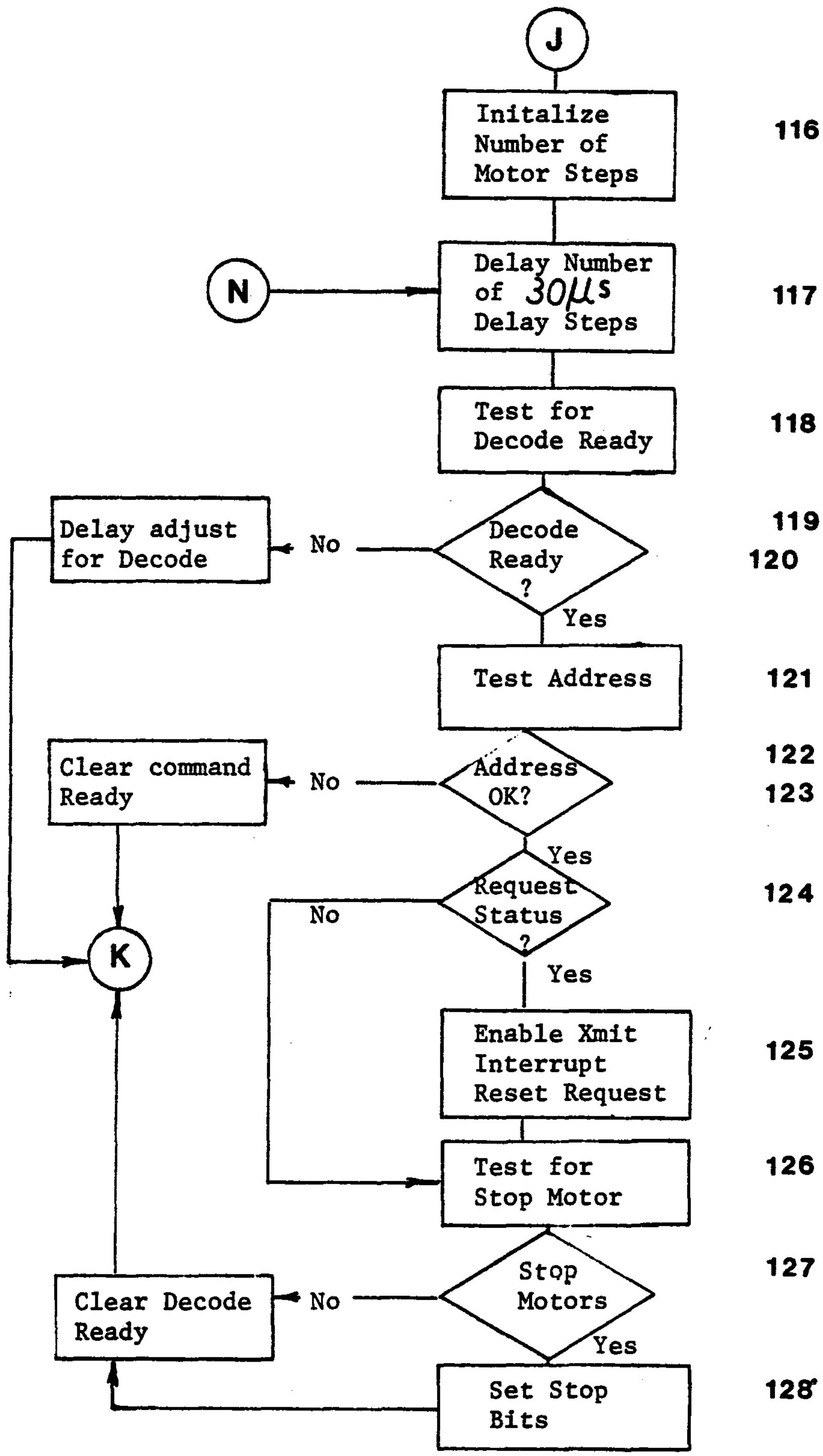


FLOW CHART FOR HELIOSTAT CONTROLLER (Page 7)

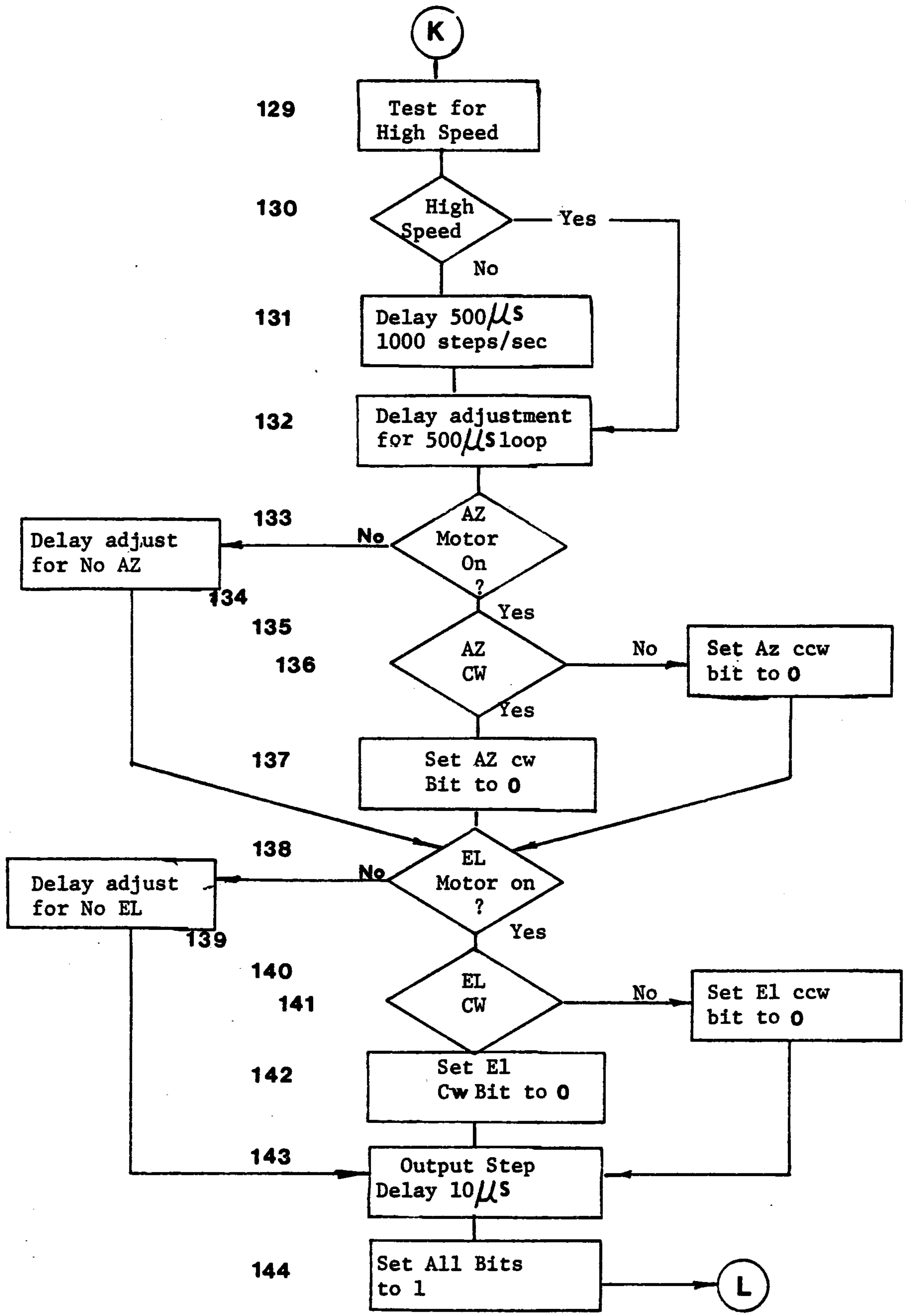



H
106
107
Az on or El on
No
RETURN
Yes
108
No
AZ Motor on
Yes
109
Set Status for Motor Moving CW
110
No
AZ Motor CCW ?
Yes
111
Set Status for CCW Direction
112
EL Motor on
No
Yes
113
Set Status for Motor Moving CW
114
EL Motor Moving CCW
No
Yes
115
Set Status for CCW
J

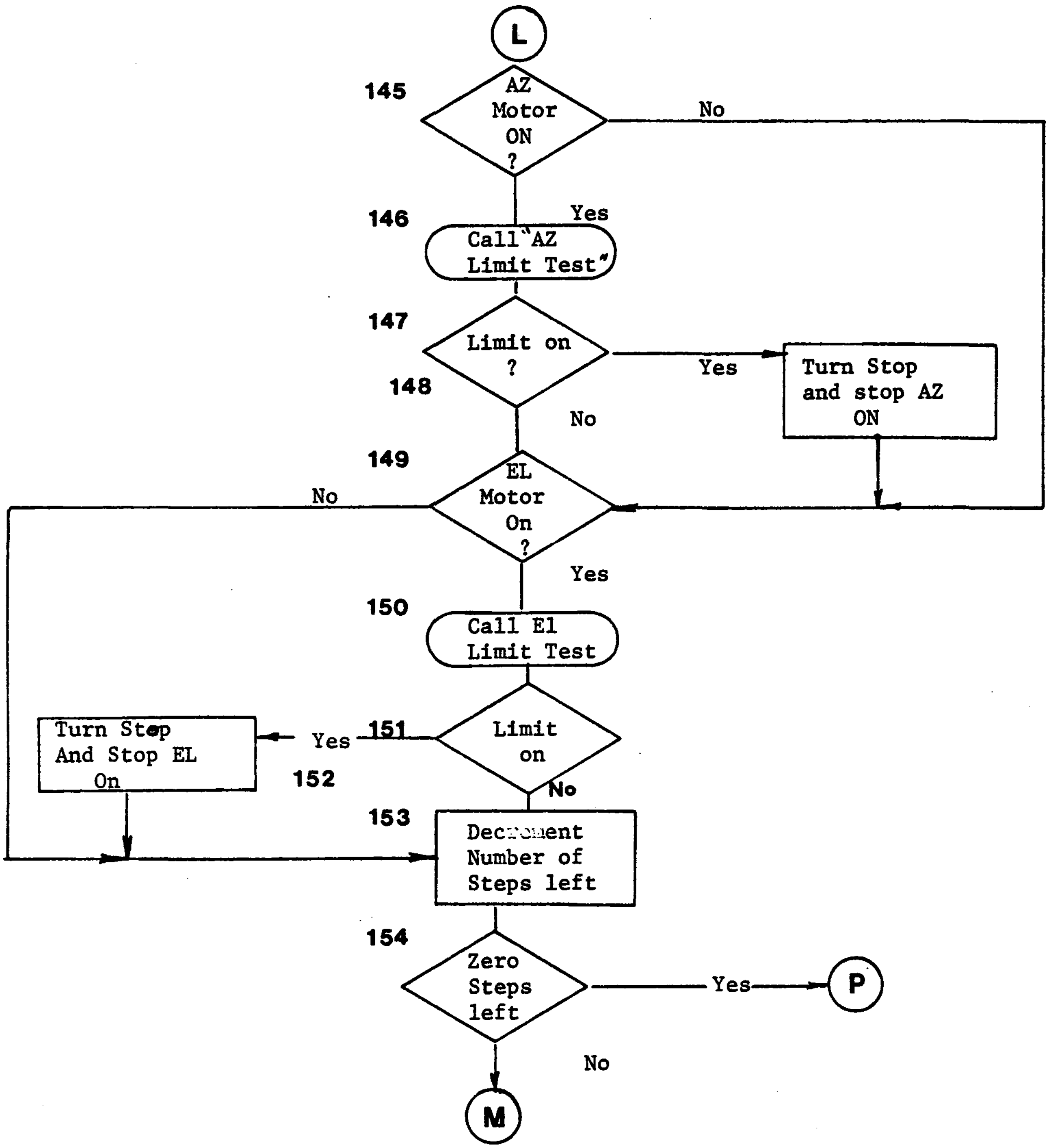
FLOW CHART FOR HELIOSTAT CONTROLLER (Page 9)



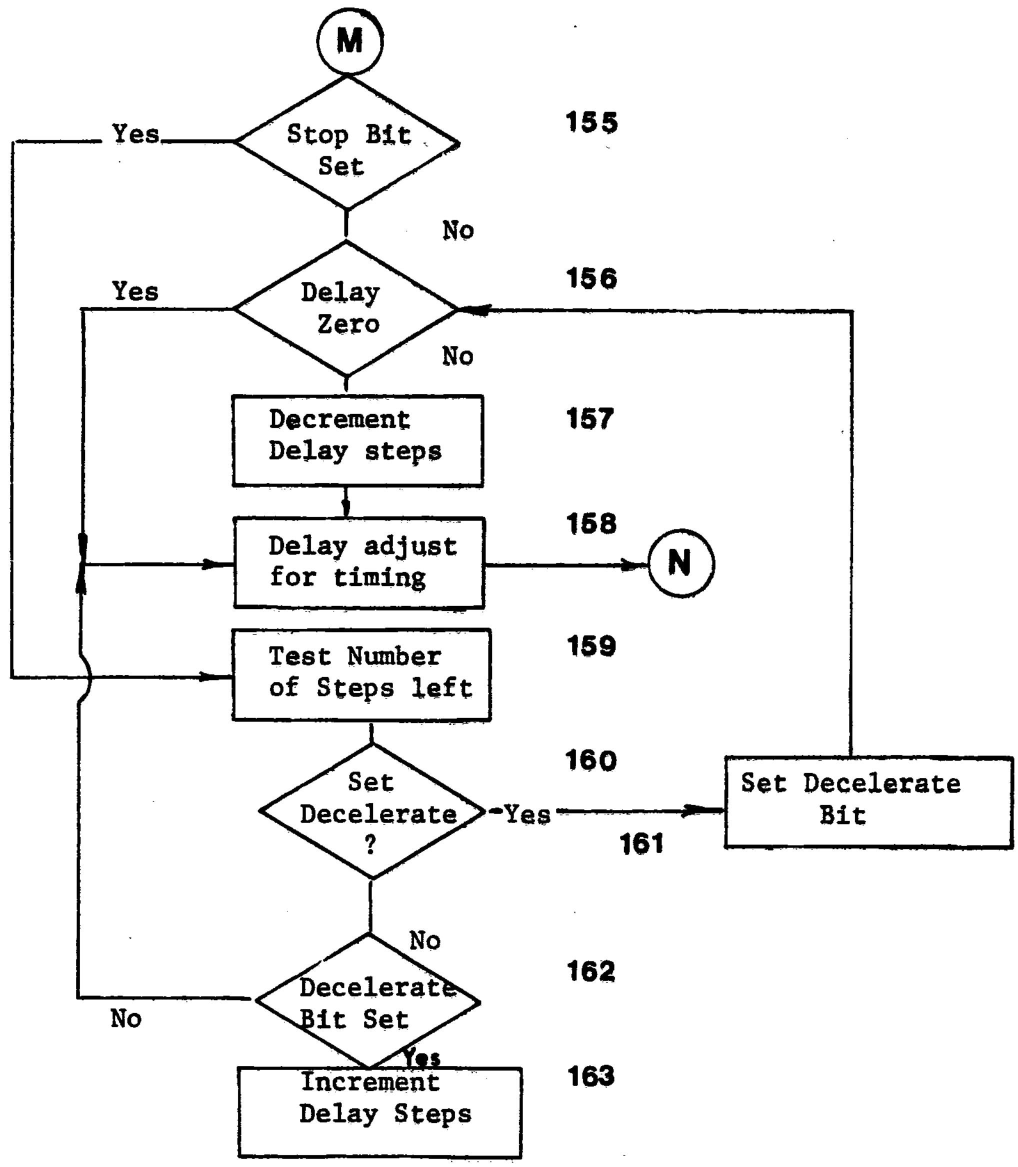
FLOW CHART FOR HELIOSTAT CONTROLLER (Page 10)

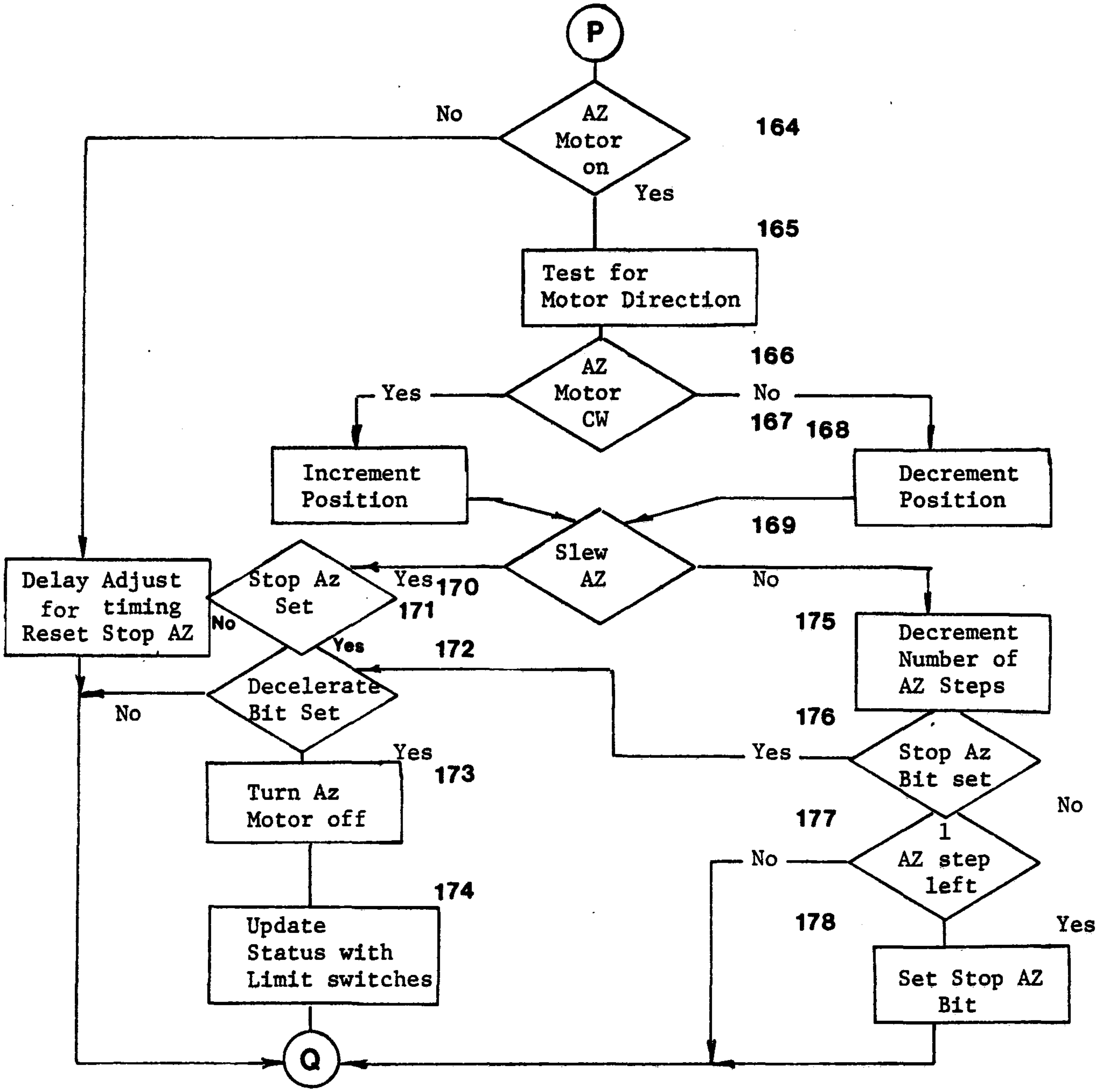


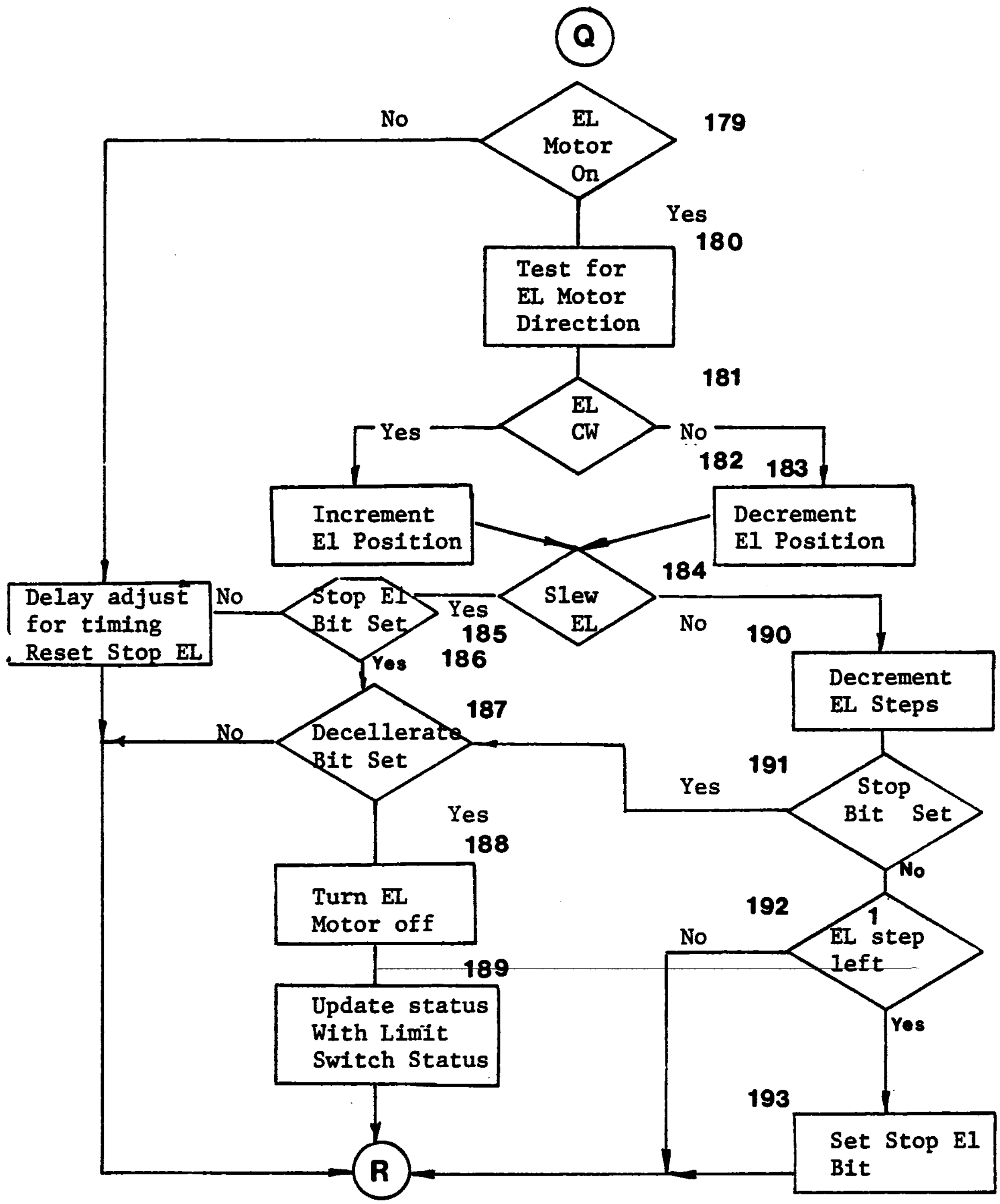
FLOW CHART FOR HELIOSTAT CONTROLLER (Page 11)



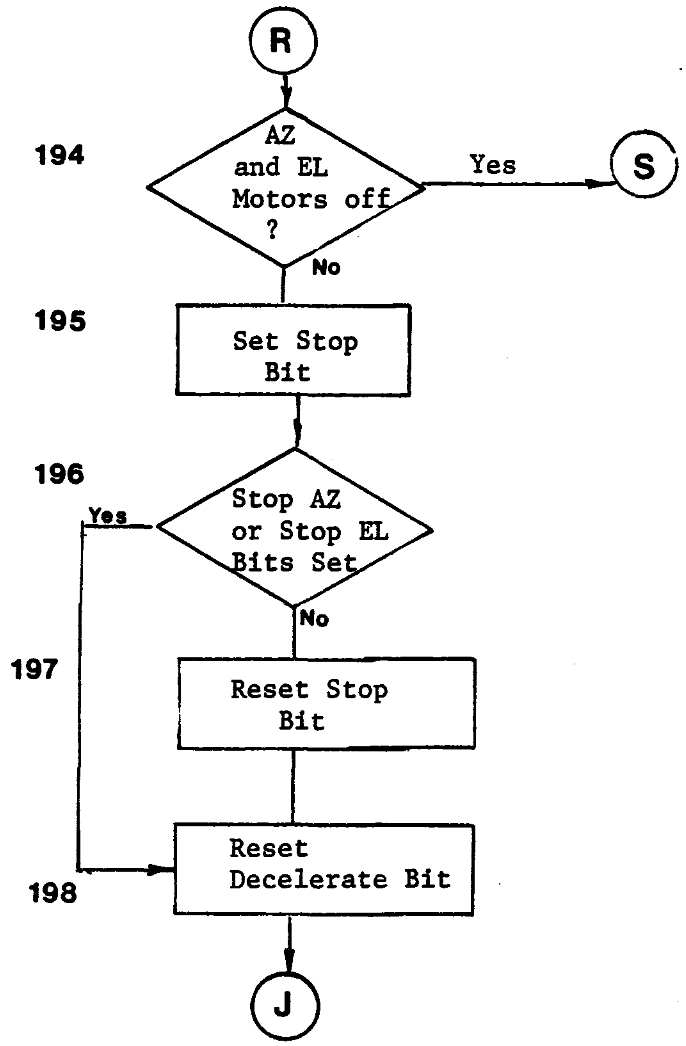
FLOW CHART FOR HELIOSTAT CONTROLLER (Page 12)



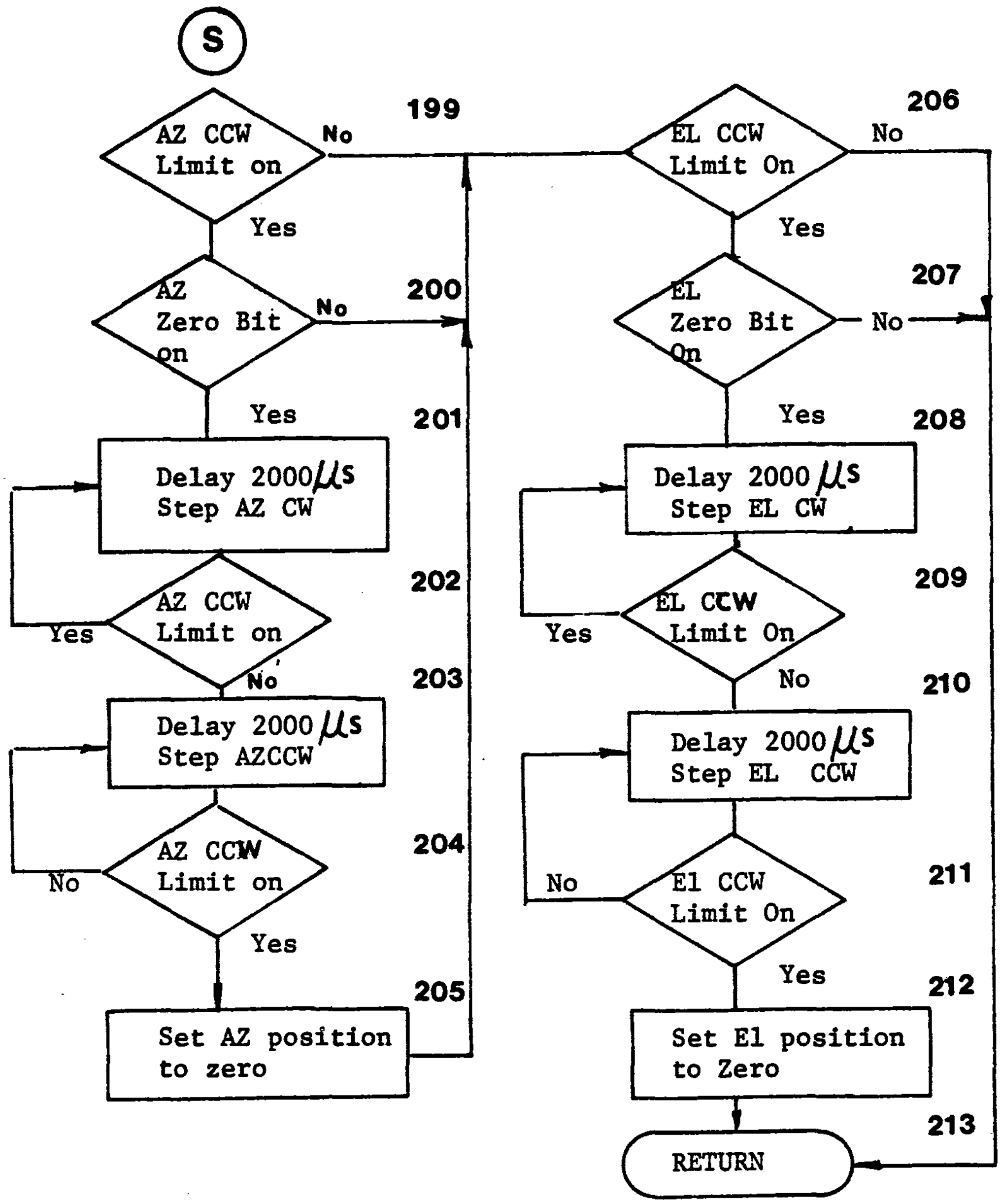

P
AZ Motor on
164
No
Yes
165
Test for Motor Direction
166
AZ Motor CW
Yes
No
167
168
Increment Position
Decrement Position
169
Slew AZ
Yes
No
170
Stop Az Set
171
No
Yes
Delay Adjust for timing Reset Stop AZ
172
Decelerate Bit Set
No
Yes
173
Turn Az Motor off
174
Update Status with Limit switches
175
Decrement Number of AZ Steps
176
Stop Az Bit set
Yes
No
177
1 AZ step left
No
Yes
178
Set Stop AZ Bit
Q


Q
EL Motor On
179
No
Yes
180
Test for EL Motor Direction
181
EL CW
Yes
No
182
183
Increment El Position
Decrement El Position
184
Slew EL
Yes
No
185
Stop El Bit Set
No
Delay adjust for timing Reset Stop EL
Yes
186
190
Decrement EL Steps
187
Decellerate Bit Set
No
Yes
191
Stop Bit Set
Yes
No
188
Turn EL Motor off
192
1 EL step left
No
Yes
189
Update status With Limit Switch Status
193
Set Stop El Bit
R

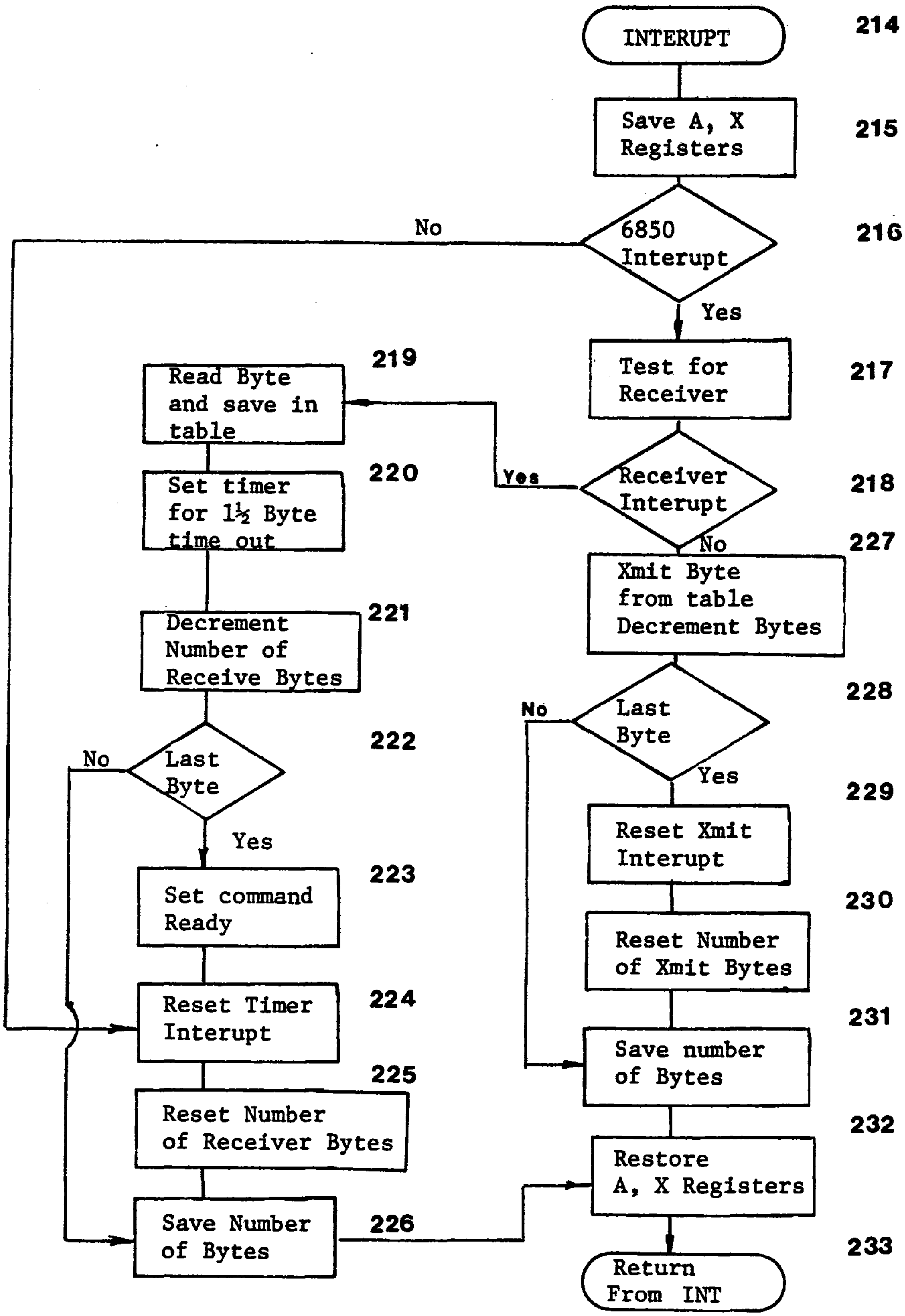
FLOW CHART FOR HELIOSTAT CONTROLLER (Page 15)



FLOW CHART FOR HELIOSTAT CONTROLLER (Page 16)



FLOW CHART FOR HELIOSTAT CONTROLLER (Page 17)



9.7 Test Results (Appendix G)

9.7.1 <u>Electronic Tests</u>

9.7.1.1 Computer Control of Northrup I Heliostat

The initial electronic testing activity was the bench evaluation of the Superior Electric Co. STM 101 translator and the computer controlled operation of Superior M063-FC06 stepper motors with the STM 101 translator. The M063 is rated at 100 in-lb in the 0-500 step/sec speed range.

Due to the high end to end gear ratio of Northrup I, 180:1 motor gear head x 440:1 Heliostat Drive (79,200:1 total in azimuth) and (180 x 520 = 93,600:1 in elevation) the laboratory size stepper motors could be used for a full scale heliostat computer tracking experiment.

A simplified translator was built and software designed to drive the heliostat in a tracking mode. This translator was tested on the Northrup I heliostat. The Commodore computer was used to drive the translator. A basic program was used to calculate the step commands from time of day, heliostat and target coordinates. The step commands were then passed to a machine language program that drove the translator. The translator interfaced to the computer through a 6522 versatile interface adapter. A small stepper motor was used to drive the Northrup I heliostat through the existing motor and gearhead. This was enough to demonstrate tracking but not to slew. Slewing was accomplished with the AC Bodine motor. Good tracking was demonstrated with the stepper motor for about a six hour period.

A low power mode was demonstrated with the Northrup translator design. This was accomplished by adding a fifth mode to the logic table that turned off all the transistor switches at once. The drawback to this method is that no holding torque is available during the low power mode. Test results on the heliostat showed no loss of steps during the low power mode on elevation and some loss of steps in azimuth. Later analysis of the azimuth problem showed an abnormal amount of backdrive in the drive mechanism due to a soft rubber coupling between the original motor and the stage 1 worm shaft.

9.7.1.2 Limit Switch Tests

The accuracy of the electronics and stepper motors is dependent on the position reference offered by the home position switch. In order to verify part specifications and obtain confidence in our design we constructed a limit switch tester. This tester consisted of a small stepper motor driving an actuator through several stages of gear reduction. Special software was designed to drive the motor into the switch, back it off, and record the position. The accuracy of each step of the motor was .000047 inch which amounts to .0047 mr for a 10" arm. The test was performed over a period of three days and a few hundred data points obtained. The repeatability was within plus or minus 3 steps.

9.7.1.3 Translator Tests

Three different translators were procured and a fourth designed and built.

The first type of translator tested was the Superior Electric STM 101. This unit consisted of power drivers and sequential switching logic. This translator requires either external pulses or allows internal speed control. The design simulates constant current to the motor with high supply voltage and series resistors. This translator has the disadvantage of dissipating more power when the motor is at rest than when moving. The power supply required is 24 volts at 6 amperes. Since the motor windings see a constant voltage source in series with a resistor, the motor quickly runs out of torque at the higher speeds due to the the back emf generated. The internal logic in the translator converts input pulses to a logic configuration which can be easily generated by a microprocessor.

Software for driving the translator was developed for a stand alone heliostat controller. By using the Commodore computer for the development system we were able to change from the basic heliostat driver to a machine language driver in one computer and a serial data transfer to another computer. Once the machine language program was checked out, the program was burned in a 2716 EROM that was plugged into the Commodore computer and tested. Once checked out a breadboard was built and checked for driving the stepper motors through the Northrup translator. After checking out the motor speed torque characteristics on a dynamometer it indicated a need for improved torque at high speeds. Several software strategies were developed for slewing the motor at high speeds. These techniques involved pulsing the motor during each step. This technique showed the need for analog feedback to control the motor current in the absence of current limiting resistors.

TC 600 Translator Tests

The Superior Electric TC 600 translator was tested for performance with the M112-FJ-326 and the M092-FD-310 motors. The results showed good torque/speed performance and a high amount of heating in the stand-by mode. The translator required four external supplies one of which was 70 volts at 10 amperes peak current. The unit generated high current switching transients at a frequency higher than the stepping rate.

TBM 105 Translator Tests

The TBM 105-9214 and the TBM 105-1230 were tested with the M092-FD-310 and the M112-FJ-326 respectively. The results showed moderate torque/speed performance and small amount of motor heating. The translator was self contained and only required a 110 volt supply. The only transients generated were the stepping signals to the motor.

9.7.2 Mechanical Tests

9.7.2.1 Component Tests

9.7.2.1.1 Mirror Module Hail Test

Extensive mirror module hail tests have been performed throughout the contract period to verify the adequacy of the mirror-silicone grease-steel substrate to resist breakage. Some initial tests were performed with "specification" ice balls of 0.75 inch diameter at speeds of 65 ft/sec. However, breakage was virtually non-existent, so subsequent tests were all performed with "margin" ice balls of 1.0 inch diameter.

A pneumatically-powered hail gun was constructed at the Northrup-Hutchins facility. Photoelectric sensors were employed to measure the time interval over a fixed, known distance which enabled the velocity to be computed. Various velocities were achieved by adjusting the chamber pressure which propelled the hail balls. The firing of an ice ball was accomplished by an electrical switch which in turn would trigger a solenoid valve to release the high pressure air into the barrel. Spherical ice balls of 1.0 inch diameter were made in a 2-piece aluminum mold which was fabricated specifically for this purpose. To insure adequate hardness, the ice balls were frozen and chilled to 20°F maximum.

For ice balls fired into the mirror interior area (away from the edges), velocities as high as 140 ft/sec could be tolerated without breakage. Edge hits would generally pass velocities up to 100 ft/sec. Infrequent breaks would occur at or near the edges at velocities near 75 ft/sec. It is believed that these were generally caused by an existing edge defect such as a minute crack or chip, and an impact in the near vicinity would cause the defect to propagate from the defect to the impact zone. Generally, breakage was very infrequent even with the "margin" ice balls of 1.0 inch diameter, and velocities well above 75 ft/sec. Hence, the mirror module design is felt to be very adequate from the hail impact standpoint.

9.7.2.1.2 Mirror Module Thermal Cycling-Freeze/Thaw

A single mirror module (S/N 200078) was subjected to a series of thermal cycles in the Northrup environmental control room. A total of 10 cycles were performed. A thermal cycle consisted of heating to 120°F at the rise rate of 60°F/hour, stabilizing at this level for 30 minutes, spraying with ambient temperature water for 2-3 minutes, ramping down at 60°F/hour to 15°F, stabilizing at this level for 30 minutes, spraying with ambient temperature water for 2-3 minutes, and then cycling back to 120°F.

The objective of this test was to demonstrate the functional and structural integrity of the mirror module. The primary aim was to determine if any damage results from thermal cycling, thermal shock, or freezing. Another equally important goal was to visually check the appearance for distortions or curvatures at the temperature extremes.

The test instrumentation consisted of 4 thermocouples for measuring mirror module temperature at the following locations:

a. Backside module sheet-adjacent to 48" rectangular cross support member-left side.

b. Backside module sheet-adjacent to 48" rectangular cross support member-right side.

c. Mirror face-left end-approximately 3" inboard and near center of 48" width.

d. Mirror face-right end-approximately 6" inboard and near center of 48" width.

In addition to these temperature measurements, an optical "zebra-board" was constructed to enable a qualitative evaluation of mirror distortion and/or curvature to be made. The "zebra-board" was fabricated from a 4' x 12' mirror-less mirror module, painted white, and gridded with 1/2-inch wide black stripes on 4-inch centers. The "zebra-board" image in the mirror module being tested was visually examined and photographed at each temperature extreme.

The test results indicated a complete success. No damage resulted from the thermal cycling, the thermal shock from the water spray, or from the resulting freeze-thaw cycles. The visual observations of the "zebra-board" revealed no observable curvature or change in distortion.

9.7.2.1.3 Mirror Module Survival Wind Load Test

Test Objective: The objective of the mirror module survival wind load test was to verify the structural integrity of the adhesive bond joints and primary load paths through the attachments and adjacent rib members when subjected to loads comparable to a 90 mph wind.

Test Description: Figure 9.7-1 illustrates the test set-up used for the mirror module survival wind load test. Since the test objective was to evaluate the mirror module adhesive and structure, a module with broken mirrors was used. The broken mirrors were removed prior to testing. The module was suspended from the 3 attachment studs (i.e., face down orientation), and dead-weight loaded with wet sand on the backside. Only one-half of the module area was loaded on test #1, and the opposite end was loaded on test #2 to enable two potentially destructive tests to be accomplished on the same module.

Instrumentation: The instrumentation used on this test consisted of a load gage to measure the sand weight, and 7 dial indicators to measure deflections. The dial indicators were attached such that the deflections being measured excluded deflections of the load gage and the test fixture main support member. The 7 dial indicators were located beneath each of the 7 longitudinal mirror module ribs.

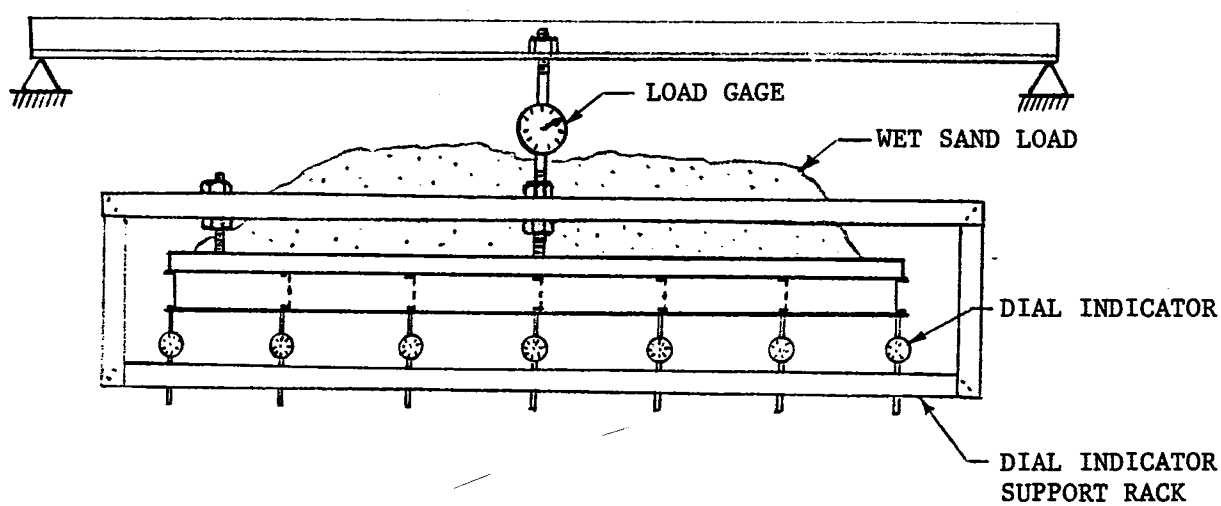


FIGURE 9.7 -1

MIRROR MODULE SURVIVAL WIND LOAD TEST

Test Conditions: The test loads were based on a 90 mph wind impacting a heliostat in the vertical stow position. This represents an over-test condition because a heliostat would normally be stowed horizontally if a high wind were anticipated. With a 90 mph wind normal to the heliostat, a peak pressure at the geometric center of 2.38 times the dynamic pressure occurs. This corresponds to a loading of 37.4 lb/ft^2. Since only one-half of the mirror module area (24.0 ft^2) was loaded on each test, an 897.6 lb sand weight simulates the worst case 90 mph wind condition. This load was applied in 100 lb increments with dial indicator readings taken at each increment.

Test Results: Table 9.7-1 and 9.7-2 present the load and deflection readings for the two tests. It will be noted that the test loads were increased to a maximum of 1500 lbs in an attempt to cause a bond failure. The dial indicator deflections indicate normal bending, and no bond failure with one possible exception. Dial indicator #2 at the 1400 lb load on test #1 indicated a large, abrupt deflection which may indicate a local bond failure. Since this occurred at a high over-test load, no sections were cut open to confirm this possibility.

Table 9.7- 1

Mirror Module Survival Wind Load Test - Run #1

Load Cell	Dial #1	Dial #2	Dial #3	Dial #4	Dial #5	Dial #6	Dial #7
98 lb	.030 "	.121"	.096"	.105"	.109"	.059"	.065"
200	.029	.120	.094	.104	.110	.065	.075
300	.030	.120	.094	.105	.113	.070	.082
400	.030	.120	.094	.106	.116	.075	.090
500	.031	.121	.095	.108	.120	.082	.100
600	.032	.121	.095	.109	.124	.090	.110
600*	.034	.123	.097	.111	.125	.089	.109
700	.033	.123	.096	.111	.127	.093	.116
800	.027	.122	.096	.111	.130	.099	.124
900	.031	.122	.095	.112	.134	.106	.134
950	.029	.121	.095	.112	.135	.110	.140
1000	.029	.121	.095	.112	.138	.114	.146
1100	.029	.121	.094	.113	.140	.119	.154
1200	.030	.121	.094	.114	.144	.126	.164
1300	.030	.122	.094	.114	.146	.132	.175
1400	.032	.143	.095	.116	.150	.138	.184
1500	.025	.143	.091	.113	.149	.138	.186
98	.018	.116	.089	.100	.103	.048	.052

*After 1.5 hour dwell at this load

Table 9.7-2

Mirror Module Survival Wind Load Test - Run # 2

Load Cell	Dial #1	Dial #2	Dial #3	Dial #4	Dial #5	Dial #6	Dial #7
95 lb	.026"	.072"	.124"	.080"	.055"	.069"	.023"
200	.025	.070	.123	.080	.060	.077	.036
300	.024	.070	.122	.081	.064	.085	.048
400	.024	.069	.122	.082	.068	.091	.058
500	.024	.068	.122	.082	.072	.100	.070
600*	.020	.073	.120	.083	.075	.110	.081
700	.020	.067	.120	.084	.079	.115	.088
800	.019	.066	.120	.084	.082	.120	.096
900	.019	.066	.120	.085	.086	.125	.104
1000	.020	.066	.120	.086	.092	.135	.118
1100	.018	.065	.120	.087	.096	.142	.129
1200	.019	.066	.120	.088	.101	.149	.139
1300	.018	.066	.120	.089	.106	.156	.149
1400	.019	.066	.120	.088	.111	.160	.157
1500	.020	.067	.120	.089	.115	.165	.165
1200	.021	.066	.122	.091	.111	.156	.155
105	.016	.066	.123	.081	.066	.079	.036

* A rear support adjustment was made which shifted the readings slightly.

9.7.2.1.4 Mirror Module Imperfection Evaluation

Several tests were performed to evaluate mirror module and/or mirror-only surface imperfections. One of these was a laser ray trace performed by Sandia-Albuquerque on two mirror modules during the period December 15-16, 1980. Figures 9.7-2 and 9.7-3 show the reflected beam deviation in inches and the corresponding deviation in milliradians for a typical scan across a mirror module. Note that two deviation values are provided, an x-deviation and a y-deviation for a scan which was made in the 144-inch (x) direction. Also provided are RMS-average milliradian deviations for the x and y component of the reflected ray. The following summarizes the RMS results for 11 such scans:

Mirror Module	Scan #	Scan Direction	RMS Reflected Beam Deviation x - component	y - component
A	4	y (48")	0.394 mrad	1.386 mrad
A	5	y (48")	0.756	1.296
A	6	y (48")	0.558	0.958
A	7	y (48")	0.544	1.638
B	4	y (48")	2.230	1.876
B	5	y (48")	0.922	1.736
B	6	y (48")	0.510	1.680
B	7	y (48")	0.608	1.358
B	1	x (144")	0.794	0.926
B	2	x (144")	0.750	0.946
B	3	x (144")	0.600	0.692
RMS of y-scans (48" direction)			0.987	1.517
RMS of x-scans (144" direction)			0.719	0.862
RMS of both scans			0.863	1.233

Figure 9.7-2

RAW DATA - LASER RAY TRACE EXAMPLE

X - Axis Scan (144" Direction)

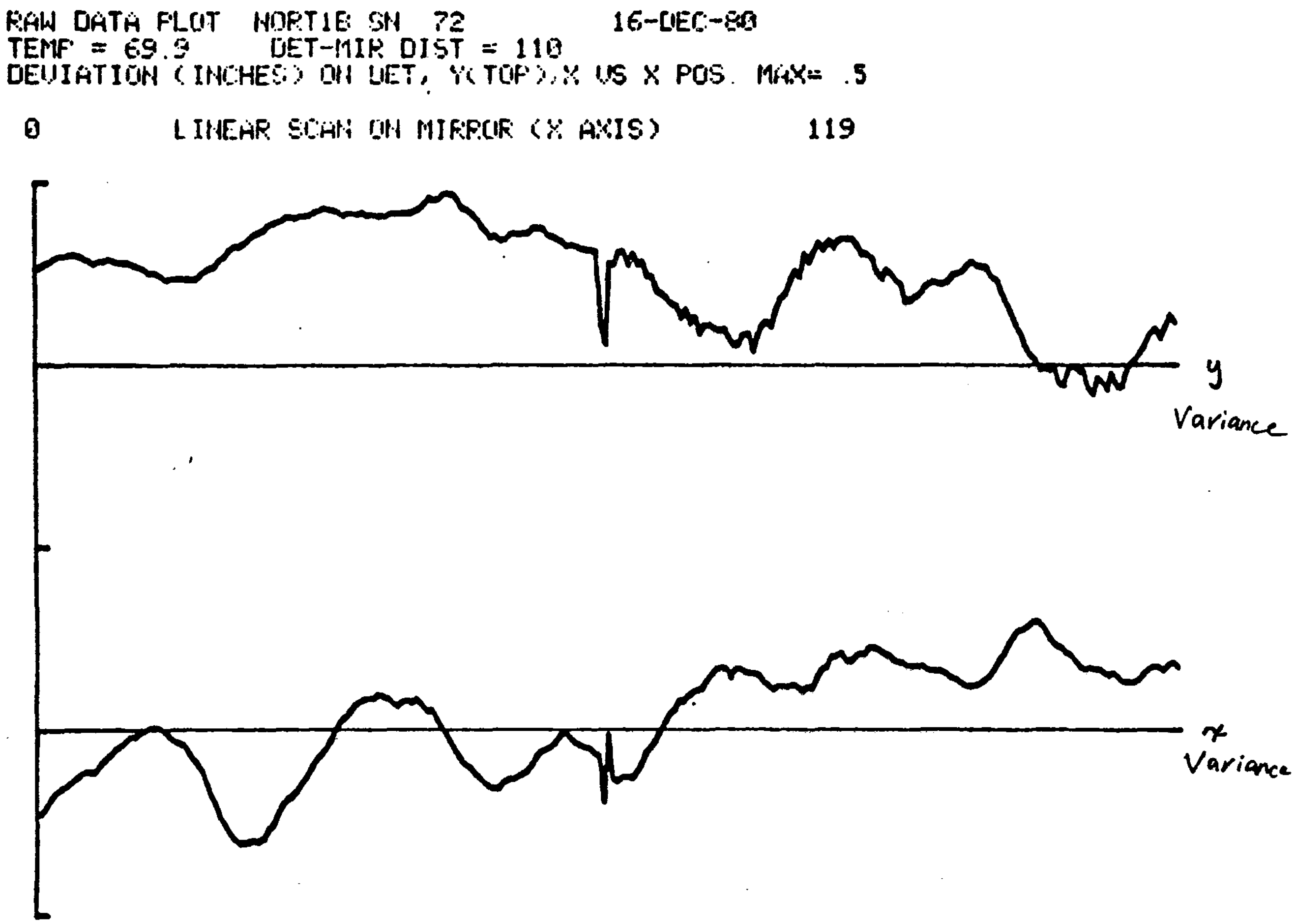
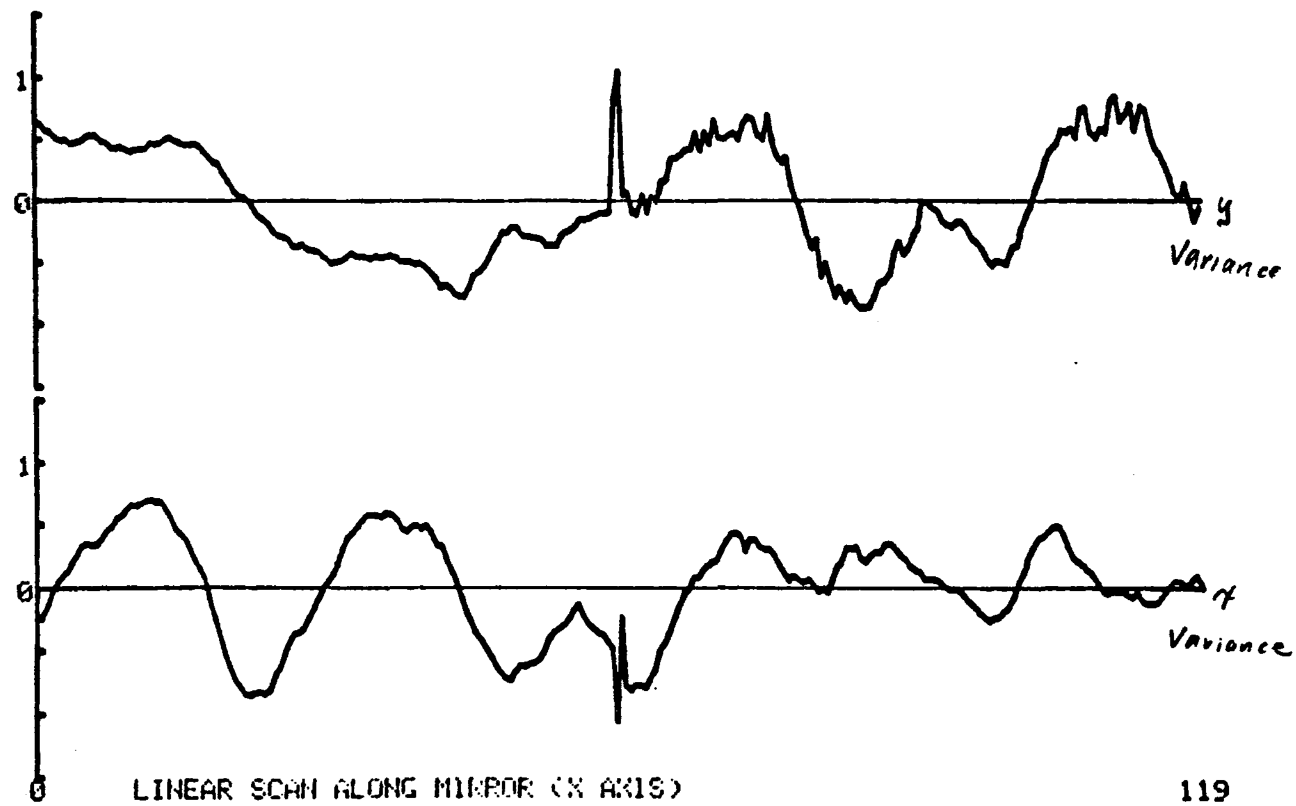


Figure 9.7-3

REDUCED DATA - LASER RAY TRACE EXAMPLE

X - Axis Scan (144" Direction)

SLOPE ANGLE VARIATION FOR NORT1B SN 72 SCANNED 16-DEC-80
TEMPERATURE = 69.9
PLOTTED IN MILLIRAD X RMS .397169 Y RMS .462658
VARIATION IN Y TOP PLOT IN X BOTTOM PLOT
LINES LX= -.783385 + .0149143 X LY= 39.6467 + .0114545 X



The interpretation of these data is not very straightforward. Intuitively, it would be expected that the x-component of the ray variance for a scan in the x-direction would correlate with the x-component of the ray variance for a scan in the y-direction. Likewise, it would be expected that the y-component of the ray variance for a scan in the y-direction would be similar to the y-component of the ray variance for a scan in the x-direction. However, the data do not match these intuitive expectations for the x-components. If it is assumed that the most meaniful values are the RMS average x-component values from the x and y scans, and the RMS average y-component values from the x and y scans, the resultant RMS imperfection angles are 0.719 milliradians for the x direction (144 inch direction), and 1.517 milliradians for the y-direction (48 inch direction).

One pertinent question regarding these data is what is the primary cause of these imperfections; is it the mirror glass or the module design and construction? A set of measurements were made on a 4' x 6' mirror facet at the Northrup-Hutchins facility to help answer this question. The measurements were made on a mirror only, not a mirror module. The mirror was placed on a very flat, leveled granite surface plate 5' x 7' in size. An 8" long calibrated Starret level was used to measure the surface angles at 45 locations on the mirror. The measurements were converted to milliradian angles and doubled to give reflected beam values. The RMS values of these measured angles were 0.771 mrad for the x-scan (72" direction) and 0.706 mrad for the y-scan (48" direction). Comparing these glass-only values to the laser ray data obtained on complete mirror module assemblies results in the following:

	Laser Ray-Complete Mirror Module	Starret Level-Mirror Facet Only
x-scan	0.719 mrad	0.771 mrad
y-scan	1.517	0.706

The implication is a strong one, and is one which is consistent with visual observations: a large portion of the distortion on a mirror module is inherent in the mirror glass. The main area where this is not true is at the edges; the original edge seal was a commercial edging known as Bailey "C"-Sash. It mechanically gripped the mirror edge so tightly that edge distortions occurred. Since the y-direction scan is only 48 inches long, this edge effect strongly influences the RMS error measured by the laser ray scan. The new edge seal employs a simple "U" cross-sectional shape which is attached with a cure-in-place RTV silicone rubber. It also gives a very tight edge grip, but via adhesion rather than a mechanical grip, and as such is nearly distortion-free.

9.7.2.1.5 Water Spray Test

The objective of the water spray test was to simulate a wash and/or driving rain of potentially sensitive components such as the drive unit, motors, and exposed cable harnesses.

The test method consisted of spraying the area around the drive unit and pedestal from a distance of approximately 10 feet using an ordinary garden-variety hose and nozzle for a period of 20-25 minutes on 5 or more different days. The spray technique was to adjust the nozzle to achieve a droplet pattern and velocity similar to a wind-driven rain; i.e., a solid-stream jet was avoided. The heliostat was allowed to warm to a mid-afternoon ambient temperature, and then sprayed with cool tap water. Following the water spray operation, the heliostat would be operated for approximately 15 minutes.

Due to schedule limitations on the heliostat #1 unit, some deviations to the plan were necessary. The heliostat #1 unit was selected for test because it had a drive unit which had excessive backlash and was due to be returned to Winsmith for tear-down and re-work. This provided an excellent opportunity to determine if any water penetration had occurred. Due to the test schedule and replacement of this drive unit, only 3 water spray cycles were performed on the complete drive unit/heliostat assembly. However, an additional 4-day period of actual heavy rain conditions (i.e., 10 inches of rainfall) had been encountered previously, so a considerable exposure was actually encountered. In addition, the drive unit was subjected to an additional 6 cycles of water spray after its removal from the heliostat and prior to its return to Winsmith for tear-down. These 6 cycles were more severe than would normally be encountered for several reasons:

a. The drive unit was painted a dark gray in color, and therefore, would warm more than the current white painted configuration.

b. The drive unit was stored in a sunny area at the test site and was not shaded as it would be when installed on a heliostat. During the 6 cycles of spraying, the drive unit was first warmed to a mid-afternoon ambient temperature, and then sprayed with cool water.

c. The drive unit being tested did not have the expansion chamber which is currently installed on all production units for the purpose of preventing differential pressures between the inside of the drive and the external ambient pressure.

The results of the water spray test and actual rain exposure were as follows:

1. The tear-down of the drive unit at Winsmith revealed no perceptible water in the oil, and no evidence of any rust on any internal parts.

2. Water did enter the pedestal and wet the electronics during the actual heavy rain period. It was found that a small passage existed between the drive unit base and the pedestal tapered shims/flange. The opening was plugged with a small wad of duct-seal, and no direct water penetration was noted thereafter.

3. Some rusting was noted at flange interfaces such as between the motor and drive, between the torque tube flanges and drive unit, and between the drive unit base and pedestal tapered shims/flange. These surfaces are now being coated with a layer of silicone grease (to both coat the surfaces with a protective moisture barrier, and to fill the minute cracks and crevices which were acting as capillary paths for water draw-in).

4. A related observation is that some moisture was noted inside the pedestal walls and on electronic chassis surfaces even without water spray or rain. The phenomenon is undoubtedly caused by high humidity and cool pedestal/electronic temperatures. These temperatures were occasionally falling below the dew point, and the water vapor in the air then condensed on the cool surfaces. No visible damage or failures occurred from this condensation, but since it was undesirable, a technique was developed wherein the electronic cooling fan was always kept running. The small amount of power plus the moving air apparantly maintained the internal temperatures above the dew point so condensation no longer occurred.

9.7.2.1.6 Drive Unit Backlash Test

Test Objective: The objective of the backlash test was to experimentally determine the free backlash in prototype drive units built to drawing specifications.

Test Description: The test was performed on three heliostats at the Hutchins Test Site on October 30, 1980. They were:

- Heliostat #1 (after changeout from the drive with undercut gears to the properly built drive)
- Heliostat #2
- Heliostat #3

The backlash was measured with dial indicators as the rack and mirror structure was moved back and forth under light reversing forces to move the drives within their backlash range. The test was performed during very quiet wind conditions to avoid wind force disturbance as much as possible.

The mirror surfaces were in the vertical position during the azimuth backlash tests and in the horizontal position during the elevation backlash tests. The dial indicators were mounted on the opposite wing from where the light force was applied, to eliminate bending distortions from the readings.

In the azimuth tests, a force of 20 to 25 lbs at a 9.75 ft moment arm was applied to ensure bottoming out the backlash in both directions. In the elevation tests, a force of 20 to 25 lbs, or that required to ensure backlash bottoming out was applied at a 9.0 ft moment arm. A force of up to 100 lbs was applied to overcome the inherent moment resulting from center-of-gravity offset.

The 20 to 25 lb force application was made with a spring scale. The larger force applications during the elevation backlash tests were made manually and estimated only.

Instrumentation: The only instrumentation required for this test was a dial indicator on a small mounting stand for the azimuth test, a dial indicator on a tall mounting stand for the elevation test, and a 25 lb spring scale.

A sketch of the locations of the dial indicators and force application points are shown in Figures 9.7-4 and 9.7-5.

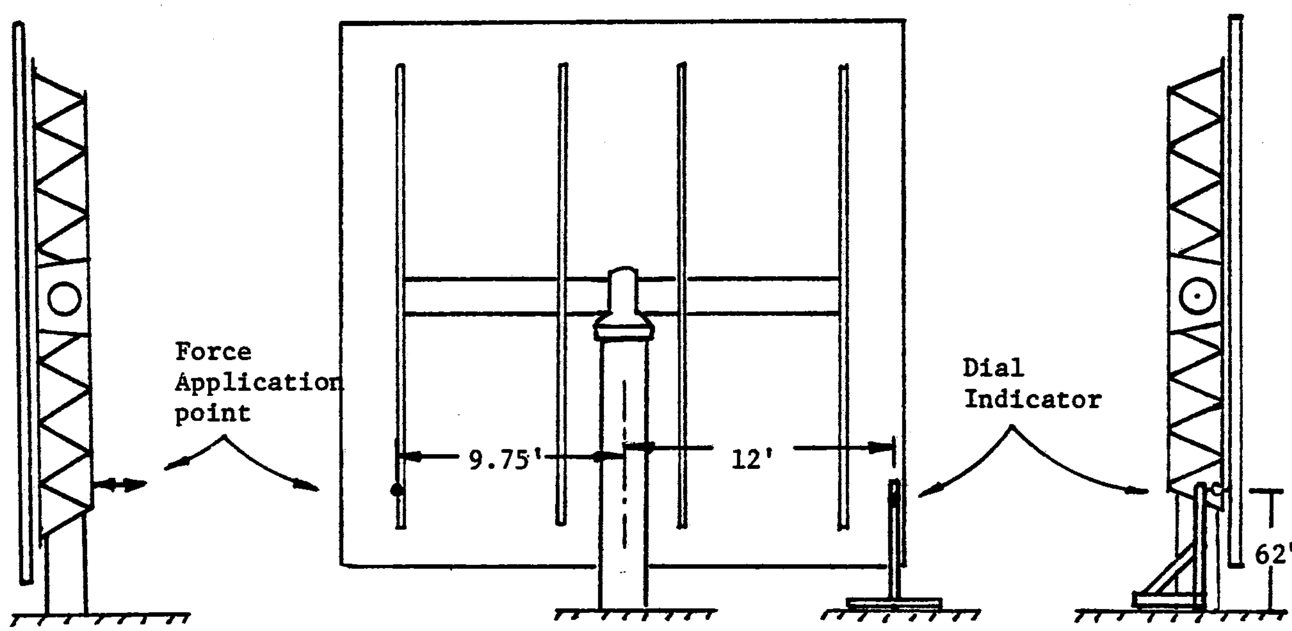
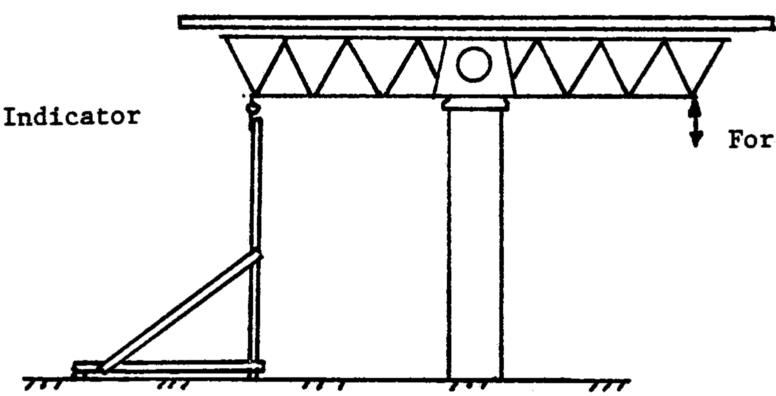
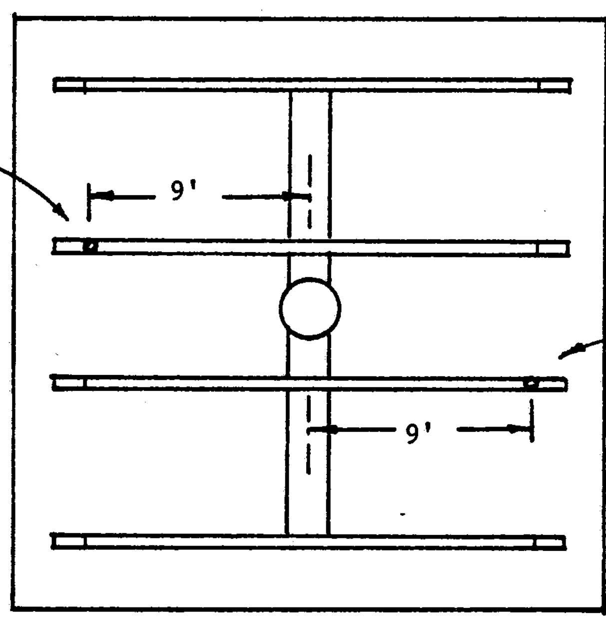


Figure 9.7- 4   Azimuth Backlash Test





View looking up

Figure 9.7-5 Elevation Backlash Test

Test Results: The backlash data is presented in Table 9.7-3. in terms of both deflection and milliradian rotation.

Table 9.7-3

	Azimuth		Elevation	
	Deflection	Rotation	Deflection	Rotation
Heliostat #1 (new drive)	.113 in	.785 mrad	.119 in	1.102 mrad
Heliostat #2	.025	.174	.127	1.176
Heliostat #3	.095	.660	.126	1.167
Average	.078	.539	.124	1.148

9.7.2.2 HELIOSTAT WIND LOAD TESTS

9.7.2.2.1 Pointing Accuracy With Operational Wind Loads Test

Test Objective: The objective of this pointing accuracy test was to experimentally determine the reflected beam motion about both the azimuth and elevation axes when the heliostat is subjected to 27 mph and 35 mph winds. This test was performed to demonstrate the requirement that the pointing error of the reflective surface (excluding foundation) is less than 3.6 mrad in a 27 mph wind. It was also performed at a 35 mph wind condition to determine the magnitude of the error, as the heliostat is required to track, but has no accuracy requirement during this wind condition.

Loading Condition: The simulated wind loads applied during this series of tests are those which produce the maximum moment about the drive axes, resulting in the maximum pointing error. The maximum wind moment results from an angle of attack of 70° from a normal to the mirror surface, as shown in Figure 9.7-6. This moment was applied about both the aximuth and elevation axes.

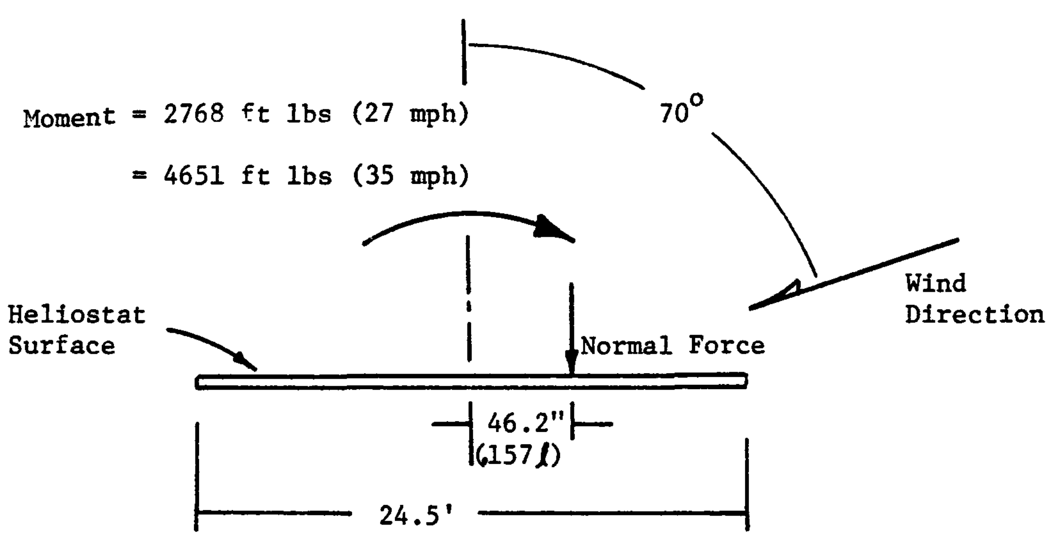


Figure 9.7-6 Wind Load Condition for Maximum Moment

Test Description: The test was performed on Heliostat #3 at the Hutchins Test Site on October 20 and 21, 1980. All major structural components on this heliostat were manufactured according to Second Generation Heliostat prints and specifications.

The beam motion due to wind moment was tested by applying the wind moment loads during actual tracking operations to get the effect of all contributing factors. The effect was recorded by actual photographs of the image on the target with and without the loading.

During the testing, loads were applied and released in a short time span, to eliminate the possibility of tracking errors which could occur over a longer span of time. Rapid loading was accomplished in the azimuth tests by backing the scissor lift test rig until the barrel weights had lifted off the static line and were fully loading the cable. Then it was driven forward, released and moved to the other side for the reversing load. The azimuth test sequences were accomplished in approximately 10 minutes. Rapid loading in the elevation tests was accomplished by using a hand hoist on each barrel weight and simply lifting the weight off the ground to apply load, then lowering it to the ground to release load.

The test setup for the azimuth test is shown in Figure 9.7-7. The setups for the elevation tests are shown in Figure 9.7-8.

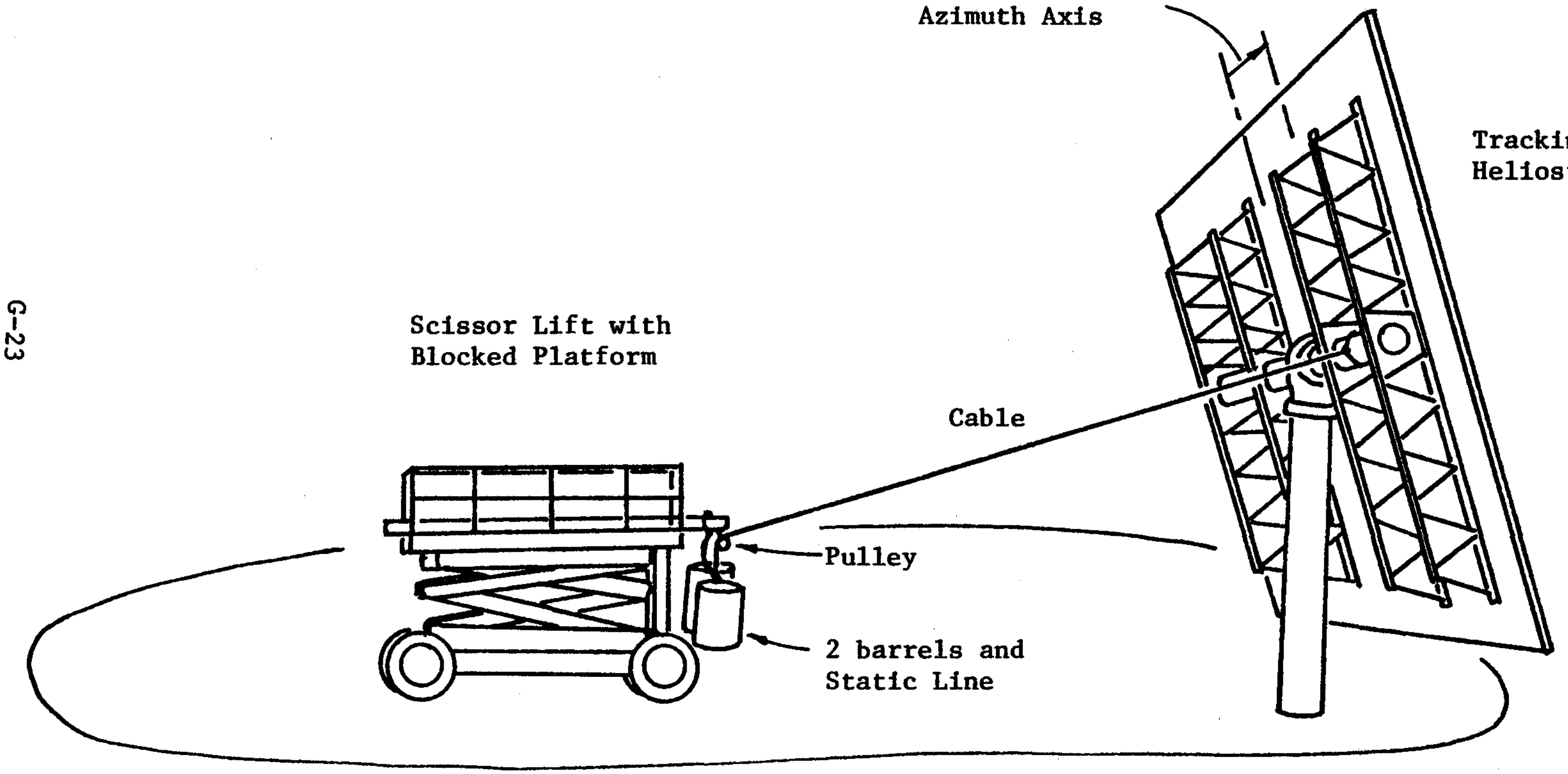


Figure 9.7-7 Test Setup for Azimuth Loading

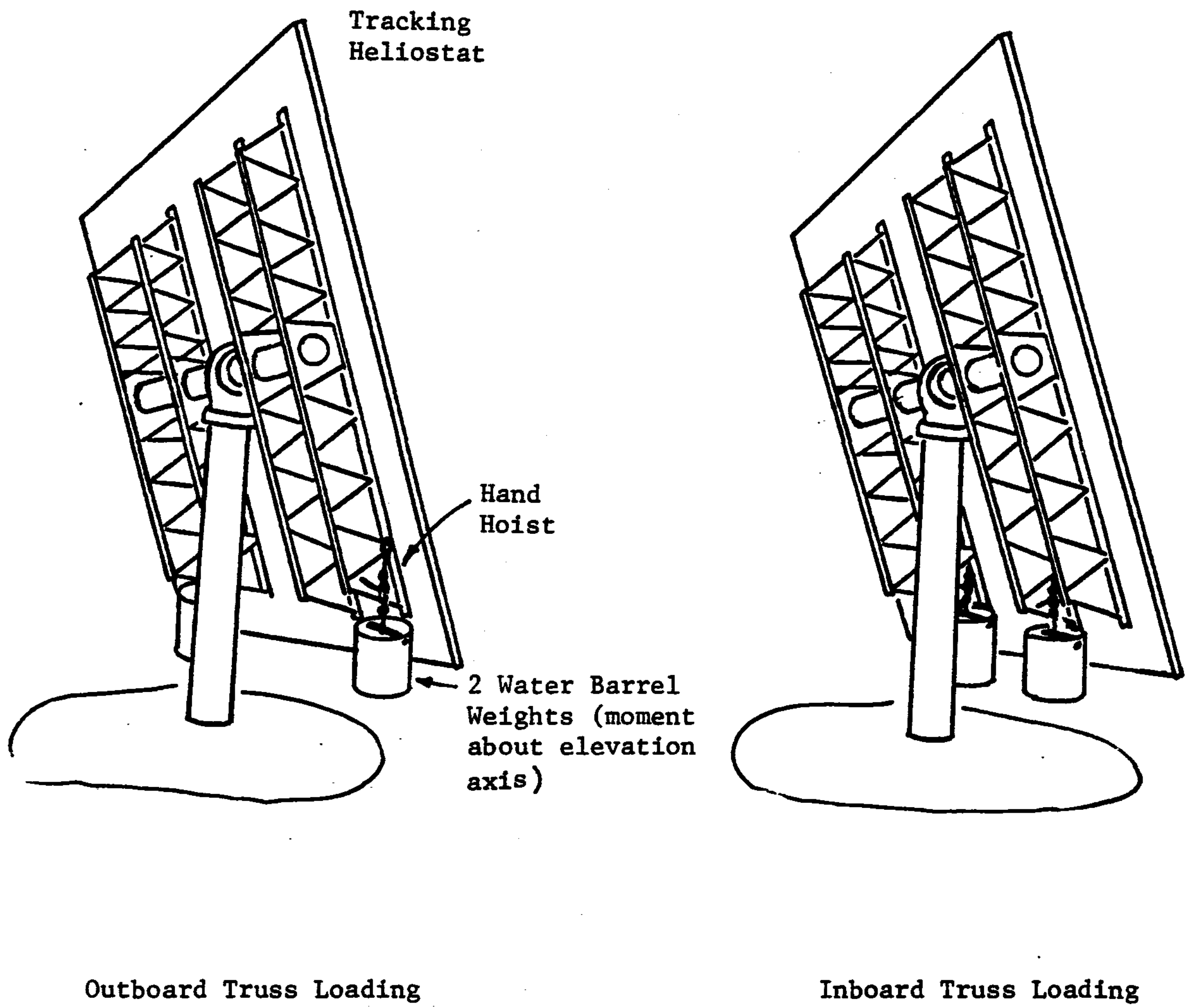


Figure 9.7-8 Test Setup for Elevation Loading

During the azimuth tests, the image was recorded:

(a) at no load (before test)

(b) during moment loading to the left (or right)

(c) at no load

(d) during moment loading to the right (or left)

(e) at no load (after test)

During the elevation tests, the image was recorded:

(a) at no load (before test)

(b) during loading with "down" moment

(c) at no load (after test)

No " up" moment loads were applied, as wind loading always produces "down" moments, which is additive to gravity moment. The elevation tests were run with the weights applied to the inner set of trusses and to the outer set of trusses in separate tests to account for any detectable differences which might exist.

A beam displacing variable which is difficult to isolate from the tests is the effect of motor update cycles. An attempt was made to minimize this effect by recording the image at approximately the same time following a motor update. The effect could cause a maximum error of approximately 20 to 30 seconds of sun time which is about .7 milliradians in azimuth and .1 milliradians in elevation.

The tests performed are tabulated below

Test	Axis	Wind Load	Loading Sequence or Location
(1)	Azimuth	27 mph	Left to Right
(2)	Azimuth	27 mph	Right to Left
(3)	Elevation	27 mph	Inboard Truss
(4)	Elevation	27 mph	Outboard Truss
(5)	Elevation	35 mph	Outboard Truss
(6)	Elevation	35 mph	Inboard Truss
(7)	Azimuth	35 mph	Left to Right

Test Instrumentation: No instrumentation was used other than a camera to photograph the image on the target.

Test Results: The beam positions at the target were determined from photographed images. The centroid of each image was established and its position was scaled from each photo using the 5 ft grid lines on the target. Figure 9.7-9 through Figure 9.7-15 shows the actual photographs.

The starting position of each test sequence was normalized to zero and each position then was established with respect to the starting position. This value in feet of deflection at the target was converted to angular displacement (milliradians). It should be noted that the displacement at the target is the "reflected beam" displacement. Therefore, half of this displacement represents the mirror surface motion, which is compared to the 3.6 mrad requirement after pedestal contribution is subtracted. The data is presented in Table 9.7-4.

(a)

(b)

(c)

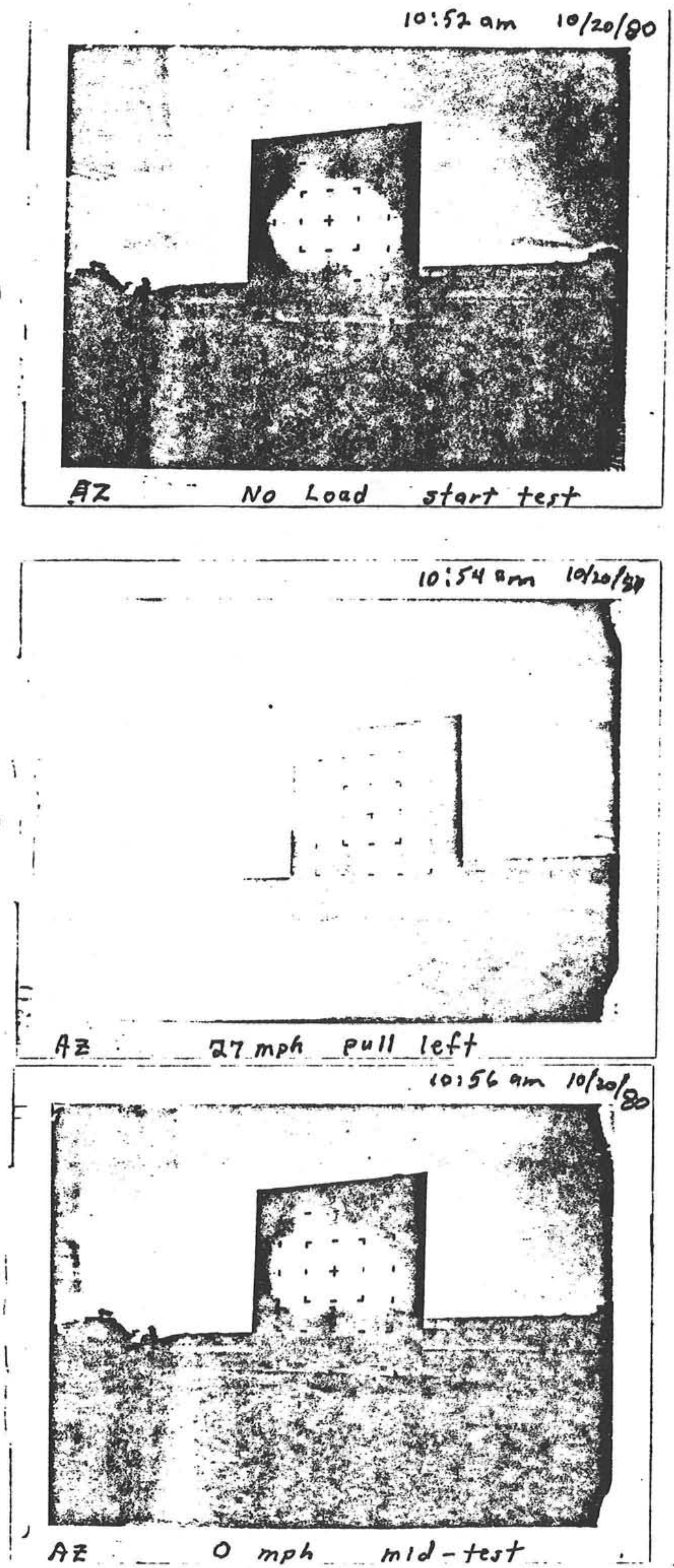
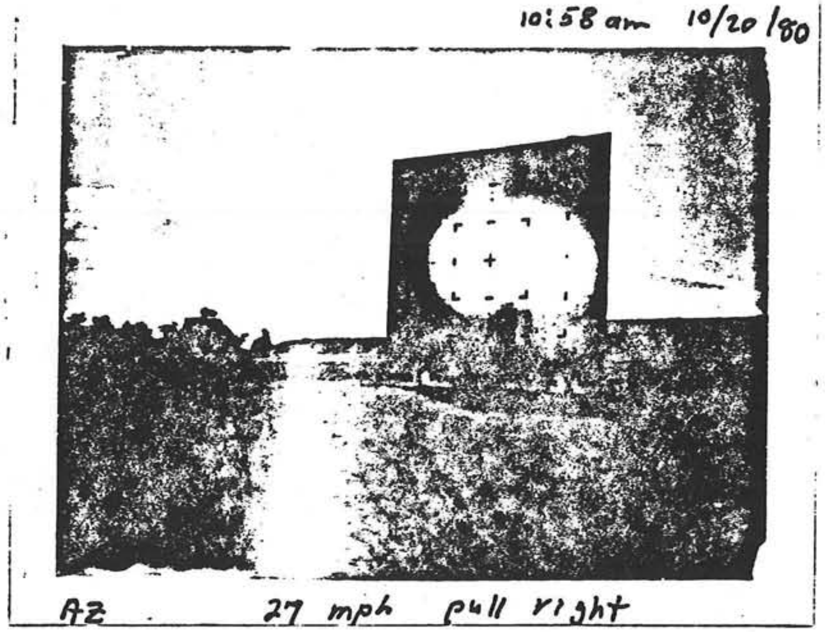


Figure 9.7-9 Test (1) Azimuth 27 mph Wind

(d)



(e)

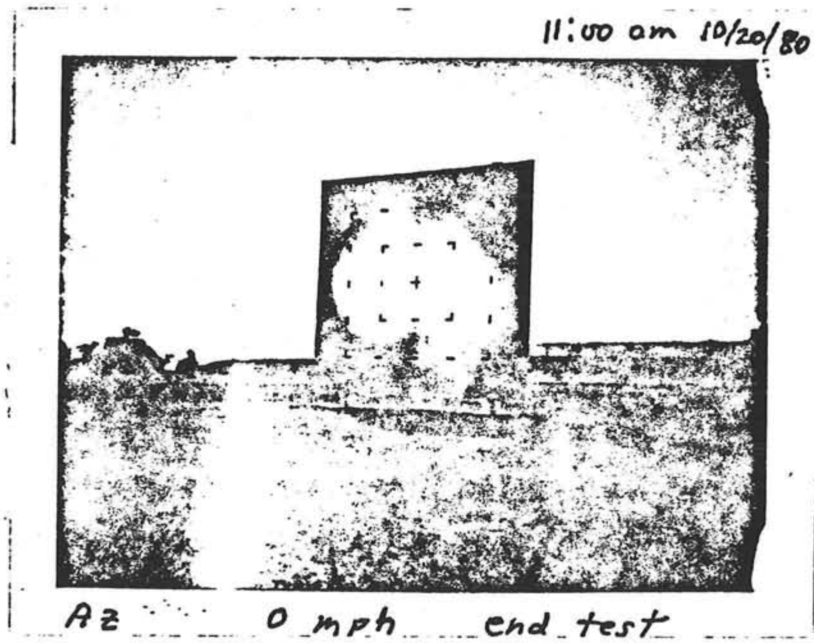
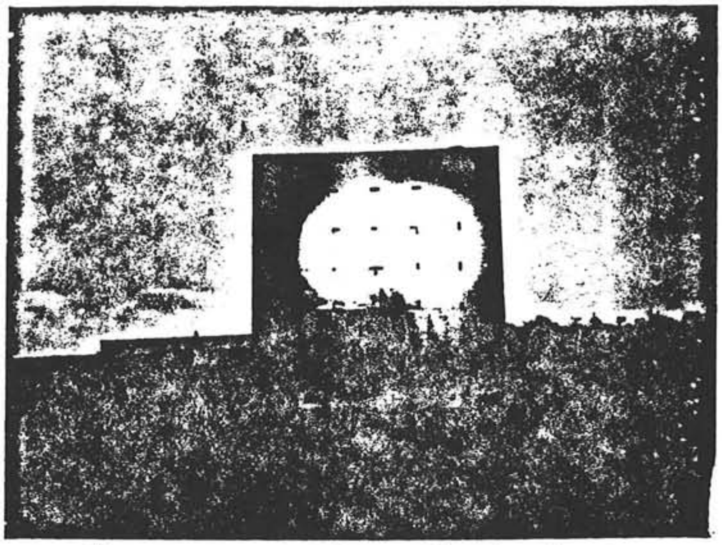
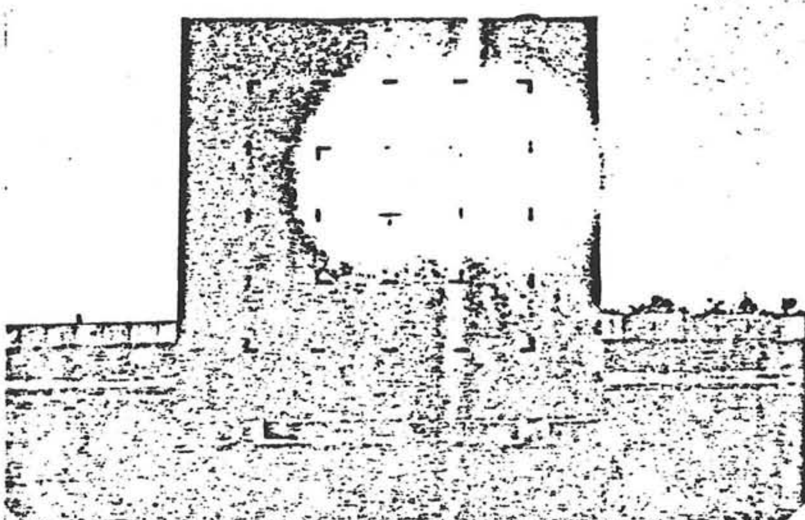


Figure 9.7-9 (Cont.) Test (1) Azimuth 27 mph Wind

(a)



(b)



(c)

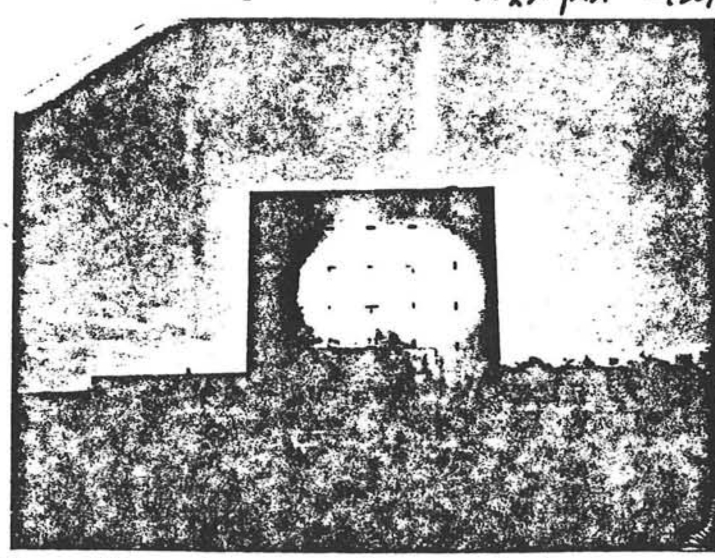
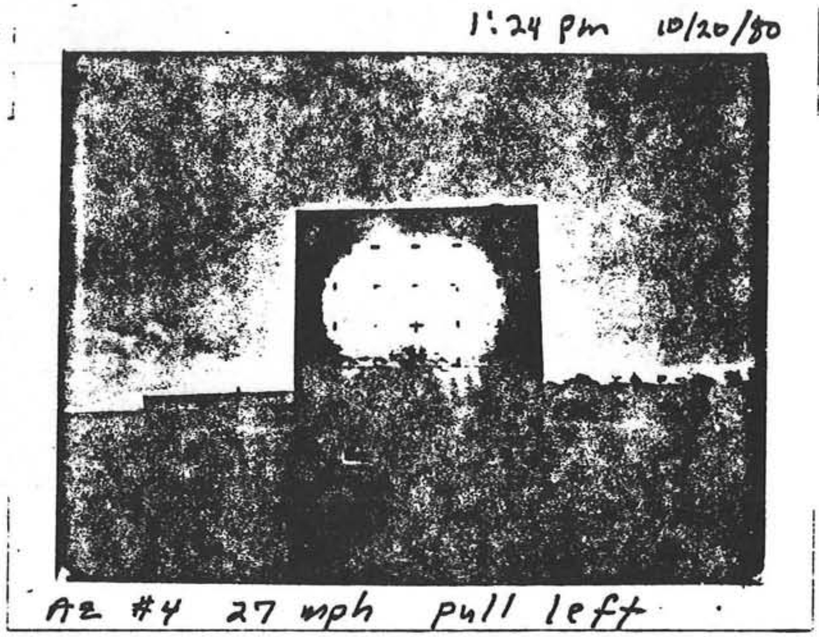


Figure 9.7-10 Test (2) Azimuth 27 mph Wind

(d)



(e)

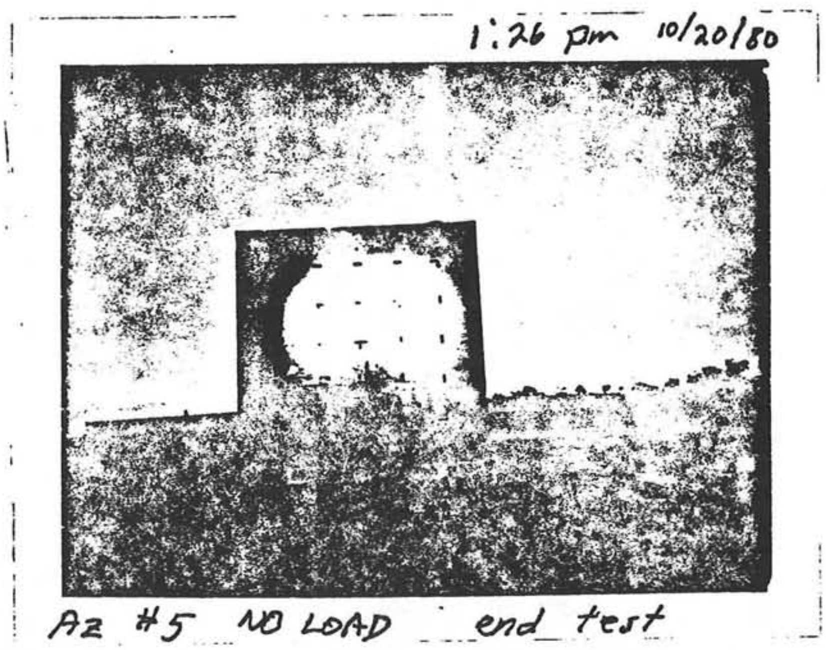
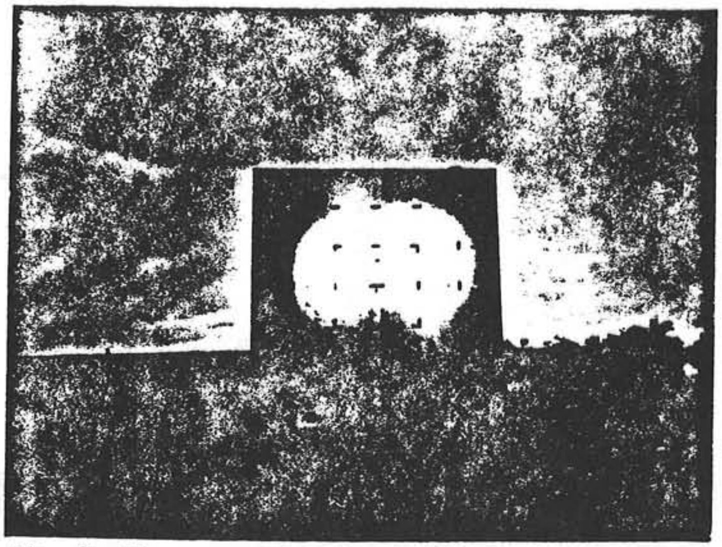


Figure 9.7-10 (Cont.) Test (2) Azimuth 27 mph Wind

Inboard
Truss
Loading

2:03 Pm 10/20/80

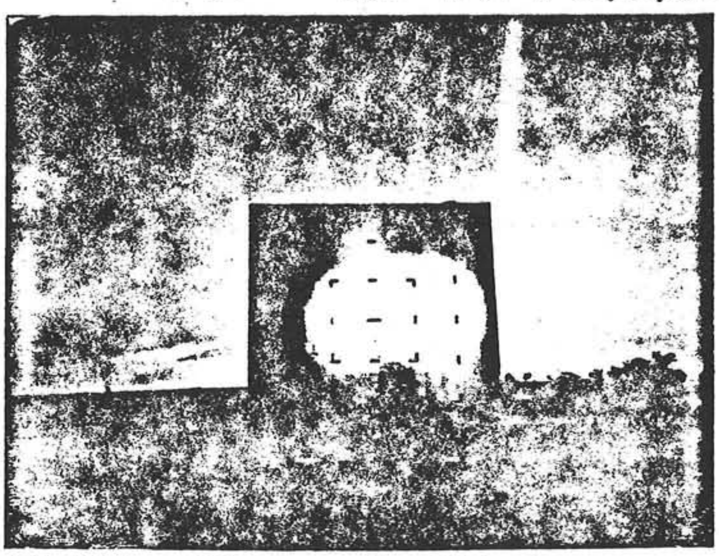
(a)



EL #1 No Load Start Test

2:05 P.m. 10/20/80

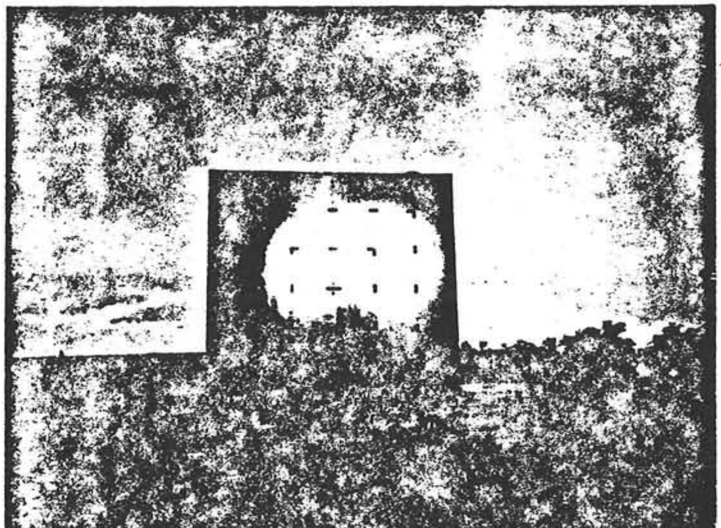
(b)



EL #2 27 Mph Pull down

2:06 pm 10/20/80

(c)



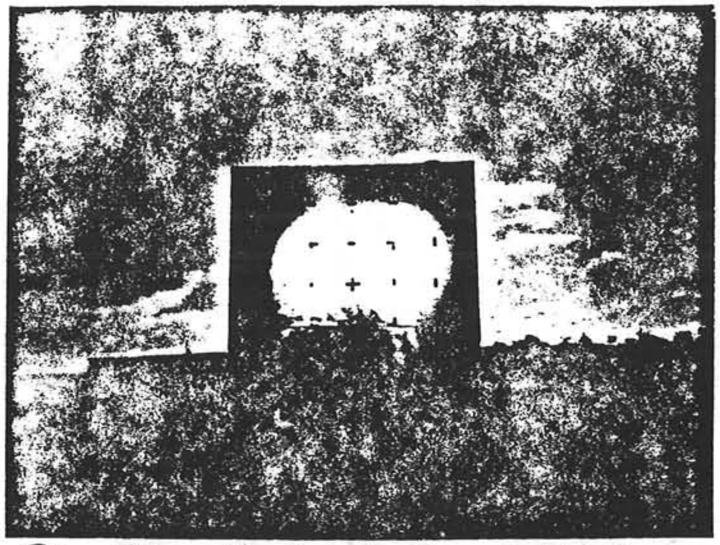
EL #3 No Load End Test

Figure 9.7-11 Test (3) Elevation 27 mph Wind

Outboard Truss Loading

2:09 Pm 10/20/80

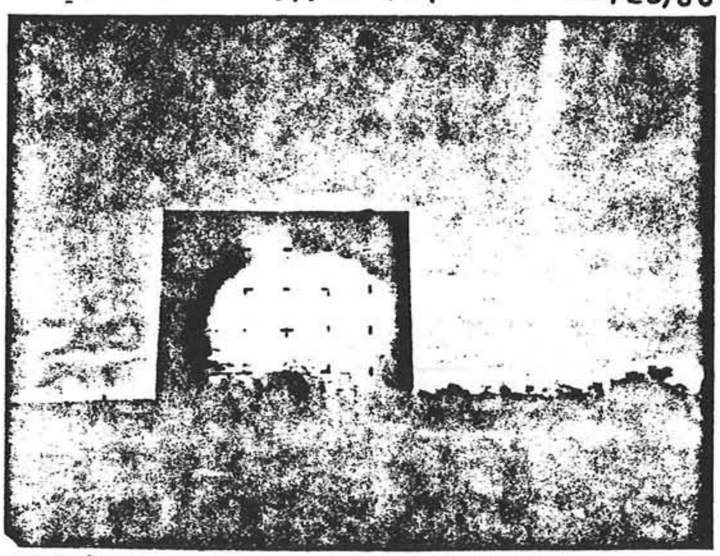
(a)



EL #1 No Load Start Test

2:11 Pm 10/20/80

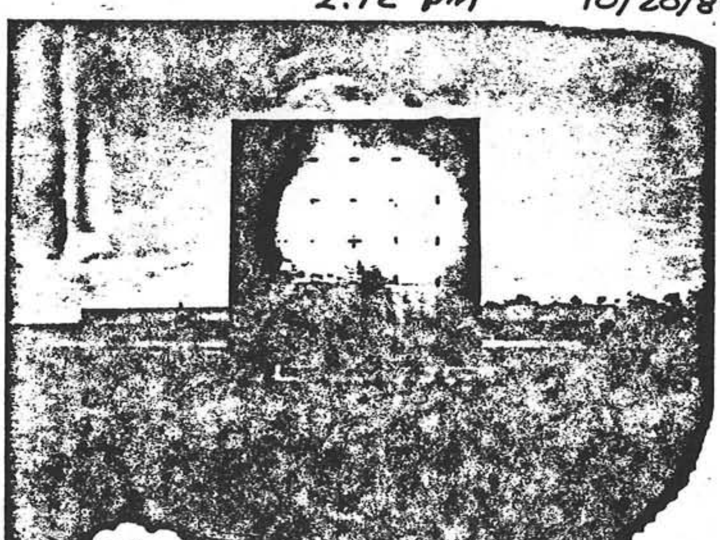
(b)



El #2 27mph Pull down

2:12 pm 10/20/80

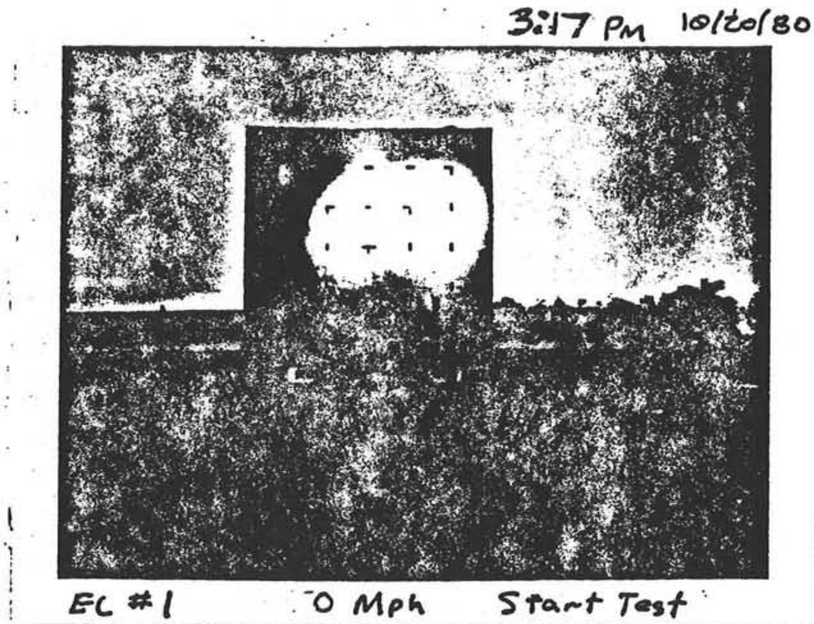
(c)



El #3 No Load End Test

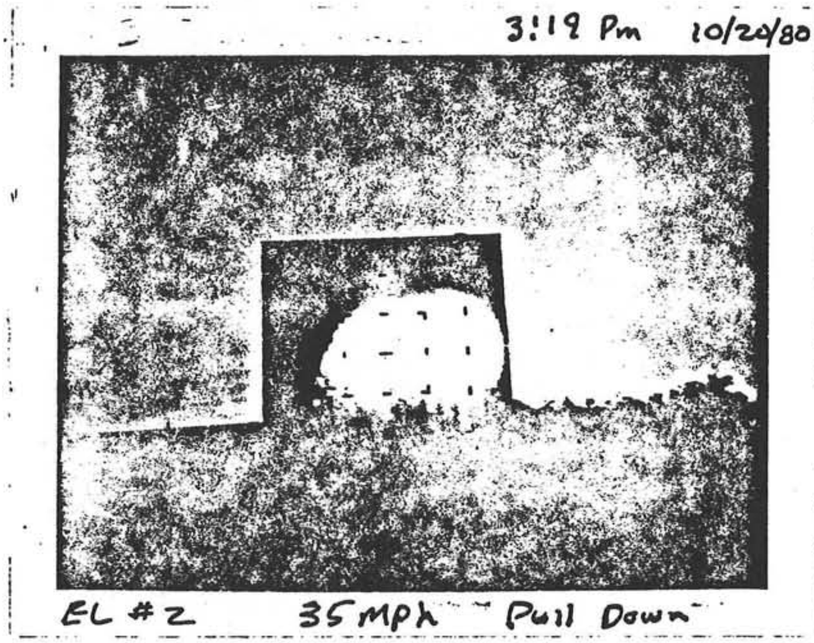
Figure 9.7-12 Test (4) Elevation 27 mph Wind

(a)



Outboard Truss Loading

(b)



El = 20.25°

Az = 69.73°

(c)

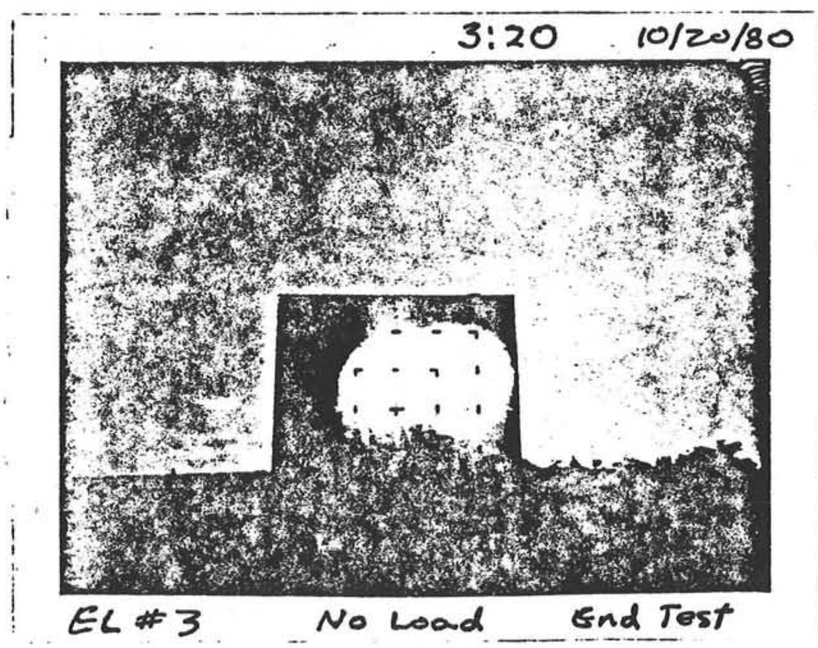


Figure 9.7-13 Test (5) Elevation 35 mph Wind

Inboard Truss Loading

El = 19.88°

Az = 68.93°

(a)

(b)

(c)

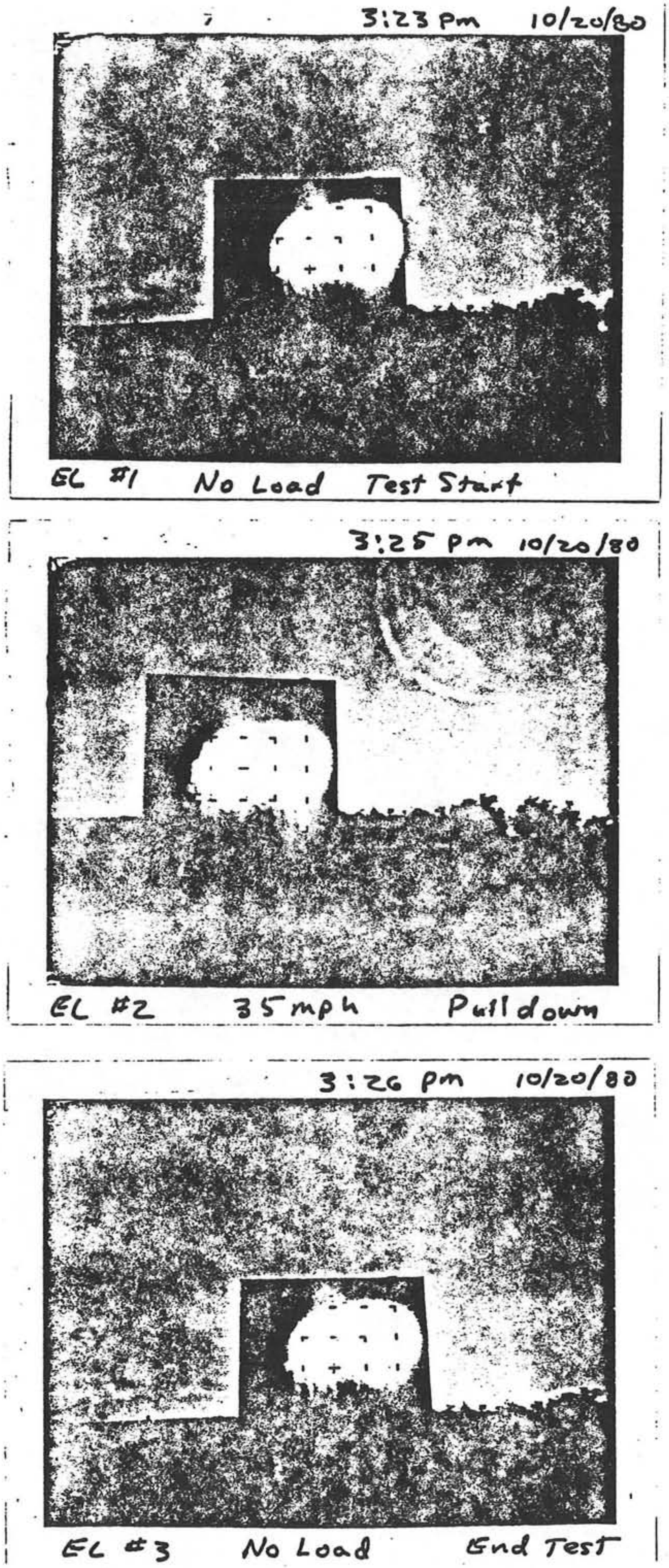
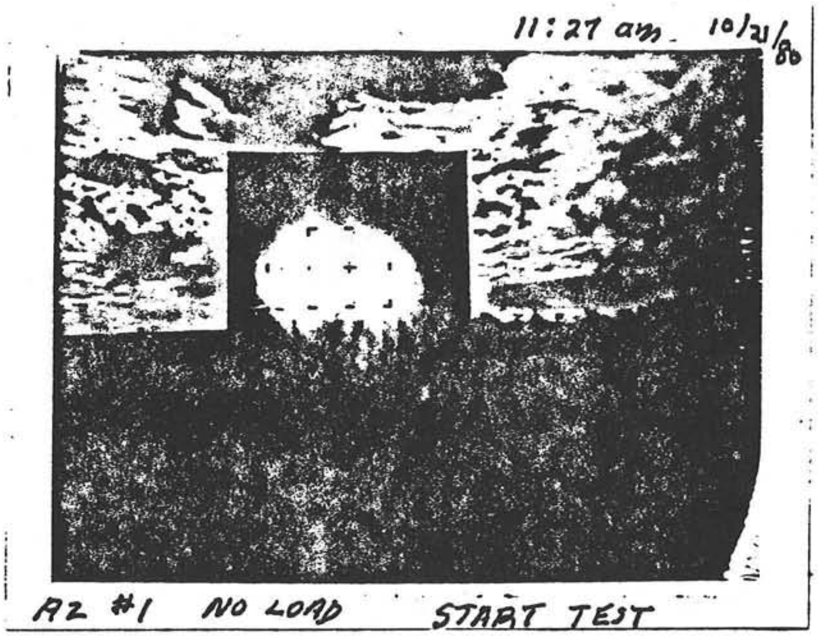


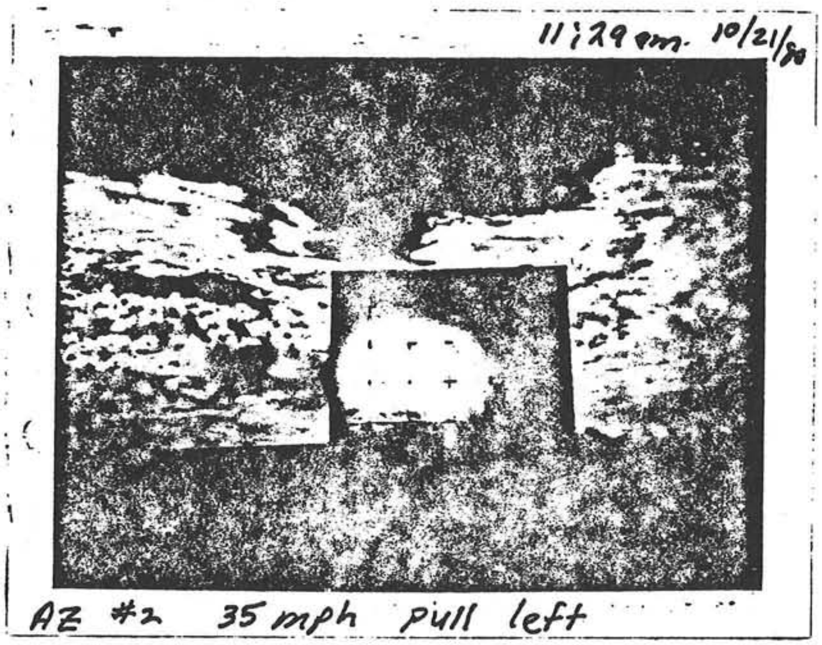
Figure 9.7-14 Test (6) Elevation 35 mph Wind

El = 21.74°
AZ = 102.28

(a)



(b)



(c)

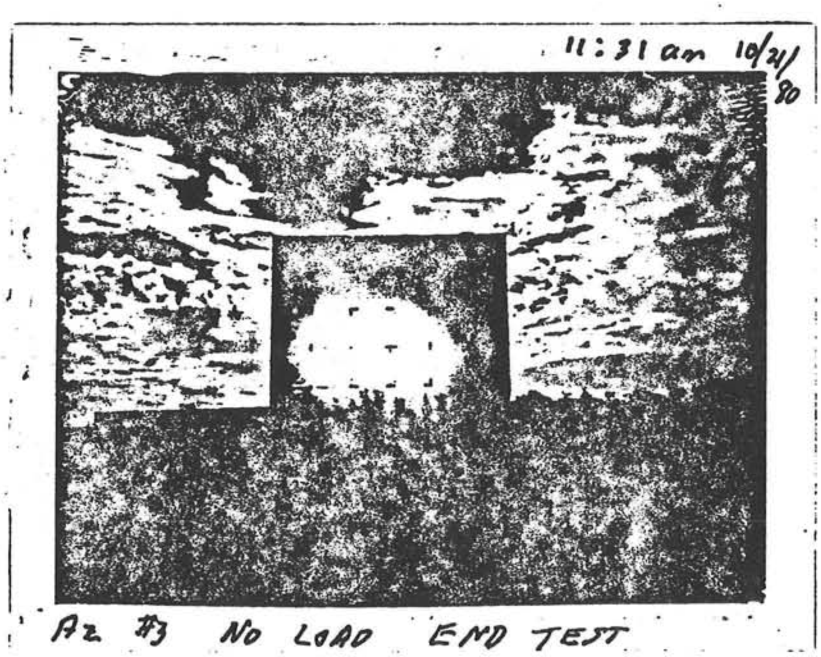
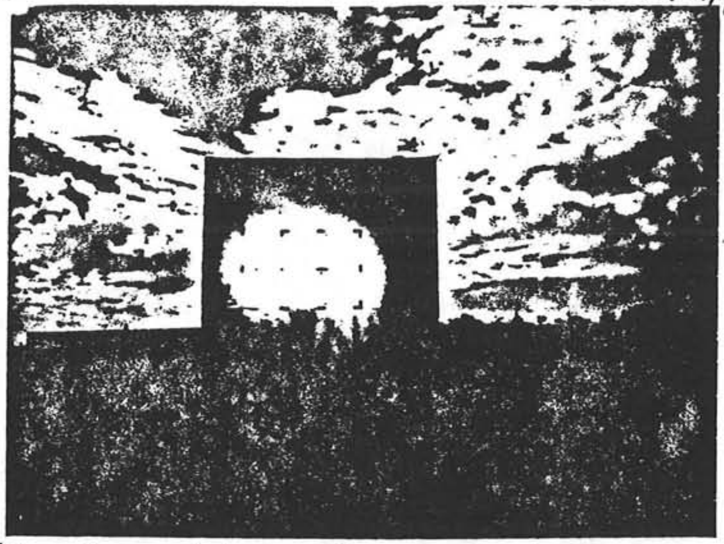


Figure 9.7-15 Test (7) Azimuth 35 mph Wind

11:34 am 10/21/80

(d)



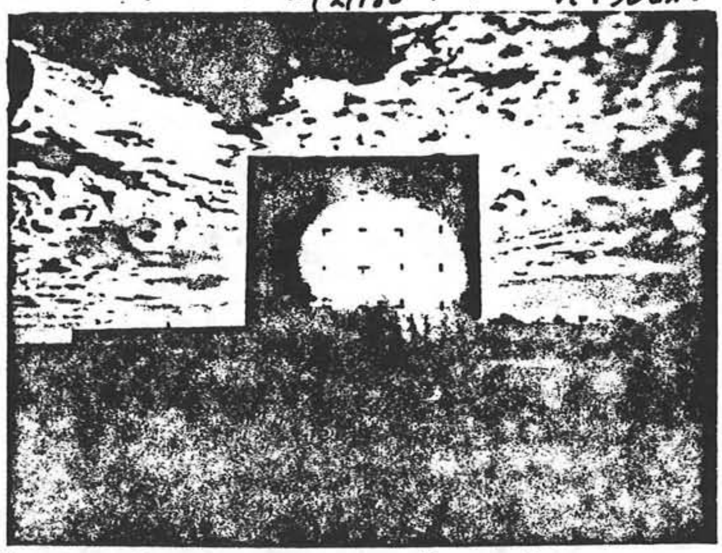
AZ #1 NO LOAD START TEST

El = 21.91°

AZ = 101.75°

10/21/80 11:36 am

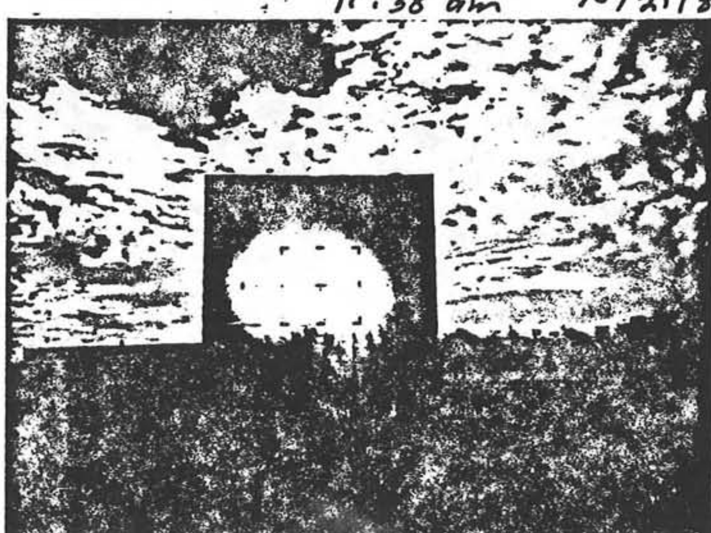
(e)



AZ #2 35 mph pull right

11:38 am 10/21/80

(f)



AZ #3 NO LOAD END TEST

Figure 9.7-15 (Cont.) Test (7) Azimuth 35 mph Wind

Table 9.7-4 Reflected Beam Deflections

Test	Wind Loading	Beam Deflection: Ft. (Actual)	Ft. (Norm. to Zero)	mrad*
(1) 27 mph	No load	+.25	0.0	0
	Pull left	-3.75	-4.0	-5.0
	No load	- .25	- .5	- .63
	Pull right	+2.25	+2.0	+2.5
	No load	-1.0	-1.25	-1.56
(2) 27 mph	No load	+1.75	0.0	0
	Pull right	+4.5	+2.75	+3.44
	No load	+2.25	+ .5	+ .63
	Pull left	-1.0	-2.75	-3.44
	No load	+1.5	- .25	- .31
(3) 27 mph	No load	+2.75	0.0	0
	Pull down	+ .5	-2.25	-2.81
	No load	+3.5	+ .75	+ .94
(4) 27 mph	No load	+2.5	0.0	0
	Pull down	+1.25	-1.25	-1.56
	No load	+3.0	+ .5	+ .63
(5) 35 mph	No load	+3.25	0.0	0
	Pull down	0.0	-3.25	-4.06
	No load	+3.25	0.0	0

Graphic Description mrad

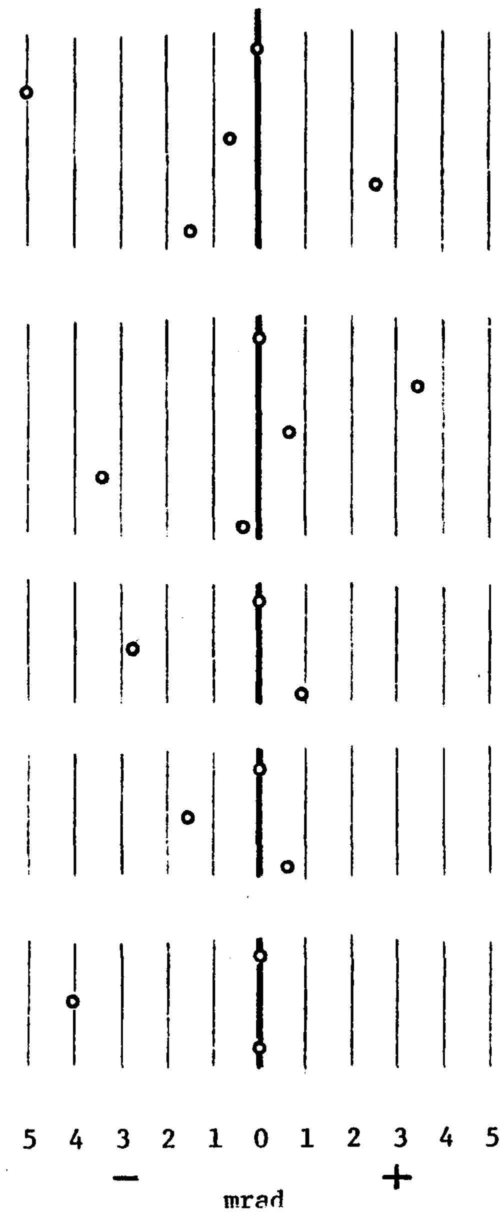
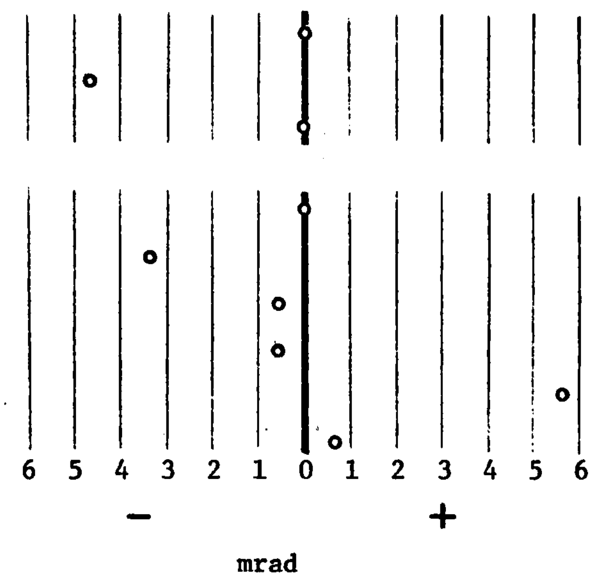


Table 9.7-4 Reflected Beam Deflections (Cont.)

Test	Wind Loading	Beam Deflection: Ft. (Actual)	Beam Deflection: Ft. (Norm. to Zero)	Beam Deflection: mrad*
(6) 35 mph	No load	+4.25	0.0	0
	Pull down	+ .5	-3.75	-4.69
	No load	+4.25	0.0	0
(7) 35 mph	No load	-2.0	0.0	0
	Pull left	-4.75	-2.75	-3.44
	No load	-2.5	- .5	- .63
	No load	-2.5	- .5	- .63
	Pull Right	+2.5	+4.5	+5.63
	No load	-1.5	+ .5	+ .63

Graphic Description mrad



* Based on 800 ft target

9.7.2.2.2 (a) Elevation Axis Test - 90 mph Wind Horizontal Stow Condition

Test Objectives: The objectives of the Elevation Axis Test are to: (a) verify the structural integrity of the drives and major structural components to withstand loads induced by 90 mph winds while in the horizontal stow position and (b) measure deflections of the drives and major structural components for comparison with pointing accuracy requirements at lower wind conditions.

The 90 mph elevation axis wind condition produces the largest moment (20,477 ft lbs) about the elevation drive axis of any condition; thus it produces the largest elevation drive main gear tooth force This tooth force is 29,250 lbs tangential load. This condition along with the cross-elevation axis condition produces the highest azimuth bearing moment (245,710 inch lbs).

Test Description: The test was performed on Heliostat #1 at the Hutchins Test Site on October 9, 1980 and October 13, 1980. All major structural components on this heliostat were manufactured according to second generation heliostat prints and specifications, except that the main gears in the drive unit were cut undersize which allowed approximately .020 inch backlash instead of the required .002-.003 inch backlash.

The test was performed with the heliostat mirror surface in the horizontal position, which simulates horizontal stow. Moment load was applied about the elevation drive axis which simulates the moment induced by a frontal 90 mph wind at 10 degrees from horizontal. Normal force was not simulated due to its non-critical nature, but the loading method resulted in about 73% of wind normal force.

Loads were applied by hanging six 55 gallon barrels from the rack trusses with ropes and filling the barrels to the appropriate level with water. The tare weight of each barrel is 50 lbs. The locations of the barrels are shown in Figure 9.7-16.

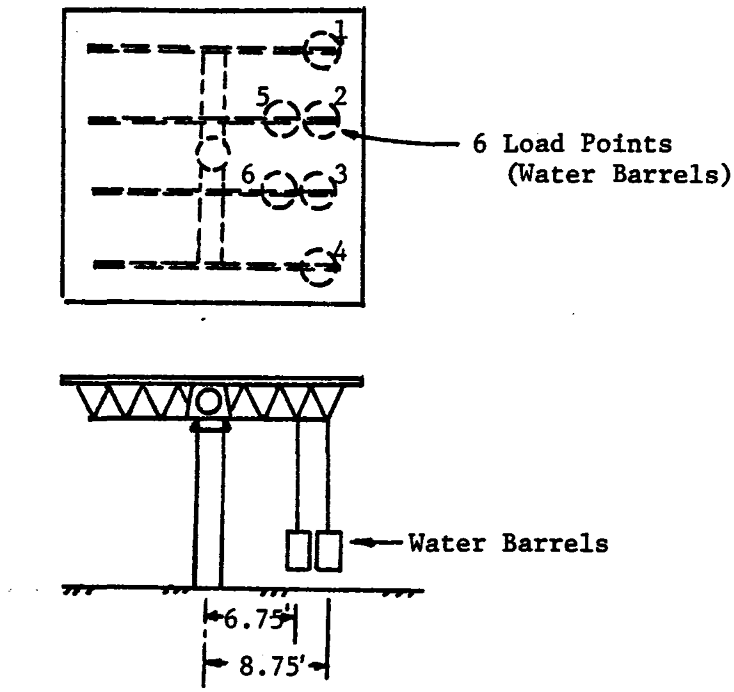


Figure 9.7-16 Loading Setup

The test was performed by incrementally applying load to 110% of limit load. At the beginning of the test (zero point), two empty barrels (nos. 2 & 3) were hung to stabilize the pseudo-balanced rack in a null position, thus the zero point is actually not true zero. The 20% and higher increments are true, however. The schedule of weights and water depths is tabulated in Table 9.7-5.

Table 9.7-5

% Load	Total Wt	Wt per Bbl	Water Wt per Bbl	Water Depth * *
0	100 lbs	50 lbs(2 only)	0	0 in
20	517.3	86.22	56.22	2.55
40	1034.6	172.44	122.44	8.62
60	1552	258.66	208.66	14.7
80	2069.3	344.88	294.88	20.8
100*	2586.6	431.1	381.1	26.84
110	2845.2	474.2	424.2	29.87

* 100% load = 20,477 ft-lbs elevation axis torque

** 1 inch of water = 14.2 lbs

The loading was sequenced in the following percentages: 0, 20, 40, 60, 20, 60, 80, 100, 110, 60, 20, 0. The 20% set load after 60% was done to detect premature yielding and to get an early indication of mechanical hysteresis prior to the higher load increments.

Two separate tests were performed on separate days. The second test was to verify repeatability and to clean up some out-of-scale problems of the dial indicators, experienced on the first test.

Photographs of the test set up and instrumentation were taken but are not included in this report due to reproduction limitations.

Instrumentation: the heliostat was instrumented with 11 dial indicators to measure linear deflections at key places on the structure and drive units. The deflection measurements along with their respective moment arms were then used to compute rotational displacements.

The rotational displacements obtained from this test are:

(a) overall rack rotation

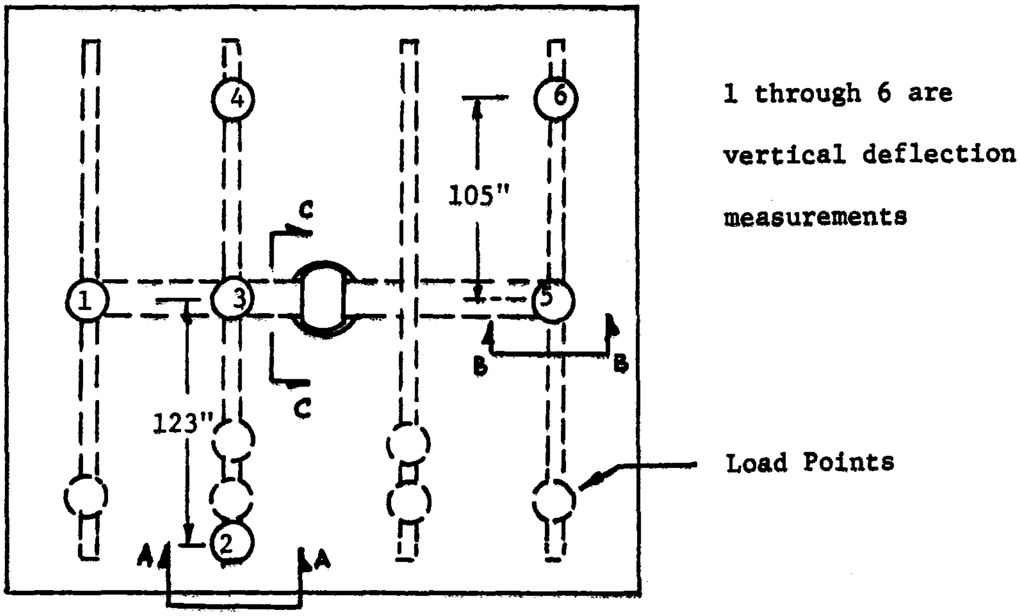
(b) elevation gear rotation (with respect to the elevation housing)

(c) azimuth bearing rotation (azimuth upper housing with respect to the lower housing)

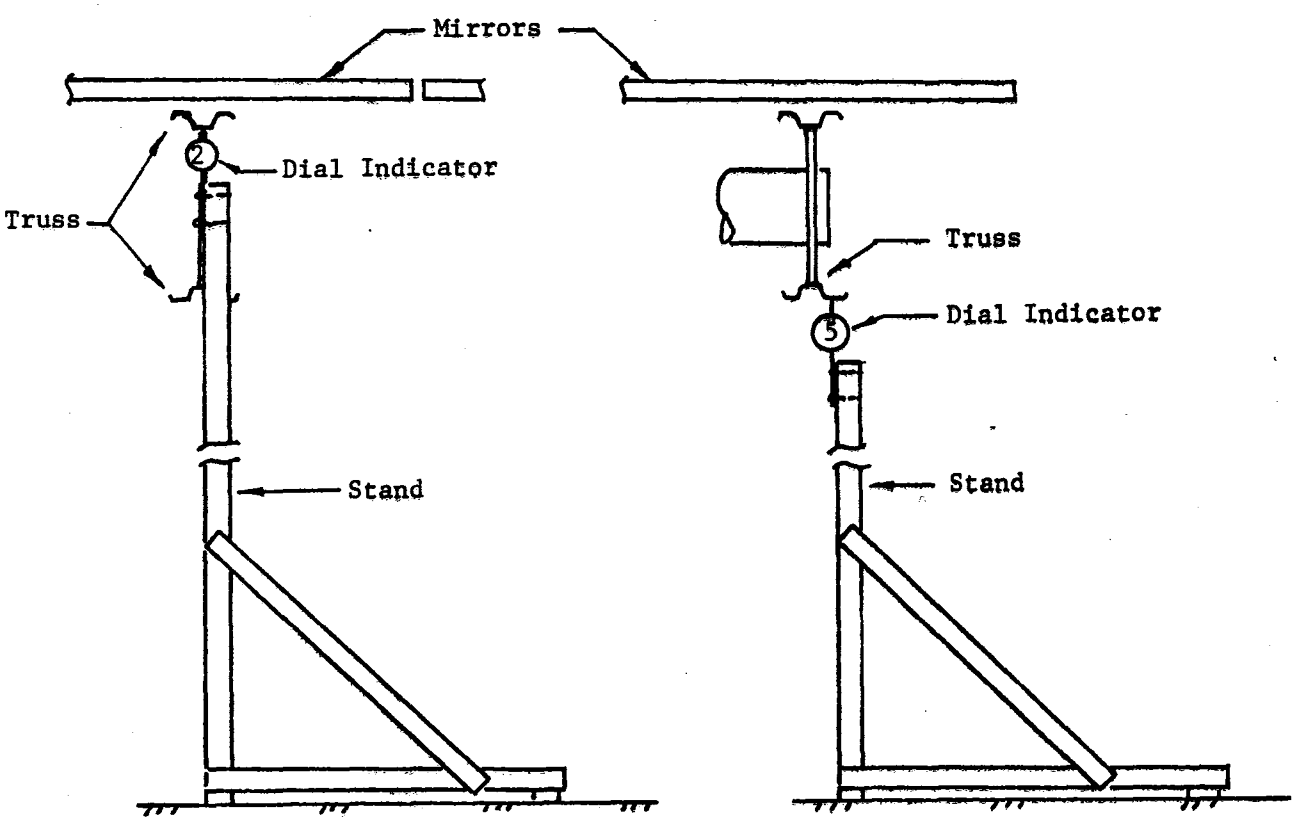
(d) pedestal displacements

(e) rack and torque tube displacements from which bending displacements may be derived.

The locations of the dial indicators are shown in Figures 9.7-17 and 9.7-18.



Plan View of Heliostat



A-A #2 Dial Indicator

B-B #1,3,4,5,6 Dial Indicators

Figure 9.7-17 Rack Deflection Instrumentation

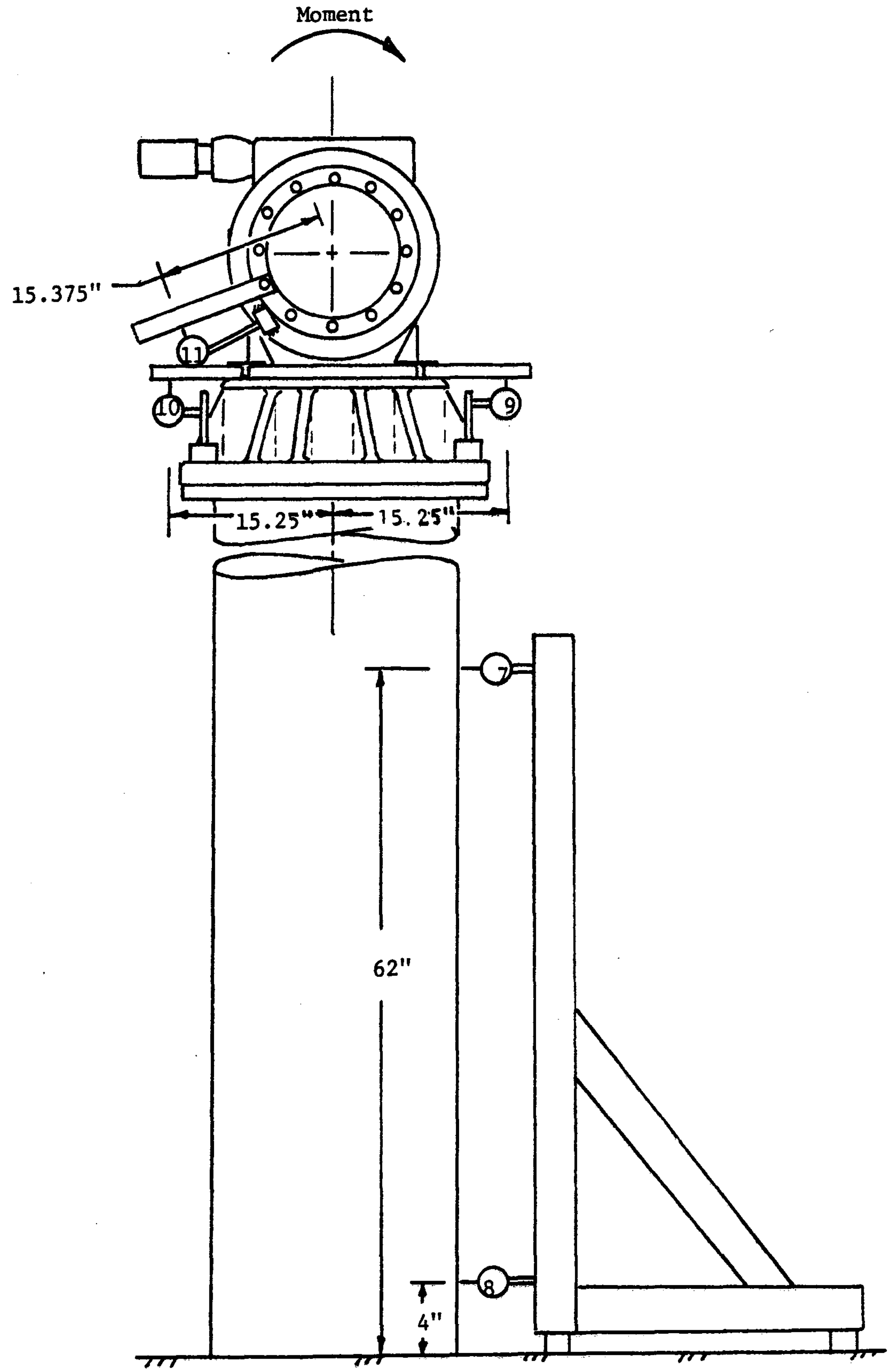


Figure 9.7-18 Drive and Pedestal Deflection Instrumentation

Test Results: The raw data sheets giving the actual dial indicator readings from test run #1 and test run #2 are presented in Tables 9.7-6 and 9.7-7. The data was normalized to zero at zero percent load and converted to rotational displacements which is presented in Tables 9.7-8 through 9.7-12. The rotational displacements are plotted versus percent load and presented in Figures 9.7-19 through 9.7-23.

No failure or detectable yielding occurred up to the maximum 110% load.

Table [illegible]-6

Test 1 Dial Indicator Readings

Load	#1	#2	#3	#4	#5	#6	#7	#8	#9	#10	#11
0%	.146	-.012	.135	1.032	.143	.921	.082	.078	.1025	.4090	.1660
20	.155	.193	.140	.864	.140	.740	.090	.081	.1084	.4046	.1541
40	.138	.496	.136	.608	.175	.510	.098	.084	.1162	.3941	.1376
60	.119	.788	.131	.348	.218	.290	.110	.090	.1223	.3851	.1206
20	.098	.310	.120	.720	.172	.651	.092	.083	.1111	.3991	.1438
60	.100	.830	.117	.310	.212	.252	.111	.091	.1208	.3845	.1190
80	.085	1.124	.113	.040	.245	.000	.119	.093	.1261	.3762	.1020
100	.078	1.442	.112	-.184	.273	-.264	.129	.096	.1320	.3682	.0848
110	.082	1.605	.113	-.330	.286	-.473	.133	.097	.1351	.3634	.0741
60	.071	1.090	.107	.062	.232	-.070	.113	.094	.1251	.3792	.0937
20	.068	.944	.102	.564	.180	.420	.093	.089	.1123	.3955	.1281
0	.093	.138	.104	.847	.130	.660	.084	.087	.1021	.4069	.1483

Table 9.7-7

Test 2 Dial Indicator Readings

Load	#1	#2	#3	#4	#5	#6	#7	#8	#9	#10	#11
0%	.205	.292	.090	2.967	.188	1.711	.073	.092	.0940	.3870	.1738
20	.210	.515	.092	2.792	.208	1.542	.080	.106	.0996	.3824	.1613
40	.214	.826	.096	2.549	.223	1.307	.089	.1035	.1064	.3729	.1460
60	.216	1.118	.099	2.314	.248	1.090	.099	.099	.1125	.3650	.1298
20	.200	.623	.091	2.695	.215	1.457	.086	.096	.1032	.3785	.1528
60	.225	1.110	.103	2.310	.227	1.070	.104	.101	.1125	.3655	.1290
80	.240	1.414	.105	2.100	.249	.860	.115	.102	.1179	.3585	.1145
100	.255	1.685	.111	1.875	.262	.630	.125	.105	.1232	.3509	.0990
110	.258	1.832	.112	1.775	.264	.525	.131	.108	.1260	.3471	.0921
60	.218	1.310	.101	2.165	.249	.930	.102	.102	.1168	.3619	.1139
20	.198	.665	.088	2.655	.215	1.430	.098	.098	.1050	.3782	.1482
0	.208	.342	.087	2.915	.189	1.670	.095	.095	.0959	.3890	.1690
0*	.208	.267	.086	2.985	.179	1.725	.096	.096	.0964	.3960	.1763

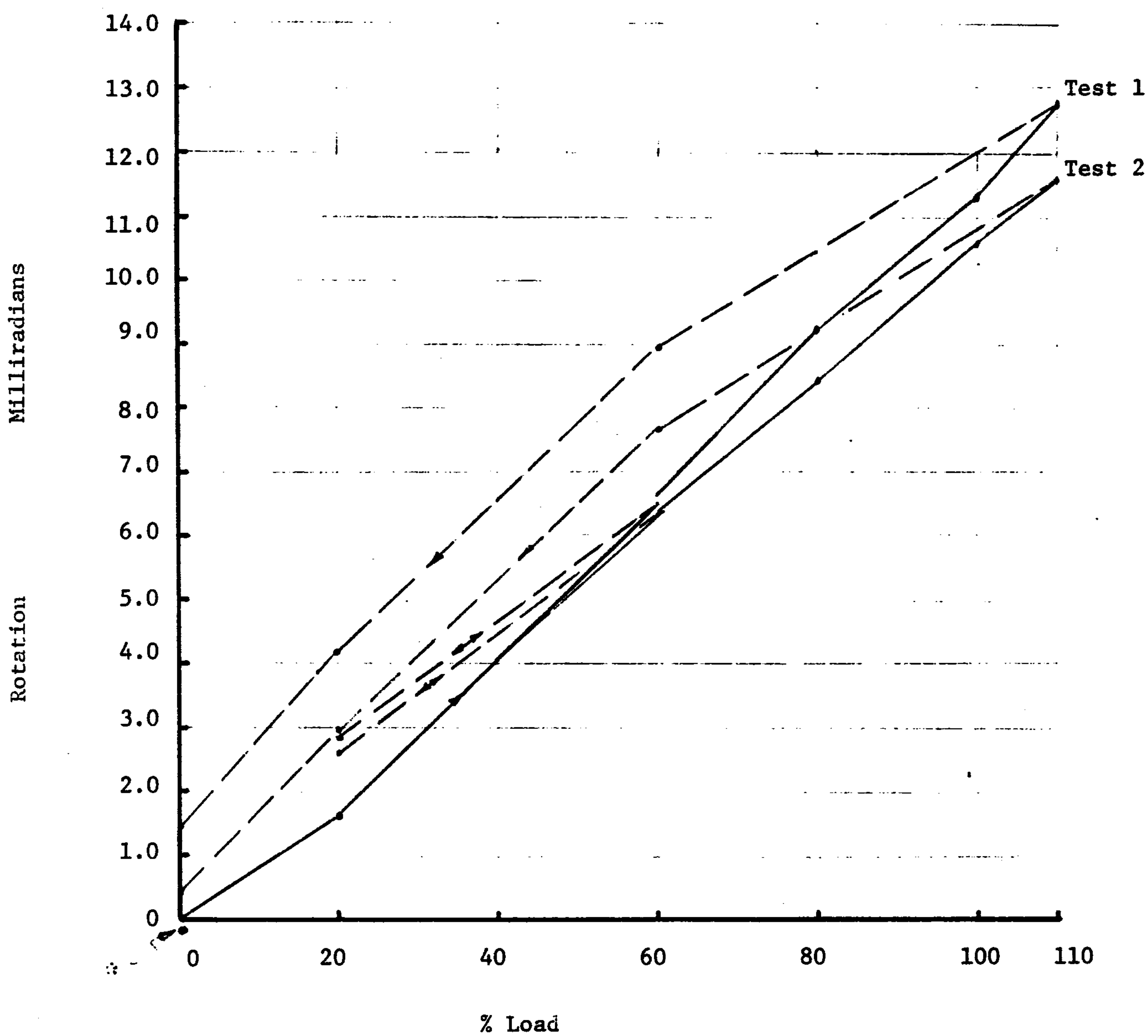
* After reverse load

Table 9.7-8

90 mph Elevation Axis Test-Butler Truss (Inboard)

	Test 1			Test 2		
% Load	Δ(#3)	Δ(#4)	θ	Δ(#3)	Δ(#4)	θ
0	0 inch	0 inch	0 mrad	0 inch	0 inch	0 mrad
20	.005	.168	1.648	.002	.175	1.686
40	.001	.424	4.048	.006	.418	4.038
60	-.004	.684	6.476	.009	.653	6.305
20	-.015	.312	2.829	.001	.272	2.6
60	-.018	.722	6.705	.013	.657	6.381
80	-.022	.992	9.238	.015	.867	8.4
100*	-.023	1.216	11.362	.021	1.092	10.6
110	-.022	1.362	12.762	.022	1.192	11.562
60	-.028	.970	8.971	.011	.802	7.743
20	-.033	.468	4.143	-.002	.312	2.952
0	-.031	.185	1.467	-.003	.052	.467
After load reversal				-.004	-.018	-.210
	+Down	+Up		+Down	+Up	

* 100% Moment = 20,476 ft lbs



*After load reversal

Figure 9.7-19 Rotation of Inboard Truss

Table 9.7-9

90 mph Elevation Axis Test-Butler Truss (outboard)

% Load	Test 1 Δ(#5)	Test 1 Δ(#6)	Test 1 θ	Test 2 Δ(#5)	Test 2 Δ(#6)	Test 2 θ
0	0 inch	0 inch	0 mrad	0 inch	0 inch	0 mrad
20	-.003	.181	1.695	.02	.169	1.8
40	.032	.411	4.219	.035	.404	4.181
60	.075	.631	6.724	.06	.621	6.486
20	.029	.27	2.848	.027	.254	2.676
60	.069	.669	7.029	.039	.641	6.476
80	.102	.921	9.743	.061	.851	8.686
100	.130	1.185	12.524	.074	1.081	11.0
110	.143	1.394	14.638	.076	1.186	12.019
60	.089	.991	10.286	.061	.781	8.019
20	.037	.501	5.124	.027	.281	2.933
0	-.013	.261	2.362	.001	.041	.4
	After load reversal			-.009	-.014	-.219
	+Down	+Up		+Down	+Up	

* 100% Moment = 20476 Ft lbs

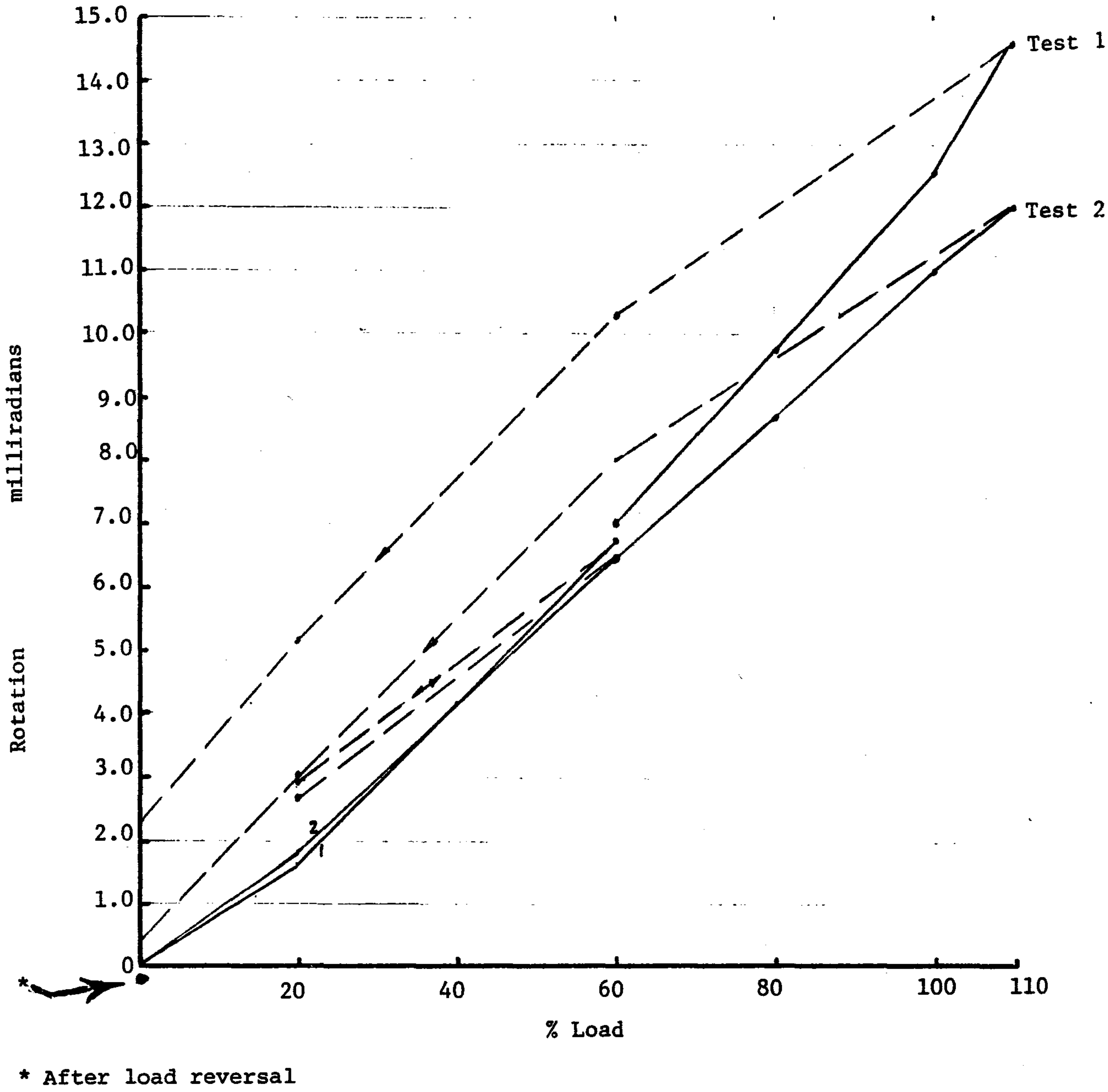


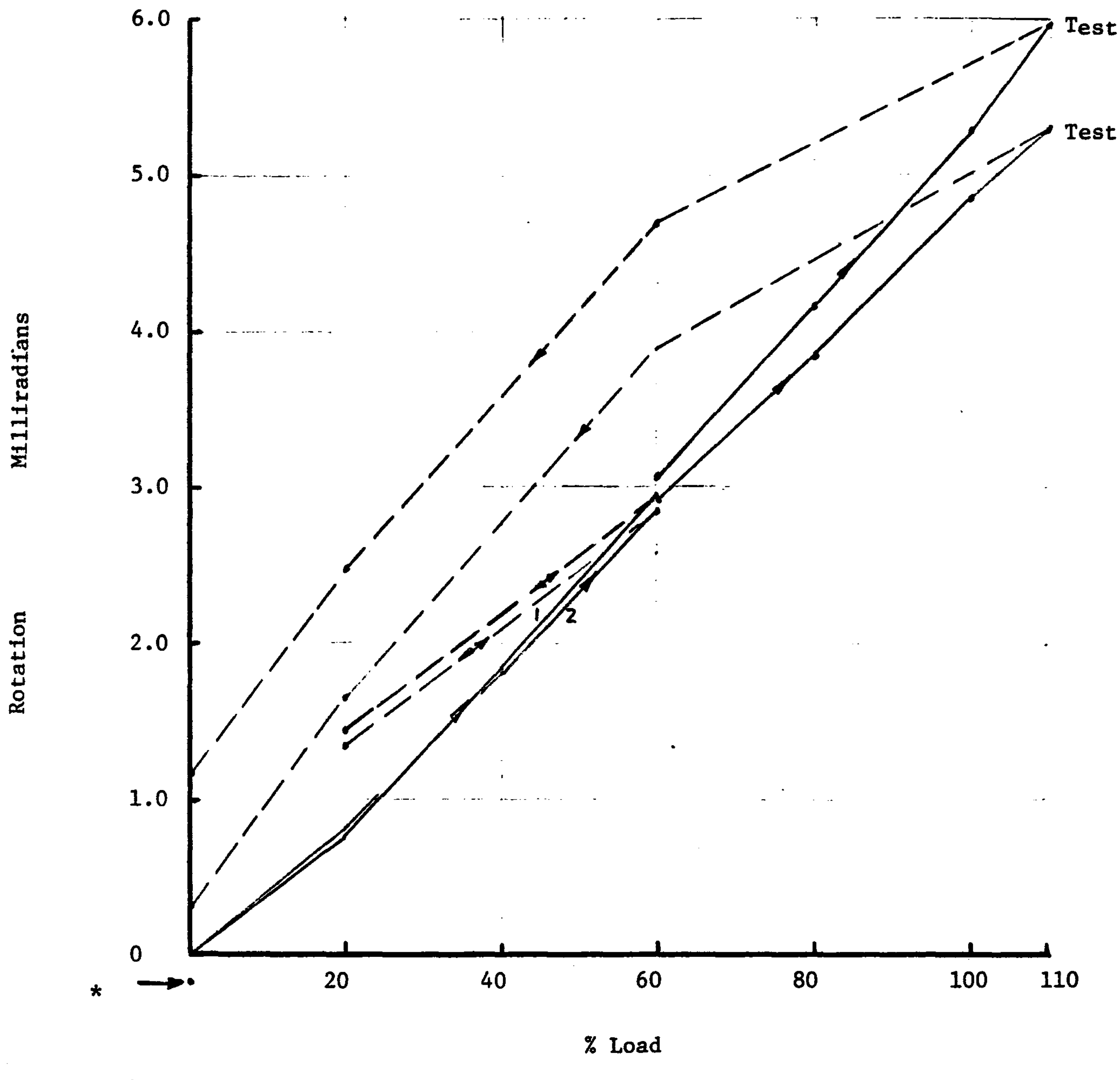
Figure 9.7-20 Rotation of outboard truss

Table 9.7-10

90 mph Elevation Axis Test - Elevation Worm

%	Test 1 (#11)	Test 1 θ	Test 2 (#11)	Test 2 θ
0	0 inch	0 mrad	0 inch	0 mrad
20	.0119	.774	.0125	.813
40	.0284	1.847	.0278	1.808
60	.0454	2.953	.044	2.862
20	.0222	1.444	.021	1.366
60	.047	3.057	.0448	2.914
80	.064	4.163	.0593	3.857
100 *	.0812	5.281	.0748	4.865
110	.0919	5.977	.0817	5.314
60	.0723	4.702	.0599	3.896
20	.0379	2.465	.0256	1.665
0	.0177	1.151	.0048	.312
After load reversal			-.0025	-.163

*100% Moment = 20476 Ft lbs



* After load reversal

Figure 9.7-21 Rotation at Elevation Worm

Table 9.7-11

90 mph Elevation Axis Test-Azimuth Bearing

% Load	Test 1 Δ(#9)	Test 1 Δ(#10)	Test 1 θ	Test 2 Δ(#9)	Test 2 Δ(#10)	Test 2 θ
0	0 inch	0 inch	0 mrad	0 inch	0 inch	0 mrad
20	.0059	.0044	.338	.0056	.0046	.334
40	.0137	.0149	.938	.0124	.0141	.869
60	.0198	.0239	1.433	.0185	.022	1.328
20	.0086	.0099	.607	.0092	.0085	.580
60	.0183	.0245	1.403	.0185	.0215	1.311
80	.0236	.0328	1.849	.0239	.0285	1.718
100 *	.0295	.0408	2.305	.0292	.0361	2.141
110	.0326	.0456	2.564	.032	.0399	2.357
60	.0226	.0298	1.718	.0228	.0251	1.570
20	.0098	.0135	.764	.011	.0088	.649
0	-.0004	.0021	.056	.0019	-.002	-.003
				.0024	-.009	-.216

*100% Moment = 20,476 Ft lbs

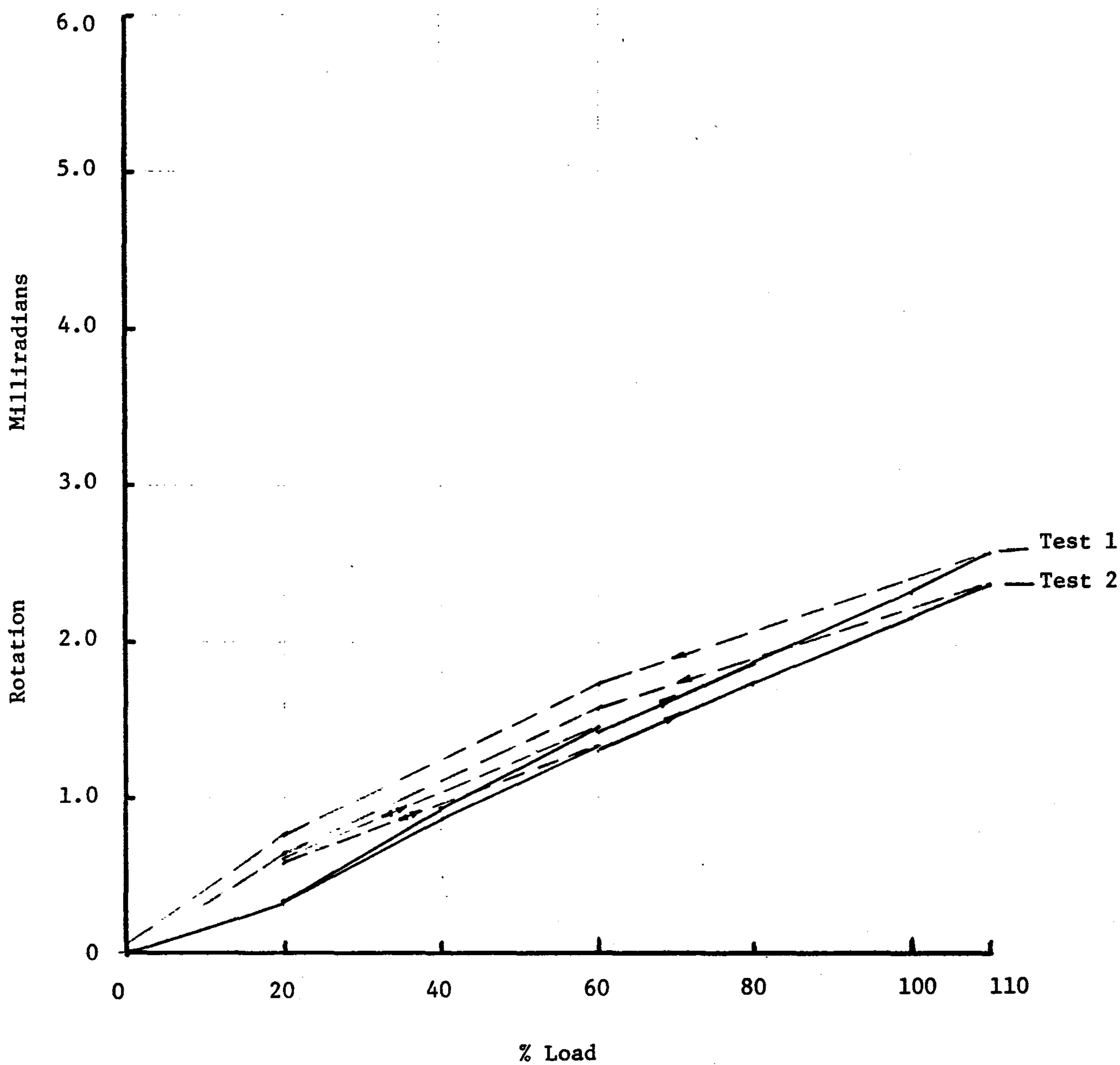


Figure 9.7-22 Rotation at Azimuth Bearing

TABLE 9.7 -12

Pedestal Deflection

% Load	#7 Test 1	#7 Test 2	#8 Test 1	#8 Test 2
0	0 inch	0 inch	0 inch	0 inch
20	.008	.007	.003	.014
40	.016	.016	.006	.0115
60	.028	.026	.012	.007
20	.010	.013	.005	.004
60	.029	.031	.013	.009
80	.037	.042	.015	.010
100	.047	.052	.018	.013
110	.051	.058	.019	.016
60	.031	.041	.016	.010
20	.011	.024	.011	.006
0	.002	.020	.009	.003
After Load reversal		.020		.004

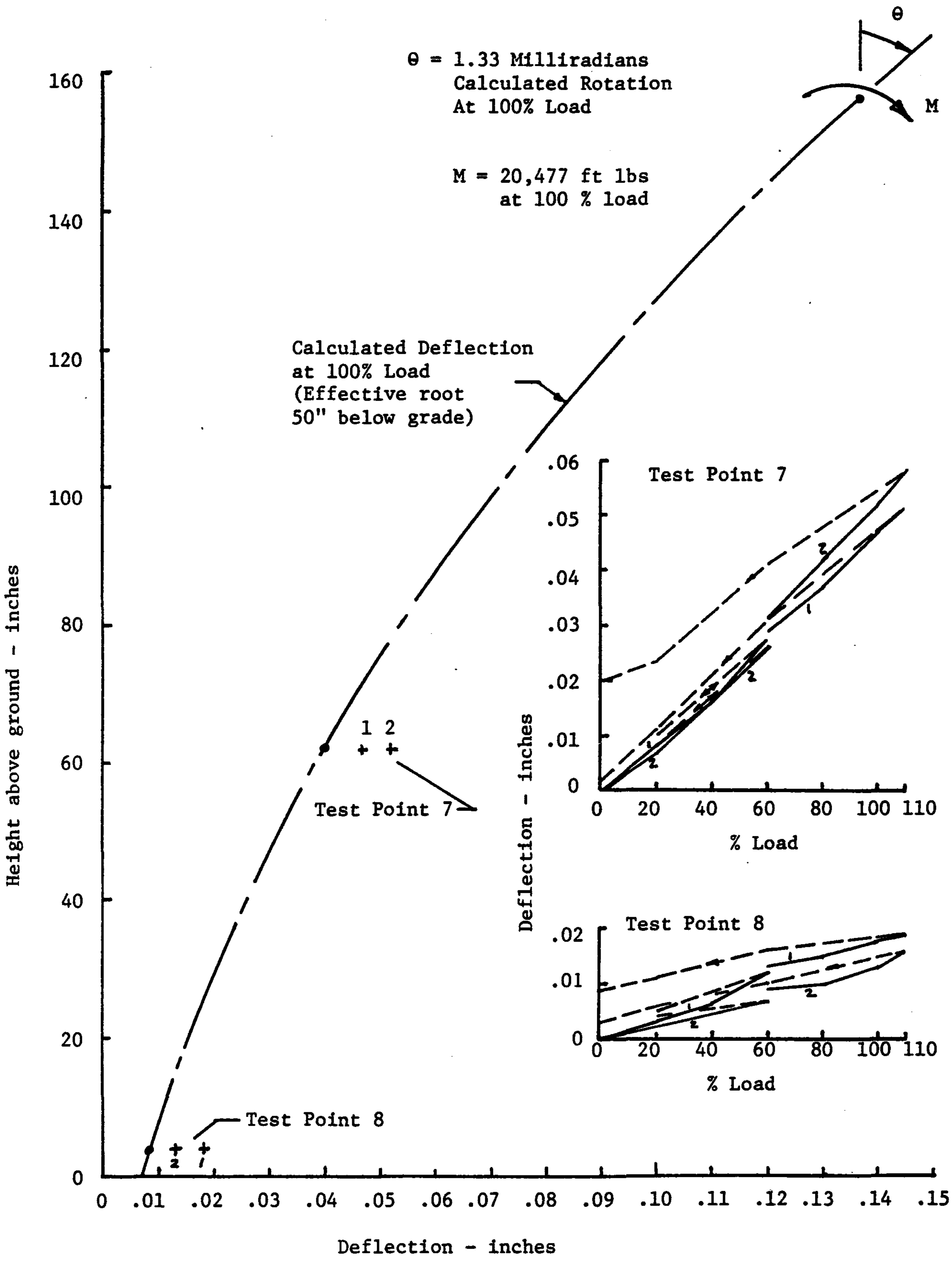


Figure 9.7-23 Pedestal Deflections

9.7.2.2.2 (b) Cross-Elevation Axis Test - 90 mph Wind Horizontal Stow Condition

Test Objectives: The objectives of the Cross-Elevation Axis Test are identical to those of the Elevation Axis Test. However, this test is to verify structural integrity and measure deflections for wind in the cross-elevation axis.

The 90 mph cross-elevation axis wind is the condition that produces

(a) The highest elevation drive bearing moment (267,645 inch lbs)

(b) The highest azimuth drive bearing moment (245,710 inch lbs). This is the same as the elevation axis condition (actual test load was 6.6% higher than the elevation axis test because the torque tube root moment was simulated).

(c) The highest torque tube root bending moment (20,874 ft lbs)

(d) The highest Butler truss bending moment and shear load (Moment = 6174 ft lbs, Shear = 1008 lbs)

Test Description: The test was performed on Heliostat #1 at the Hutchins Test Site on October 15, 1980. All major structural components on this heliostat were manufactured according to second generation heliostat prints and specifications, except that the main gears in the drive unit were cut undersize which allowed approximately .020 inch backlash instead of the required .002-.003 inch backlash.

The test was performed with the heliostat mirror surface in the horizontal position, which simulates horizontal stow. Moment load was applied about the cross elevation axis which simulates the moment induced by a 90 mph side wind at 10 degrees from horizontal. Normal force was not simulated due to its non-critical nature, but the loading method resulted in about 65% of wind normal force.

Loads were applied by hanging six 55 gallon barrels from the outboard rack truss with ropes and filling the barrels to the appropriate level with water. The tare weight of each barrel is 50 lbs. The locations of the barrels are shown in Figure 9.7-24.

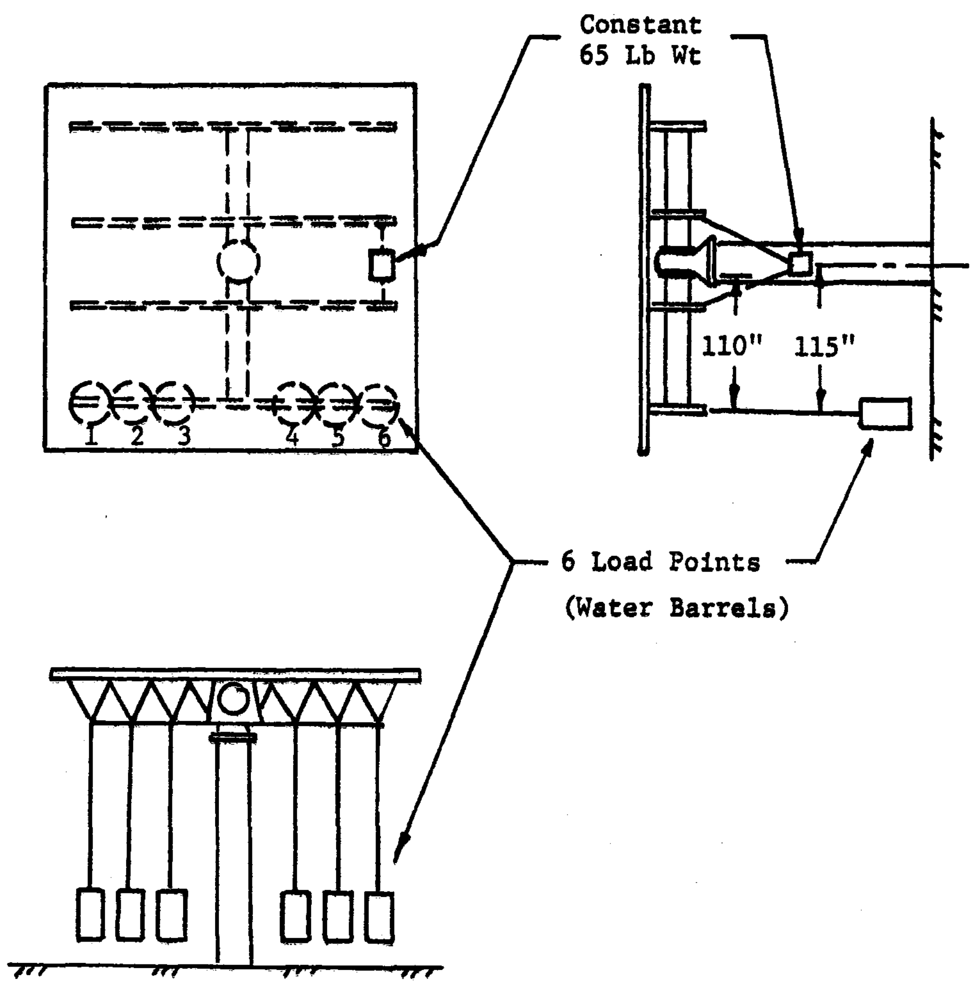


Figure 9.7-24 Loading Setup

The test was performed by incrementally applying load to 110% of limit load. At the beginnning of the test (zero point), two empty barrels (nos. 3 & 4) were hung to stabilize the pseudo-balanced rack in a null position, thus the zero point is actually not true zero. The 20% and higher increments are true, however. The schedule of weights and water depths are tabulated in Table 9.7 -13.

Table 9.7-13

% Load	Total Wt	Wt per Bbl	Water Wt per Bbl	Water Depth **
-0	100 lbs	50 lbs(2 only)	0	0
0	100	50	0	0
20	455.4	75.9	25.9	1.8
40	910.9	151.8	101.8	7.2
60	1366.3	227.7	177.7	12.5
80	1821.7	303.6	253.6	17.9
100 *	2277.2	379.5	329.5	23.2
110	2504.9	417.5	367.5	25.9

* 100% load = 20,870 ft-lbs torque about the torque tube root
21,823 ft-lbs about the drive center line

** 1 inch of water = 14.2 lbs

The loading was sequenced in the following percentages: -0, 0, 20, 40, 60, 20, 60, 80, 100, 110, 60, 20, 0, -0. The -0 increment is the designation for applying negative moment of 100 lbs (2 bbls) at the beginning of the test. The 20% set load after 60% was done to detect premature yielding and to get an early indication of mechanical hysteresis prior to the higher load increments.

Instrumentation: The heliostat was instrumented with 12 dial indicators to measure linear deflections at key places on the structure and drive units. The deflection measurements along with their respective moment arms were then used to compute rotational displacements.

The rotational displacements obtained from this test are:

(a) overall rack rotation

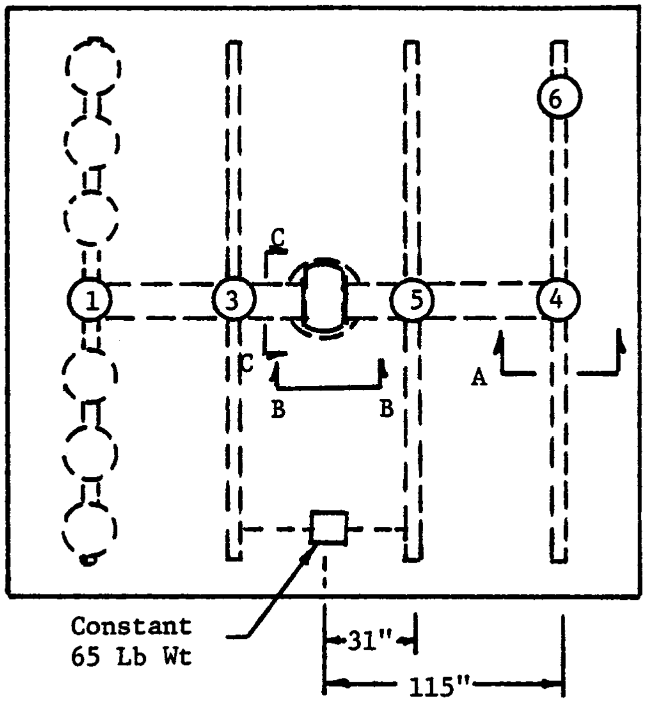
(b) elevation bearing rotation (with respect to the outer elevation housing)

(c) azimuth bearing rotation (azimuth upper housing with respect to the lower housing)

(d) pedestal displacements

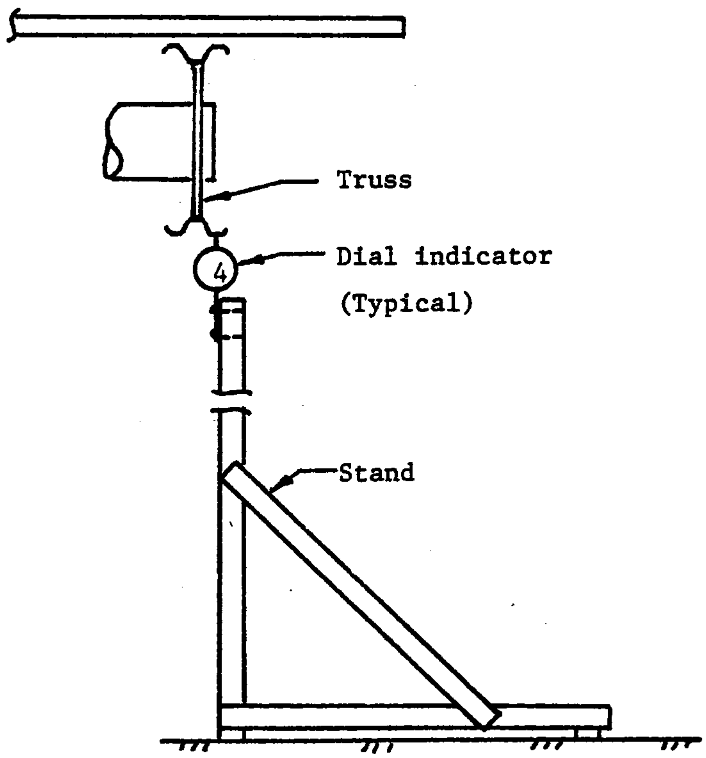
(e) rack and torque tube displacements from which bending may be derived.

The locations of the dial indicators are shown in Figures 9.7-25, 9.7-26 and 9.7-27.



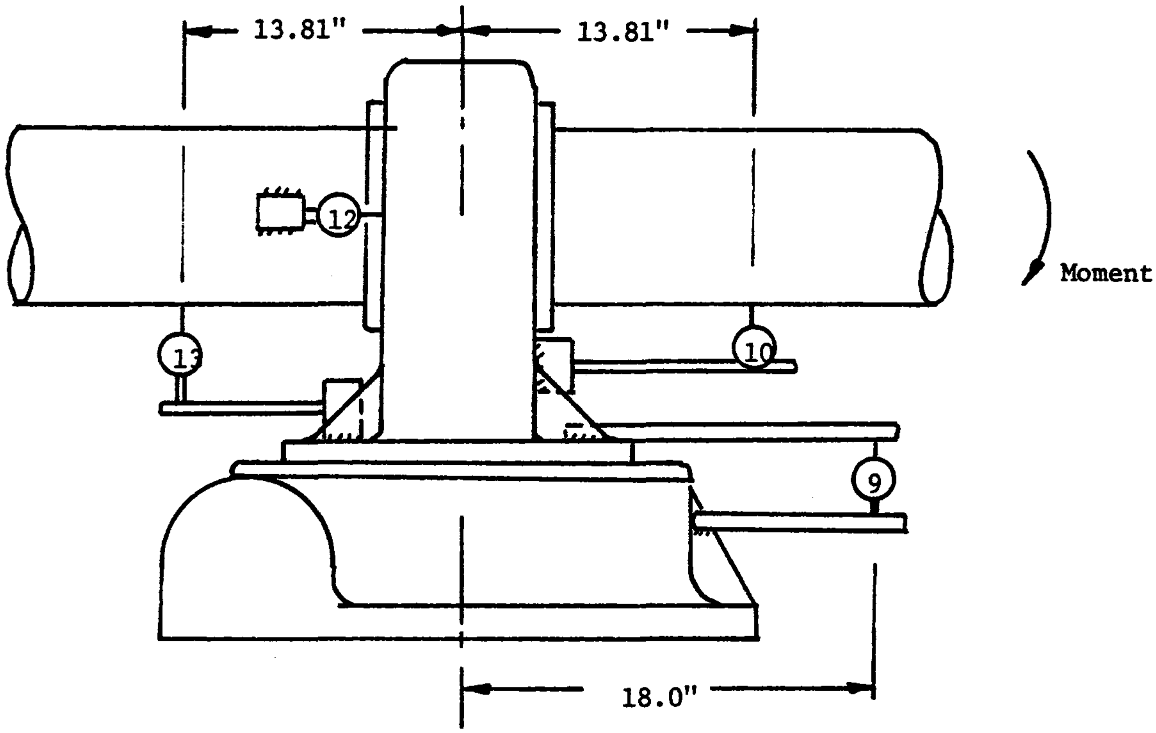
1,3,4,5,6 are vertical deflection measurements

Plan View of heliostat

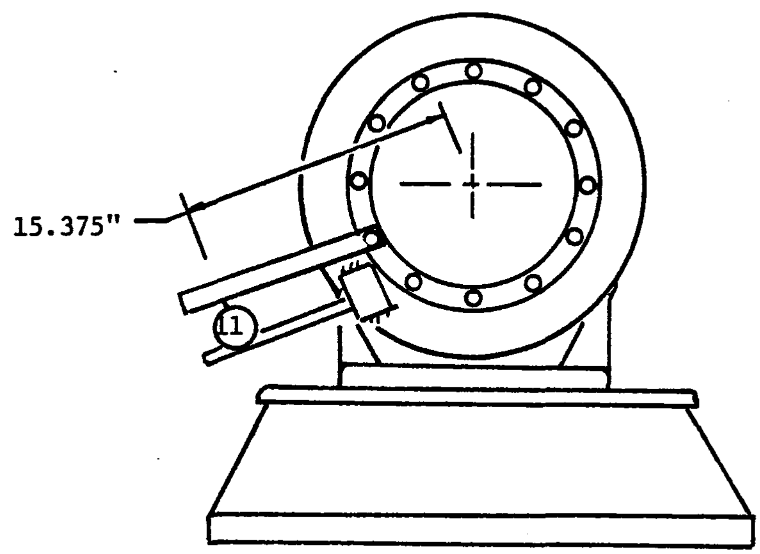


View A-A

Figure 9.7-25 Rack Deflection Instrumentation

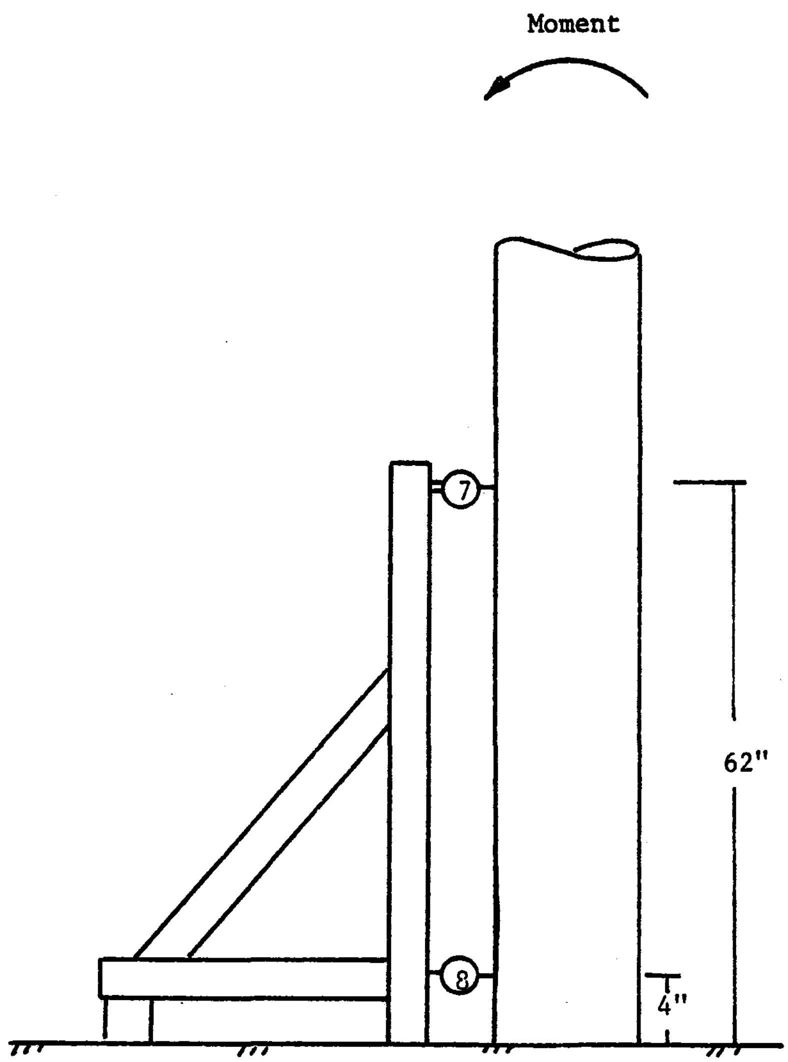


View B-B (of figure 9.7-)



View C-C (of figure 9.7-)

Figure 9.7-26 Drive Deflection Instrumentation



View B-B (of figure 9.7-

Figure 9.7-27 Pedestal Deflection Instrumentation

Test Results: The raw data sheet giving the actual dial indicator readings from the test run is presented in Table 9.7-14. The data was normalized to zero at zero percent load, and converted to rotational displacements which is presented in Tables 9.7-15 through 9.7-18. The rotational displacements are plotted versus percent load and presented in Figures 9.7-28 through 9.7-31.

No failure or detectable yielding occurred up to the maximum 110% load.

TABLE 9.7-14

Dial Indicator Readings

LOAD, %	#1	#3	#9	#10	#11	#12	#13	#5	#4	#6	#7	#8
-0	.174	.100	.2476	.1790	.1775	.1737	.2527	.894	2.703	1.530	.315	.273
+0	.270	.125	.2529	.0825	.1790	.1739	.2471	.862	2.585	1.460	.319	.273
20	.515	.182	.2625	.0931	.1825	.1741	.2335	.802	2.370	1.252	.326	.2745
40	.835	.262	.2700	.1079	.1862	.1748	.2160	.718	2.100	1.098	.335	.278
60	1.155	.341	.2781	.1225	.1920	.1748	.1975	.633	1.818	0.775	.345	.2795
20	.625	.210	.2662	.0998	.1855	.1748	.2265	.765	2.275	1.180	.328	.276
60	1.175	.338	.2781	.1228	.1930	.1751	.1975	.627	1.810	0.760	.346	.281
80	1.473	.416	.2855	.1350	.1955	.1750	.1805	.550	1.545	.530	.357	.284
100	1.790	.480	.2950	.1485	.1985	.1752	.1620	.482	1.270	.297	.370	.289
110	1.945	.518	.2991	.1552	.2000	.1752	.1535	.436	1.120	.175	.375	.290
60	1.345 (1.325)	.375 (.360)	.2862 (.2840)	.1295 (.1285)	.1950 (.1980)	.1753 (.1752)	.1885 (.1880)	.590 (.585)	1.640 (1.620)	.645 (.625)	.353 (.354)	.285 (.289)
20	.715	.212	.270	.103	.189	.1750	.2210	.742	2.165	1.090	.335	.285
+ 0	.385	.140	.259	.092	.180	.1740	.236	.831	2.465	1.390	.327	.281
- 0	.203	.084	.2504	.0825	.1760	.1733	.248	.883	2.620	1.520	.325	.280

Table 9.7-15

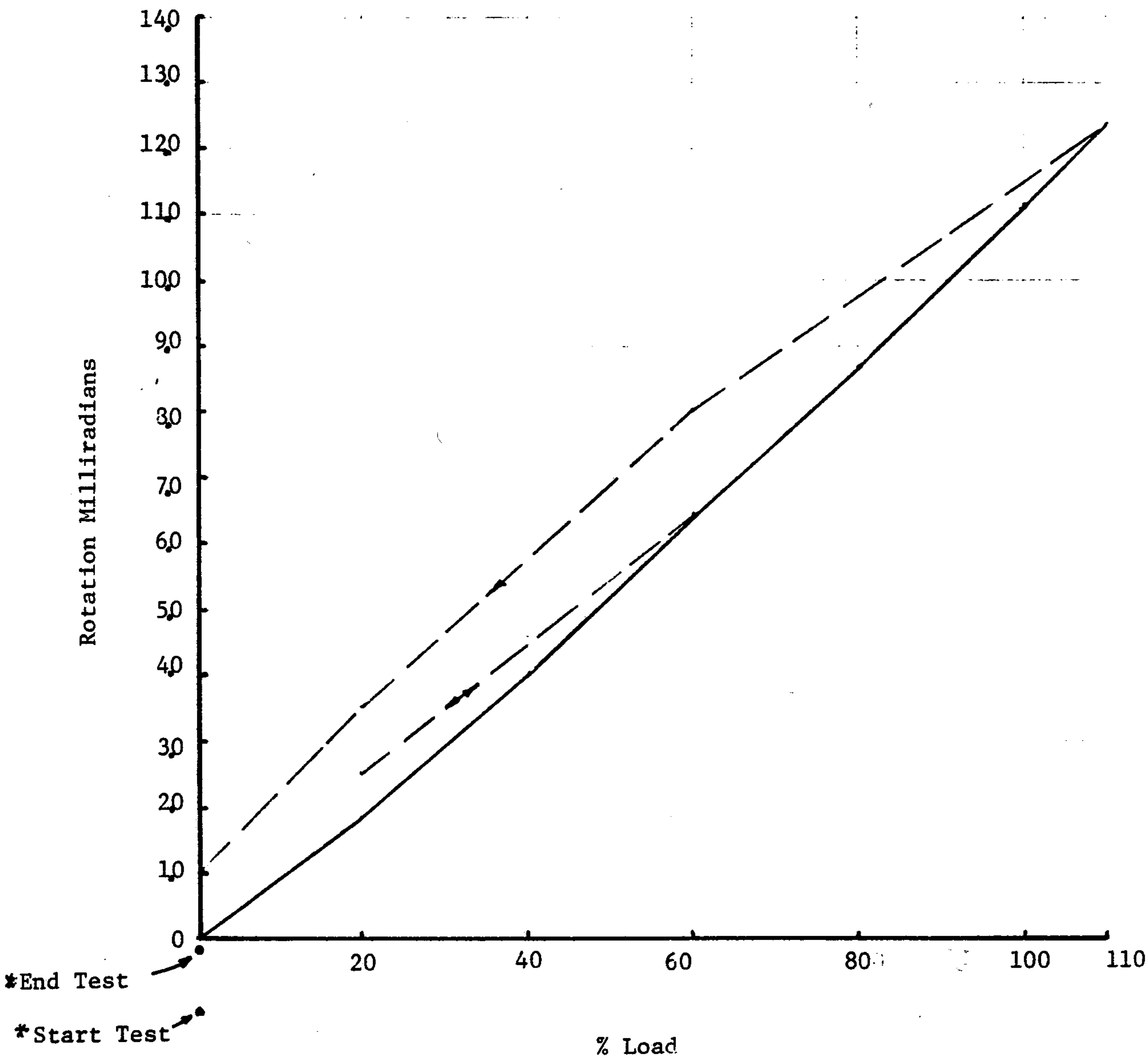
90 mph Cross - Axis Test

Torque Tube (Rack total motion)

% Load	Δ (#4)	Δ (#5)	θ
-0* *	-.118 inch	-.032 inch	-1.024 mrad
0	0	0	0
20	.215	.060	1.845
40	.485	.144	4.060
60	.767	.229	6.405
20	.310	.097	2.536
60	.775	.235	6.429
80	1.040	.312	8.667
100 *	1.315	.38	11.131
110	1.465	.426	12.369
60	.945 (.965)	.272 (.277)	8.012
20	.420	.12	3.571
0	.120	.031	1.060
-0 * *	-.035	-.021	.167

* 100% Moment = 21,823 ft lbs about drive center line

* * Reverse moment = 958 ft lbs



Reverse Moment = 958 ft lbs

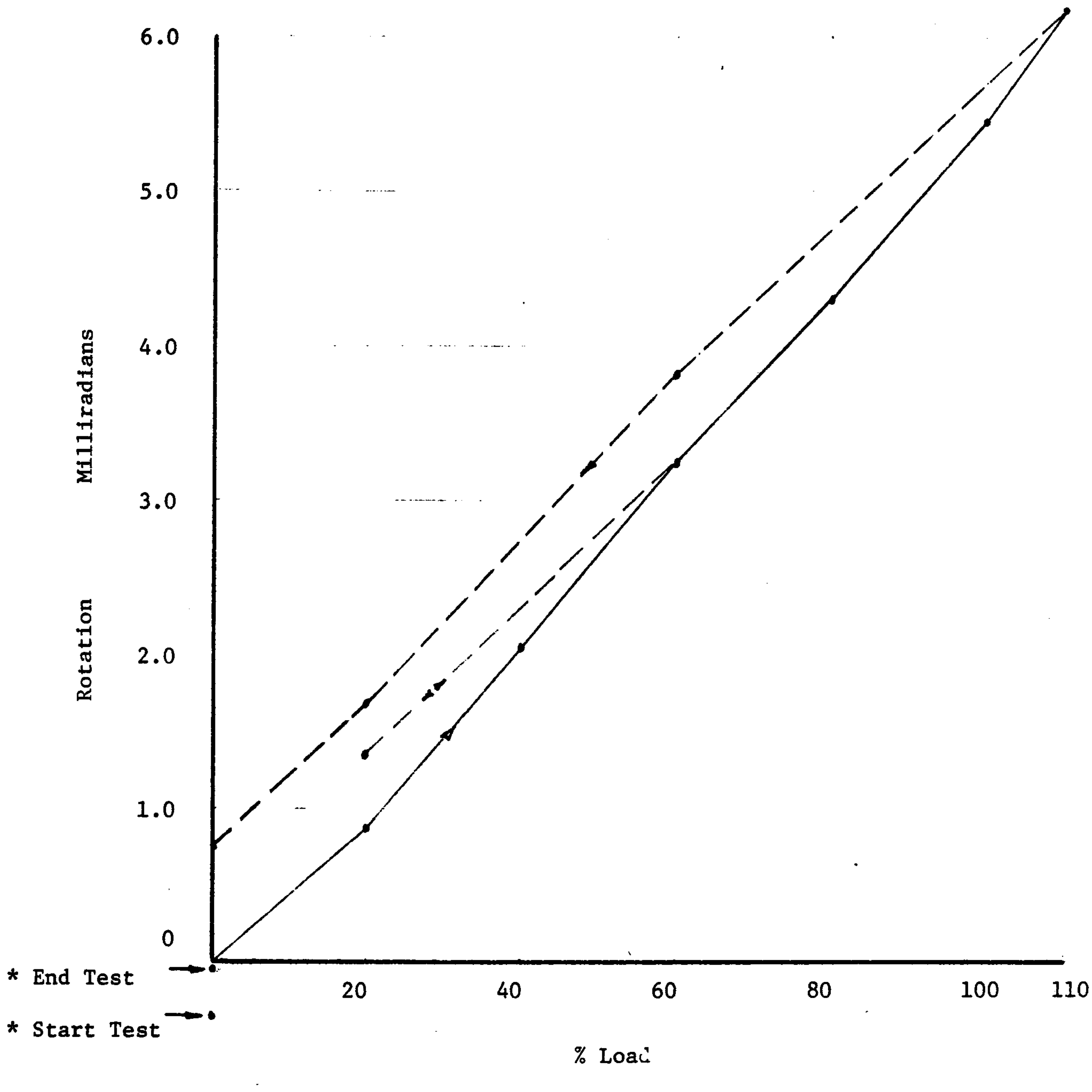
Figure 9.7-28 Rack Rotation

TABLE 9.7-16

90 mph Cross - Axis Test

Elevation Bearing

% Load	Δ(#10)	Δ(#13)	θ
-0	-.0035 inch	-.0056 inch	-.329 mrad
0	0	0	0
20	.0106	.0136	.876
40	.0254	.0311	2.045
60	.040	.0496	3.243
20	.0173	.0206	1.372
60	.0403	.0496	3.254
80	.0525	.0666	4.311
100	.066	.0851	5.469
110	.0727	.0936	6.019
60	.047 (.046)	.0586 (.0591)	3.822 (3.804)
20	.0205	.0261	1.687
0	.0095	.0111	.746
-0	0	-.0009	-.033



* Reverse moment = 958 ft lbs

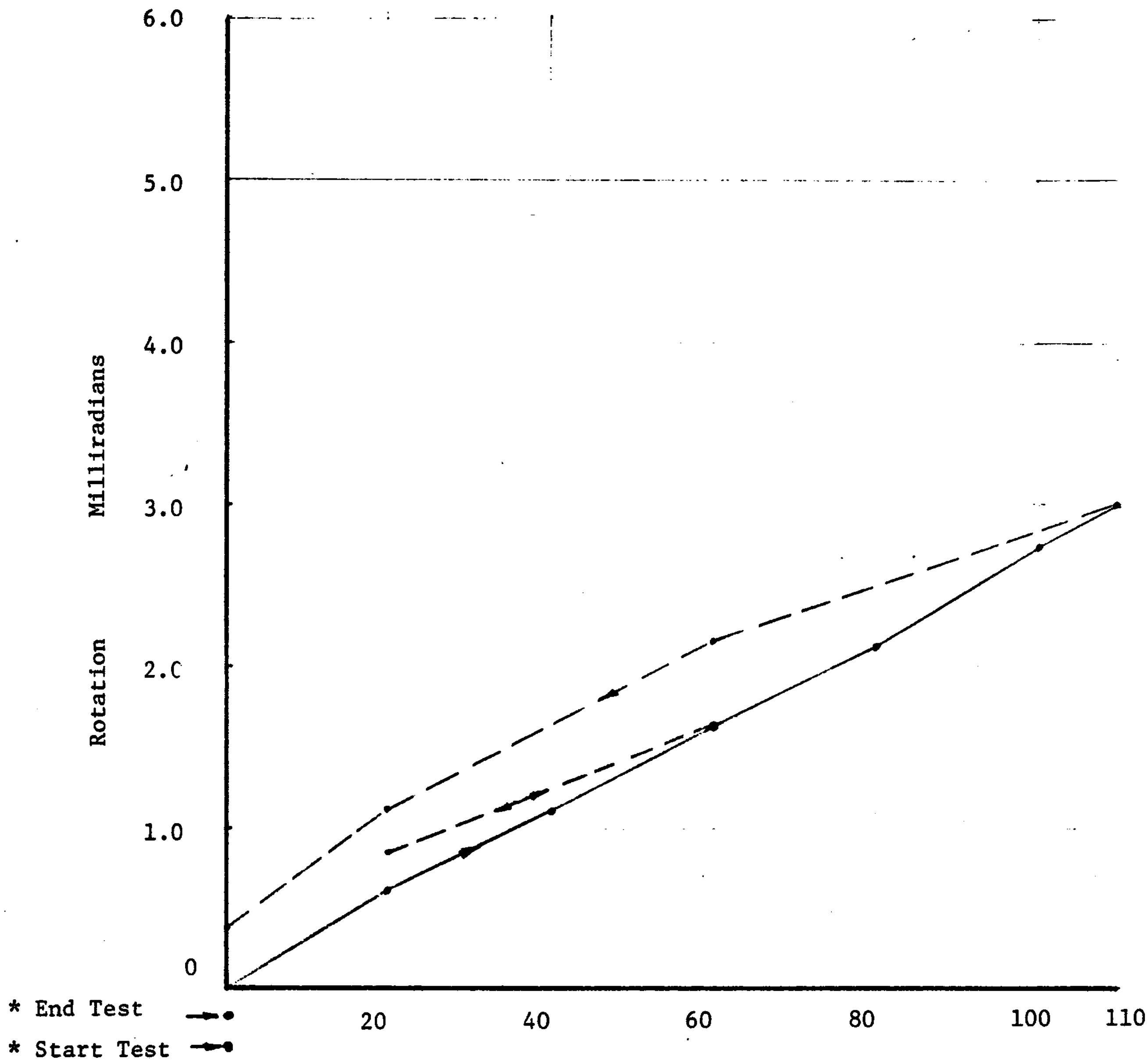
Figure 9.7-29 Elevation Bearing Rotations

Table 9.7- 17

90 mph Cross - Axis Test

Azimuth Bearing

% Load	Δ (#9)		θ	
-0	-.0053	inch	-.344	mrad
0	0		0	
20	.0096		.623	
40	.0171		1.110	
60	.0252		1.636	
20	.0133		.864	
60	.0252		1.636	
80	.0326		2.117	
100	.0421		2.734	
110	.0462		3.000	
60	.0333	(.0311)	2.162	(2.019)
20	.0171		1.110	
0	.0061		.396	
-0	-.0025		-.162	



* Reverse Moment = 958 ft lbs

Figure 9.7- 30 Azimuth Bearing Rotation

TABLE 9.7-18

PEDESTAL DEFLECTION

% Load	#7	#8
-0	-.004 inch	.0 inch
0	0	.0
20	.007	.0015
40	.016	.005
60	.026	.0065
20	.009	.003
60	.027	.008
80	.038	.011
100	.051	.016
110	.056	.017
60	.034	.014
20	.016	.012
0	.008	.008
-0	.006	.007

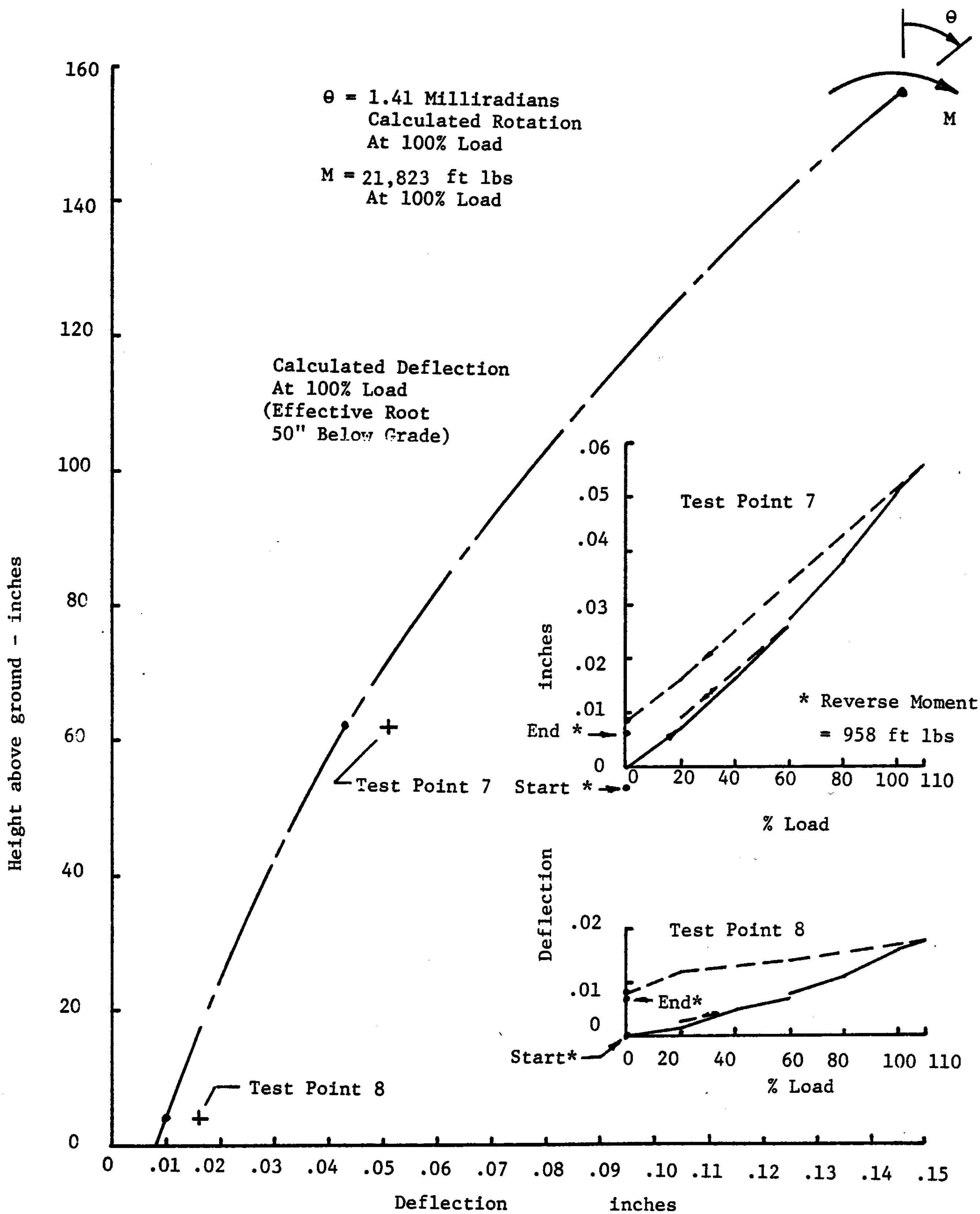


Figure 9.7-31 Pedestal Deflection

9.7.2.2.3 Azimuth Axis Test - 50 mph Vertical Condition

Test Objectives: The objectives of the Azimuth Axis Test are to: (a) verify the structural integrity of the drives and major structural components to withstand loads induced by 50 mph winds while in the vertical drive or stow position, and (b) measure deflections of the drives and major structural components for comparison with pointing accuracy requirements at lower wind conditions.

The 50 mph azimuth wind condition produces the largest moment (9497 ft lbs) about the azimuth axis of any condition. Therefore, it produces the largest azimuth drive main gear tooth force of 13,560 lbs (tangential load). This condition also produces the largest pedestal twisting moment.

Test Description: The test was performed on Heliostat #1 at the Hutchins Test Site on October 17, 1980. All major structural components on this heliostat were manufactured according to second generation heliostat prints and specifications, except that the main gears in the drive unit were cut undersize which allowed approximately .020 inch backlash instead of the required .002-.003 inch backlash.

The test was performed with the heliostat mirror surface in the vertical position, which simulates vertical stow or driving to stow. Moment load was applied about the azimuth drive axis which simulates the moment induced by 50 mph wind at 70 degrees from the mirror surface normal. Normal force was not simulated due to its non-critical nature, but the loading method resulted in about 35% of wind normal force.

Moment load about the azimuth axis was applied by hanging two 55 gallon barrels from a cable and pulley system designed to provide a horizontal force to a wood beam inserted into the torque tube. The barrels were then filled to the appropriate level with water. The tare weight of each barrel is 50 lbs. The test set up is shown in Figure 9.7-32.

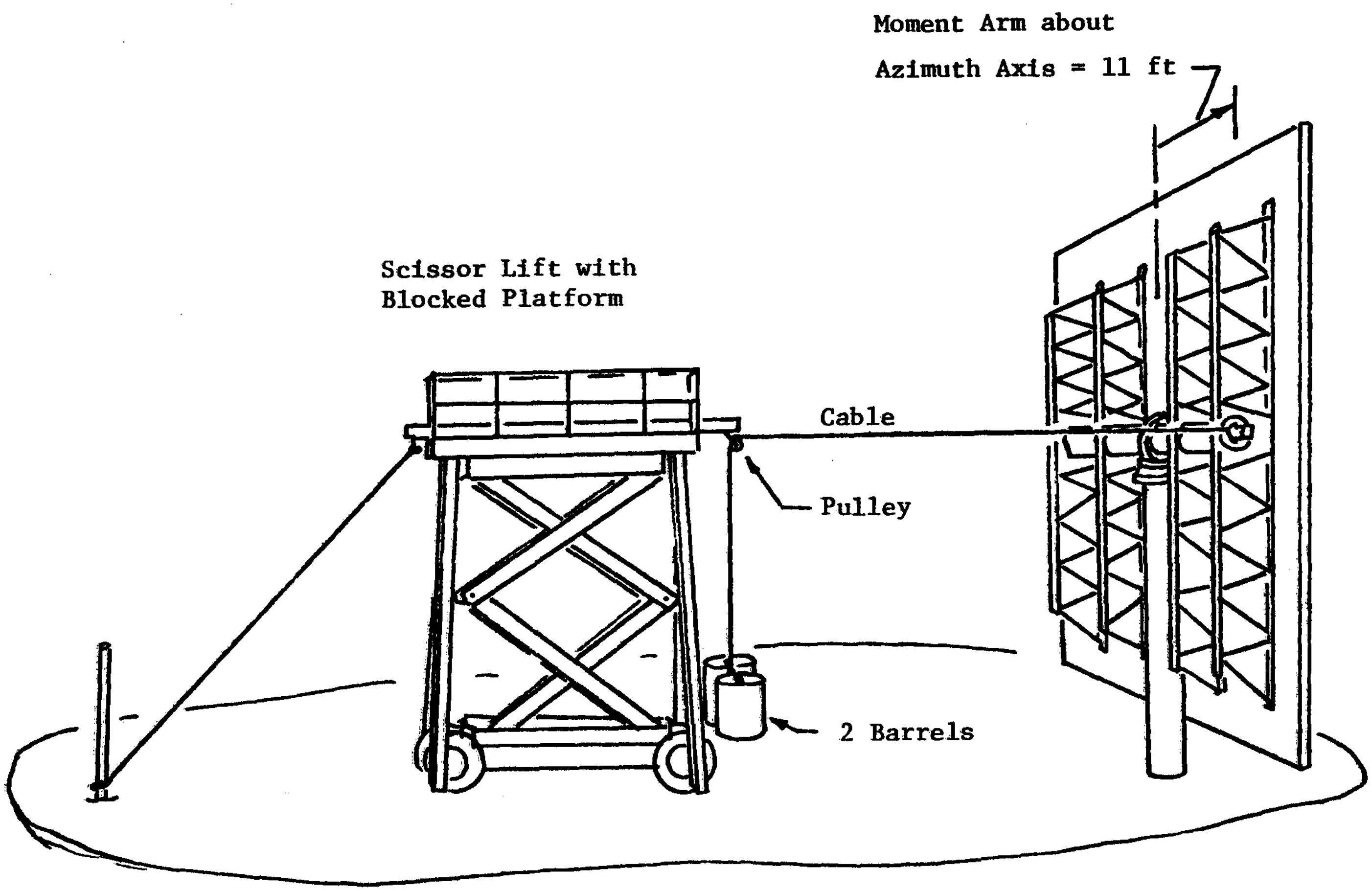


Figure 9.7-32 Test Loading Setup

The test was performed by incrementally applying load to 110% of limit load. At the beginning of the test (zero point), a 12 lb weight was hung to stabilize the rack in a null position. The schedule of weights and water depths is tabulated in Table 9.7-19.

Table 9.7-19

% Load	Total Wt.	Wt. per Bbl	Water Wt per Bbl	Water Depth *
0	12 lbs	-	-	-
20	172.7	86.3	36.3	2.6
40	345.4	172.7	122.7	8.6
60	518.0	259.0	209.0	14.7
80	690.7	345.4	295.4	20.8
100*	863.4	431.7	381.7	26.9
110	949.7	474.9	424.9	29.9

* 100% load = 9497 ft-lbs azimuth axis torque

** 1 inch of water = 14.2 lbs

The loading was sequenced in the following percentages: 0, 20, 40, 60, 20, 60, 80, 100, 110, 60, 20, 0, 20, 40, 60, 20, 60, 80, 100, 110, 60, 20, 0. The 20% set load after 60% was done to detect premature yielding and to get an early indication of mechanical hysteresis prior to the higher load increments.

Instrumentation: The heliostat was instrumented with 10 dial indicators to measure linear deflections at key places on the structure and drive units. The deflection measurements along with their respective moment arms were then used to compute rotational displacements.

The rotational displacements obtained from this test are:

(a) overall rack rotation

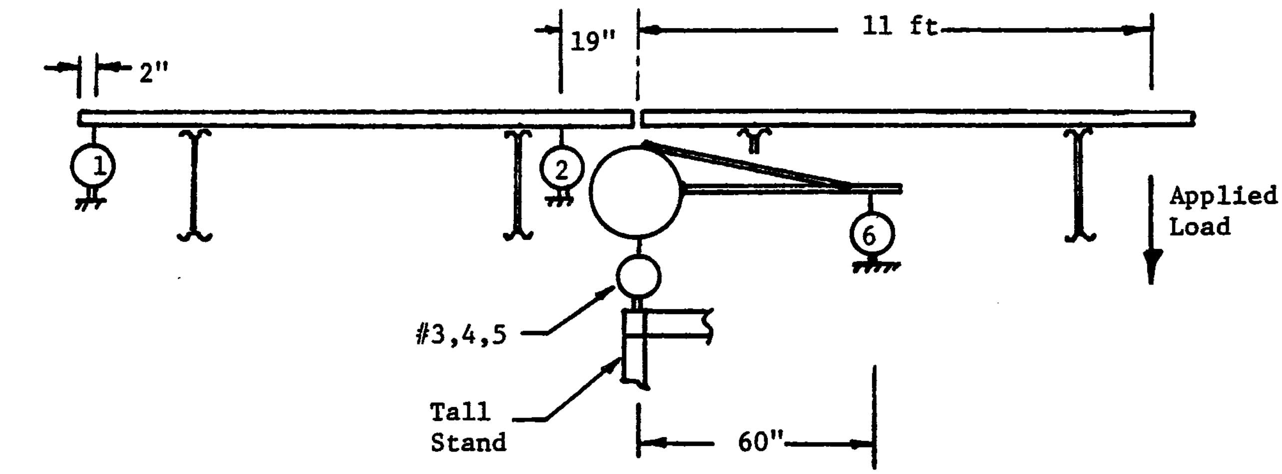
(b) azimuth gear rotation (with respect to the azimuth housing)

(c) elevation bearing rotation (elevation inner housing with respect to the outer housing)

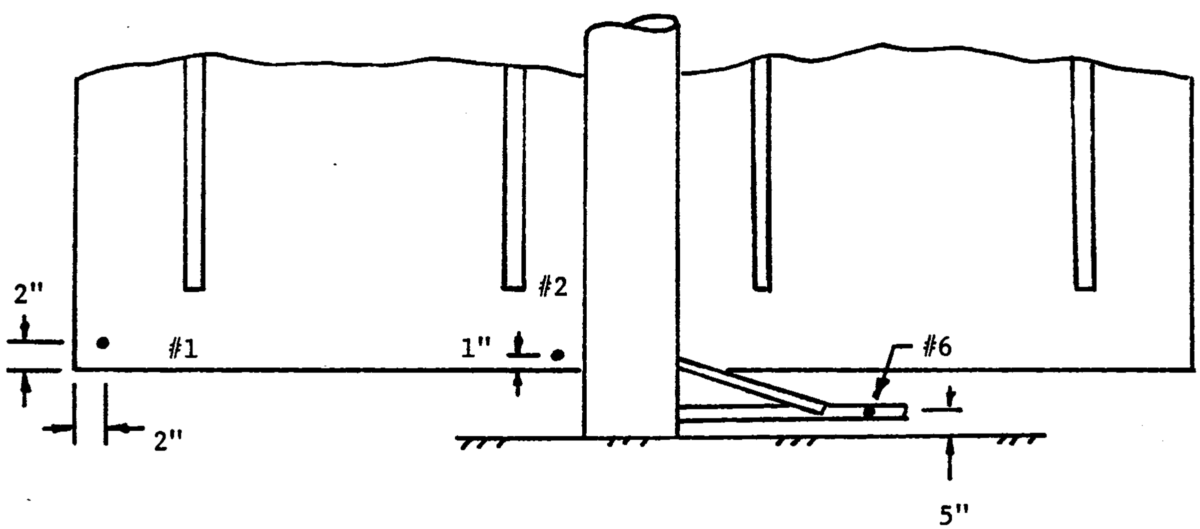
(d) pedestal lateral displacements

(e) pedestal base twist

The locations of the dial indicators are shown in Figure 9.7-33, 9.7-34 and 9.7-35.

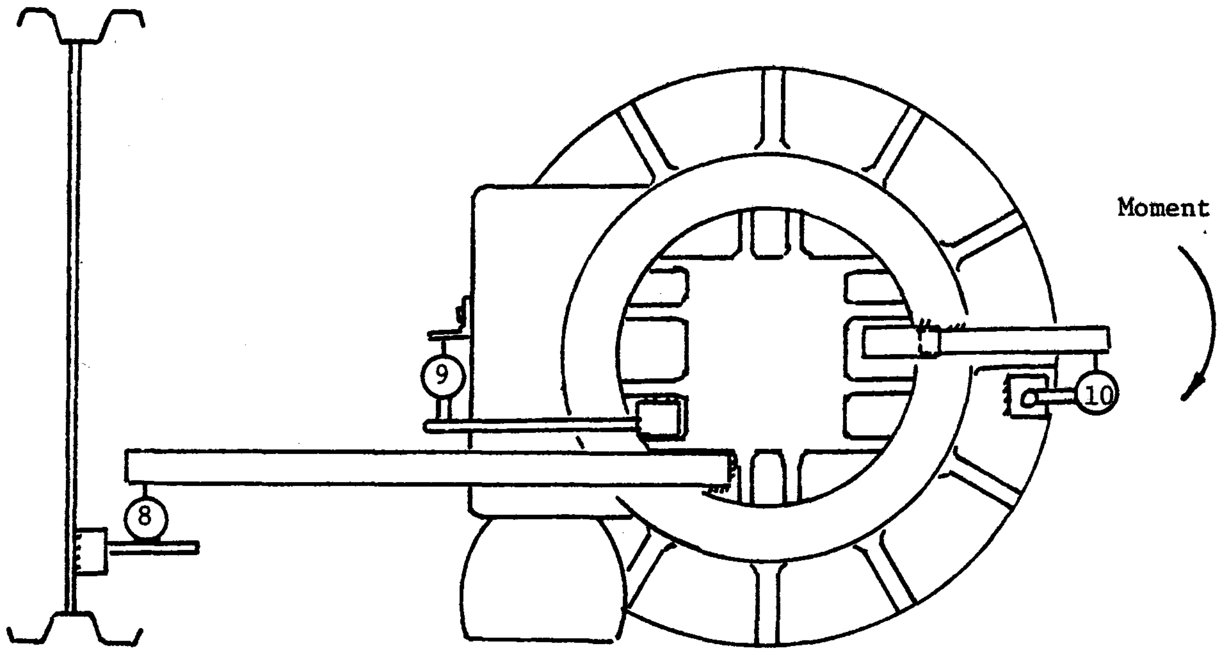


View Looking Down



View Looking at Back of Heliostat

Figure 9.7-33 Rack/Mirror and Pedestal Twist Deflection Instrumentation



View A-A

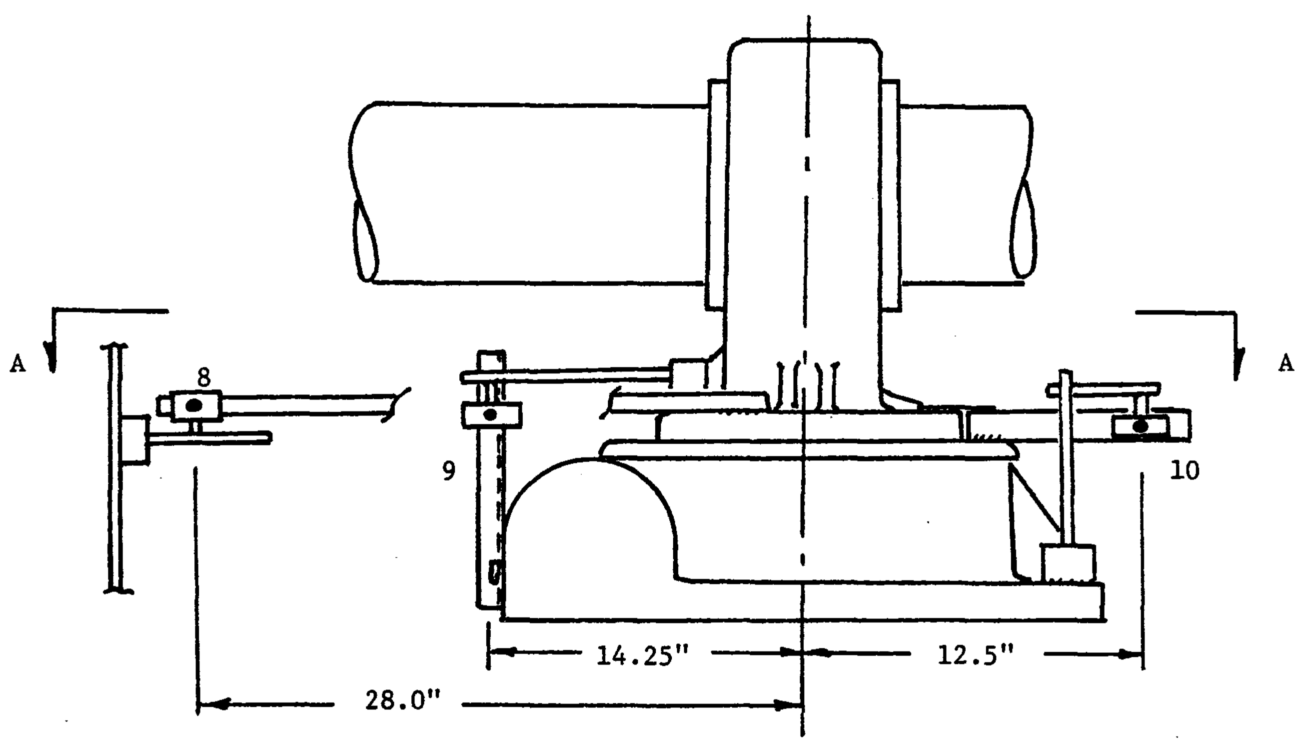


Figure 9.7-34 Drive Deflection Instrumentation

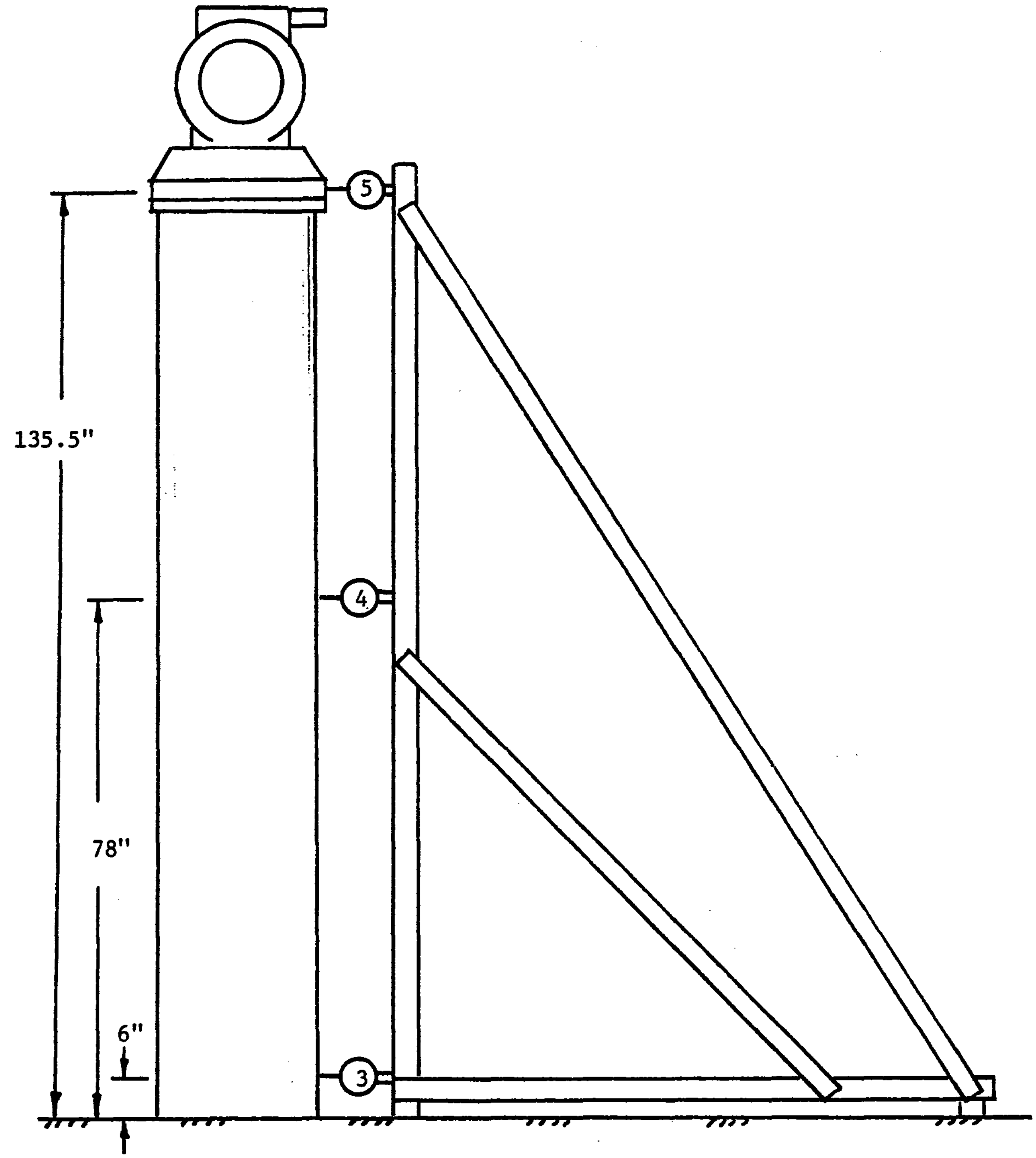


Figure 9.7-35 Pedestal Deflection Instrumentation

Test Results:

The raw data sheets giving the actual dial indicator readings from test run #1 and test run #2 are presented in Table 9.7-20 and 9.7-21. The data was normalized to zero at zero percent load and converted to rotational displacements which is presented in Tables 9.7-22 through 9.7-26. The rotational displacements are plotted and presented in Figures 9.7-36 through 9.7-40.

It may be noted that a distinctive shift of approximately 3 milliradians occurred in both the elevation "bearing" and the azimuth "worm" measurements of the drive unit. This shift occurred between 20% and 40% load and was accompanied by a distinct sound at the time of loading. It is believed that the cause of the shift was some combination of backdriving in the azimuth drive and/or the hard setting of bearings or bearing races in the drives that wouldn't have occurred under light loads. It is also believed that the shock effect of the initial set in one drive (elevation or azimuth) caused the other one to set. The subsequent data taken during the first and second test runs followed a linear pattern and no yielding is believed to have occurred, and certainly no failure occurred.

Table 9.7-20

Dial Indicator Readings

Test Run #1

% Load	#1	#2	#3	#4	#5	#6	#8	#9	#10
0	2.775	1.742	.013	.310	.031	.014	.650	.1872	.5668
20	2.715	1.702	.014	.3132	.0465	.0183	.666	.197	.5724
40	2.720	1.583	.0155	.3155	.055	.0223	.761	.2735	.5841
60	2.790	1.527	.018	.323	.070	.0293	.770	.284	.5917
20	1.920	1.578	.015	.314	.047	.022	.7591	.2785	.5848
60	2.712	1.533	.018	.322	.070	.0280	.770	.284	.5918
80	1.642	1.496	.0205	.326	.092	.034	.780	.290	.5976
100	1.365	1.417	.0225	.330	.097	.041	.797	.302	.6105
110	1.200	1.400	.0235	.333	.099	.0445	.800	.303	.6123
60	1.527	1.454	.021	.327	.084	.0355	.789	.299	.6062
20	1.879	1.531	.017	.317	.056	.023	.773	.288	.5935
0	2.170	1.612	.015	.310	.039	.017	.757	.275	.5815

Table ...-21

Dial Indicator Readings

Test Run # 2

% Load	#1	#2	#3	#4	#5	#6	#8	#9	#10
0	2.170	1.612	.015	.310	.039	.017	.757	.275	.5815
20	1.925		.0145	.311	.045	.020	.760	.281	.5859
40	1.820	1.555	.017	.314	.060	.024	.765	.285	.5915
60	1.750	1.517	.020	.321	.0751	.029	.773	.290	.5955
20	1.968	1.566	.017	.3135	.052	.022	.762	.284	.589
60	1.635	1.514	.020	.320	.072	.029	.773	.290	.596
80	1.592	1.479	.021	.3225	.0855	.0345	.781	.295	.6013
100	1.322	1.433	.023	.330	.0985	.040	.788	.299	.6075
110	1.282	1.392	.0245	.333	.1061	.045	.794	.305	.6141
60	1.432	1.453	.021	.3233	.080	.035	.782	.299	.6069
20	1.897	1.535	.017	.314	.056	.0225	.765	.288	.5931
0	2.050	1.597	.0152	.310	.0445	.0175	.752	.277	.5823

Table 9.7-22

50 mph Azimuth Test

Mirrors (Rack total motion)

	Test 1			Test 2		
%	Δ(#1)	Δ(#2)	θ	Δ(#1)	Δ(#2)	θ
0	0 inch	0 inch	0 mrad	.605 inch	.13 inch	3.831 mrad
20	.060	.04	- .161	.85		
40	.055	.159	- .839	.955	.187	6.194
60	.015	.215	-1.613	1.025	.225	6.452
20	.855	.164	5.573	.807	.176	5.089
60	.063	.209	-1.177	1.14	.228	7.355
80	1.133	.246	7.153	1.183	.263	7.419
100	1.41	.325	8.75	1.453	.309	9.226
110	1.575	.342	9.944	1.493	.35	9.218
60	1.248	.288	7.742	1.343	.289	8.5
20	.896	.211	5.524	.878	.207	5.411
0	.605	.13	3.831	.725	.145	4.677

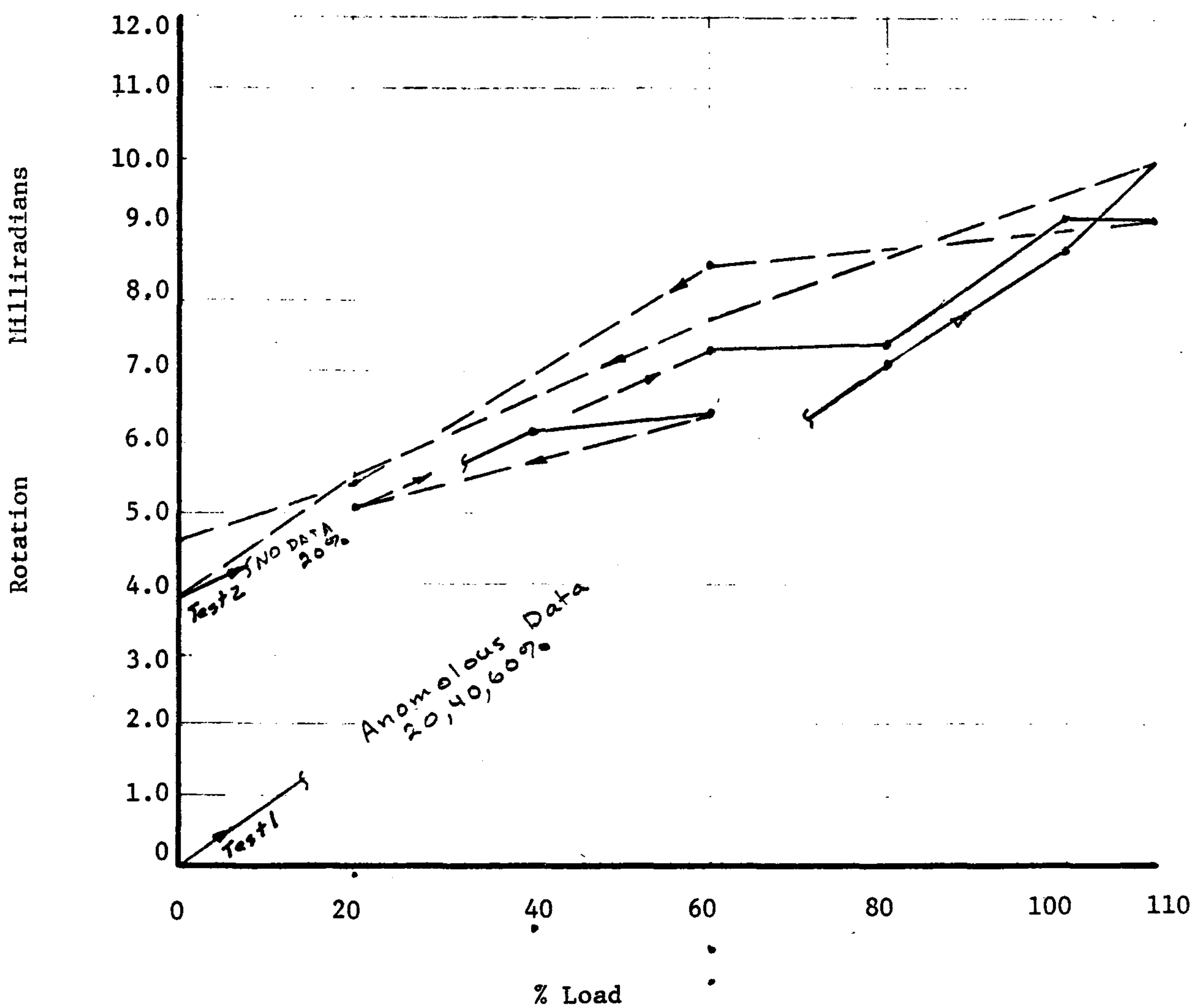


Figure 9.7-36 Rack Rotation

Table 9.7-23

<u>50 mph Azimuth Test</u>

Elevation Bearing

	Test 1		Test 2	
%	Δ (#8)	θ	Δ (#8)	θ
0	0 inch	0 mrad	.107 inch	3.452 mrad
20	.016	.516	.11	3.548
40	.111	3.581	.115	3.710
60	.12	3.871	.123	3.968
20	.1091	3.519	.112	3.613
60	.12	3.871	.123	3.968
80	.13	4.194	.131	4.226
100	.147	4.742	.138	4.452
110	.15	4.839	.144	4.645
60	.139	4.484	.132	4.258
20	.123	3.968	.115	3.710
0	.107	3.452	.102	3.290

100% Moment = 9497 FT LBS

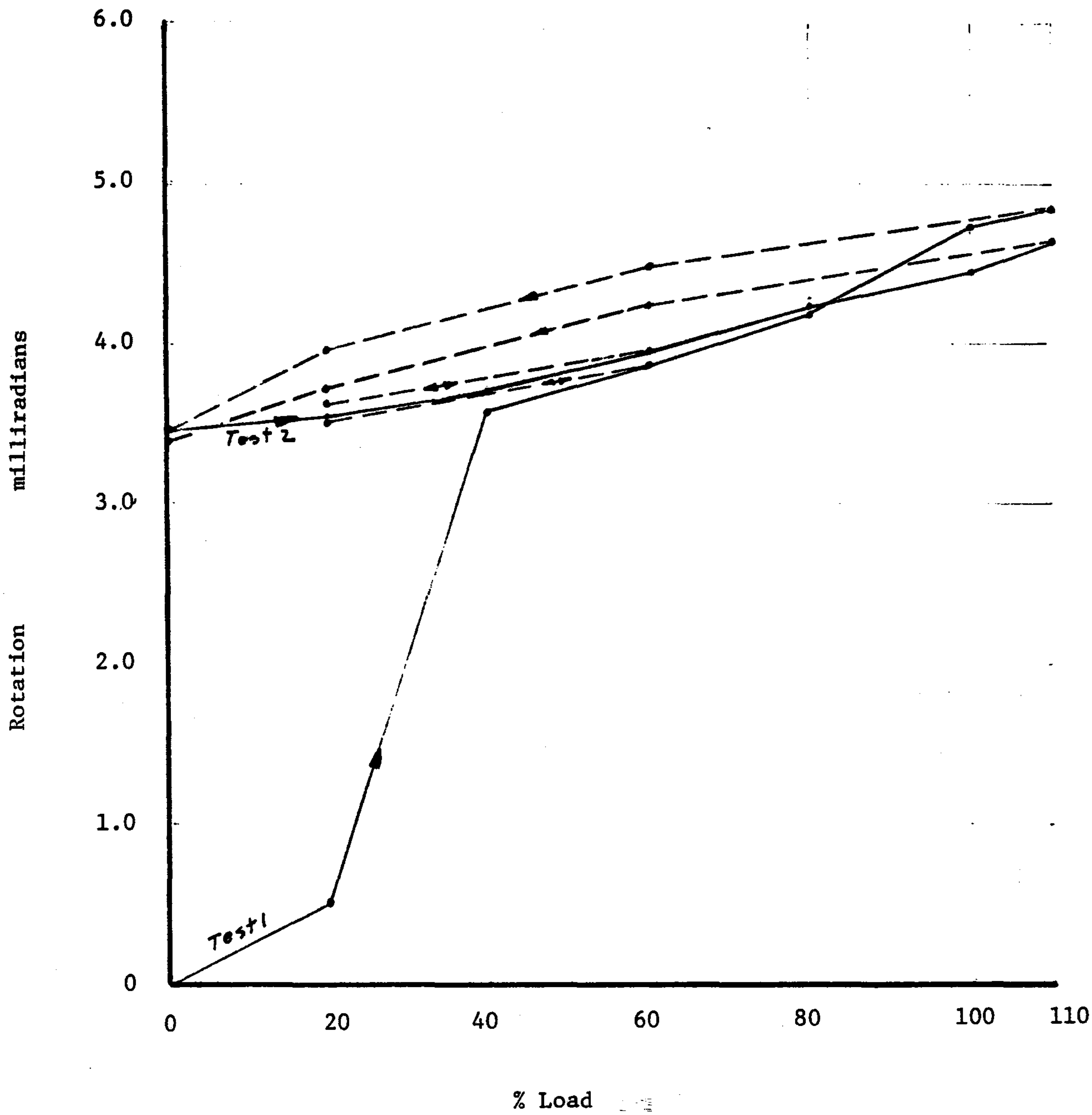


Figure 9.7-37 Elevation Bearing Rotation

Table 9.7-24

50 mph Azimuth Test

Azimuth Worm

	Test 1			Test 2		
%	Δ (#9)	Δ (#10)	θ	Δ (#9)	Δ (#10)	θ
0	0 inch	0 inch	0mrad	.0878 inch	.0147inch	3.832mrad
20	.0098	.0056	.576	.0938	.0191	4.221
40	.0863	.0173	3.873	.0978	.0247	4.579
60	.0968	.0249	4.550	.1028	.0287	4.916
20	.0913	.018	4.086	.0968	.0222	4.449
60	.0968	.025	4.553	.1028	.0292	4.935
80	.1028	.0308	4.994	.1078	.0345	5.320
100	.1148	.0437	5.925	.1118	.0407	5.701
110	.1158	.0455	6.030	.1178	.0473	6.172
60	.1118	.0394	5.652	.1118	.0401	5.679
20	.1008	.0267	4.766	.1008	.0263	4.751
0	.0878	.0147	3.832	.0898	.0155	3.936

100% Moment = 9497 FT LBS

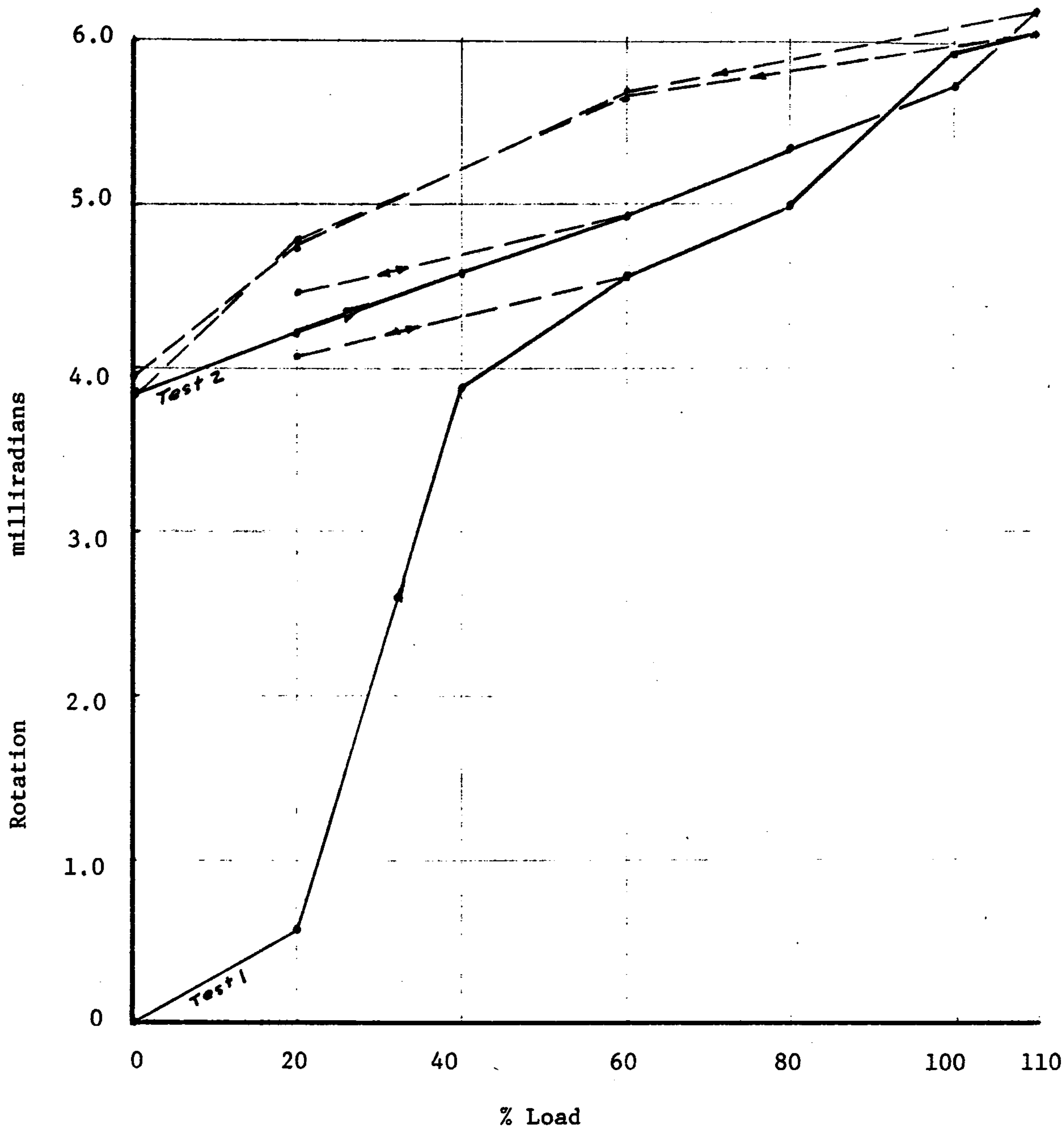


Figure 9.7-38 Rotation at Azimuth Worm

Table 9.7- 25

50 mph Azimuth Test

Pedestal Base Twist

%	Test 1 Δ (#6)	Test 1 Δ (#3)	Test 1 Θ	Test 2 Δ (#6)	Test 2 Δ (#3)	Test 2 Θ
0	0 inch	0 inch	0 mrad	.003 inch	.002 inch	.017 mrad
20	.0043	.001	.055	.006	.0015	.075
40	.0093	.002	.122	.010	.004	.100
60	.0153	.005	.172	.015	.007	.133
20	.008	.002	.100	.008	.004	.067
60	.014	.005	.150	.015	.007	.133
80	.020	.0075	.208	.0205	.008	.208
100	.027	.0095	.292	.026	.010	.267
110	.0305	.0105	.333	.031	.0115	.325
60	.0215	.008	.225	.021	.008	.217
20	.009	.004	.083	.0085	.004	.075
0	.003	.002	.017	.0035	.0022	.022

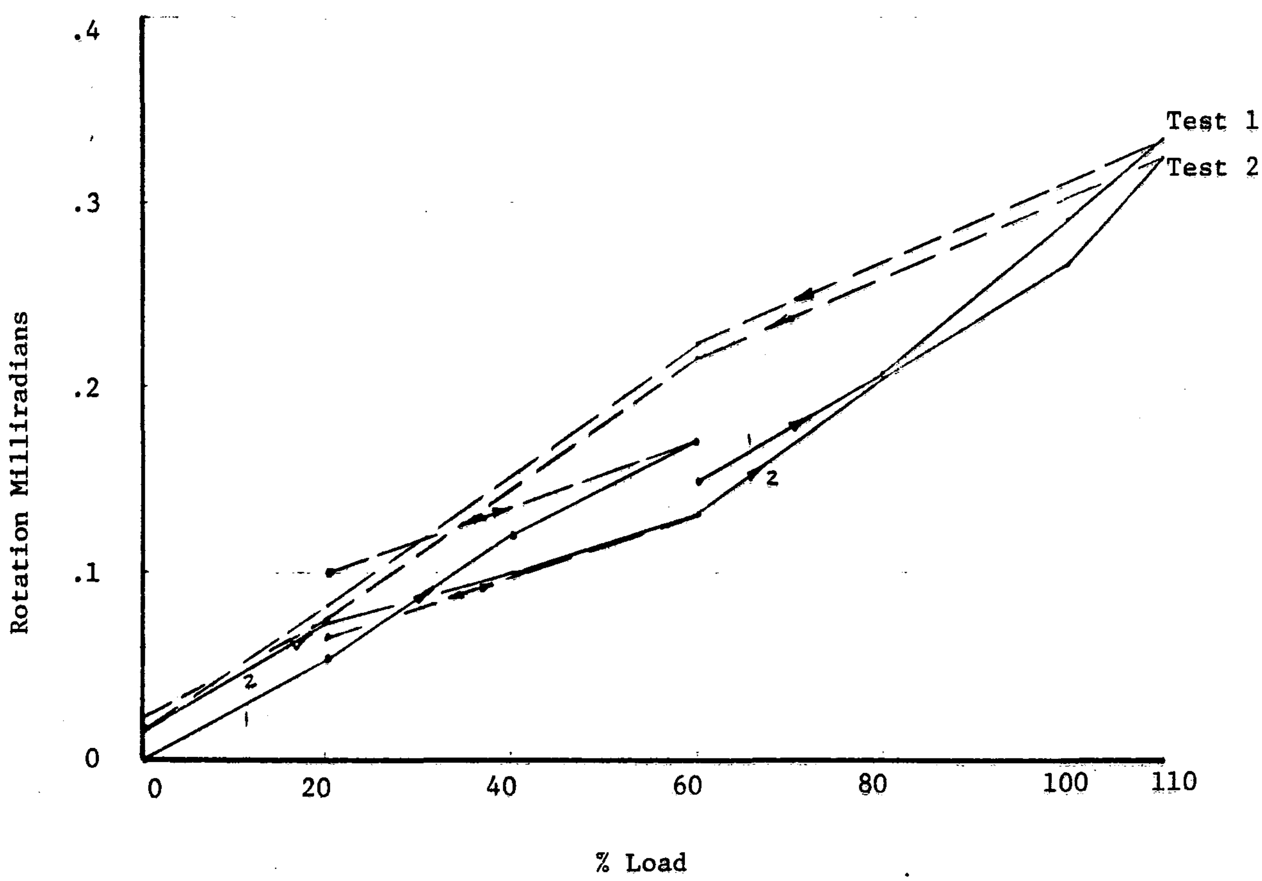


Figure 9.7- 39 Pedestal Base Twist

Table 9.7-26

Pedestal Deflection

% Load	3		4		5	
	Test 1	Test 2	Test 1	Test 2	Test 1	Test 2
0	0 inch	.002 inch	0 inch	.0 inch	0 inch	.008 inch
20	.001	.0015	.0032	.001	.0155	.014
40	.0025	.004	.0055	.004	.024	.029
60	.005	.007	.013	.011	.039	.0441
20	.002	.004	.004	.0035	.016	.021
60	.005	.007	.012	.010	.039	.041
80	.0075	.008	.016	.0125	.051	.0545
100	.0095	.010	.020	.020	.066	.0675
110	.0105	.0115	.023	.023	.068	.0751
60	.008	.008	.017	.0133	.053	.049
20	.004	.004	.007	.004	.025	.025
0	.002	.0022	.0	.0	.008	.0135

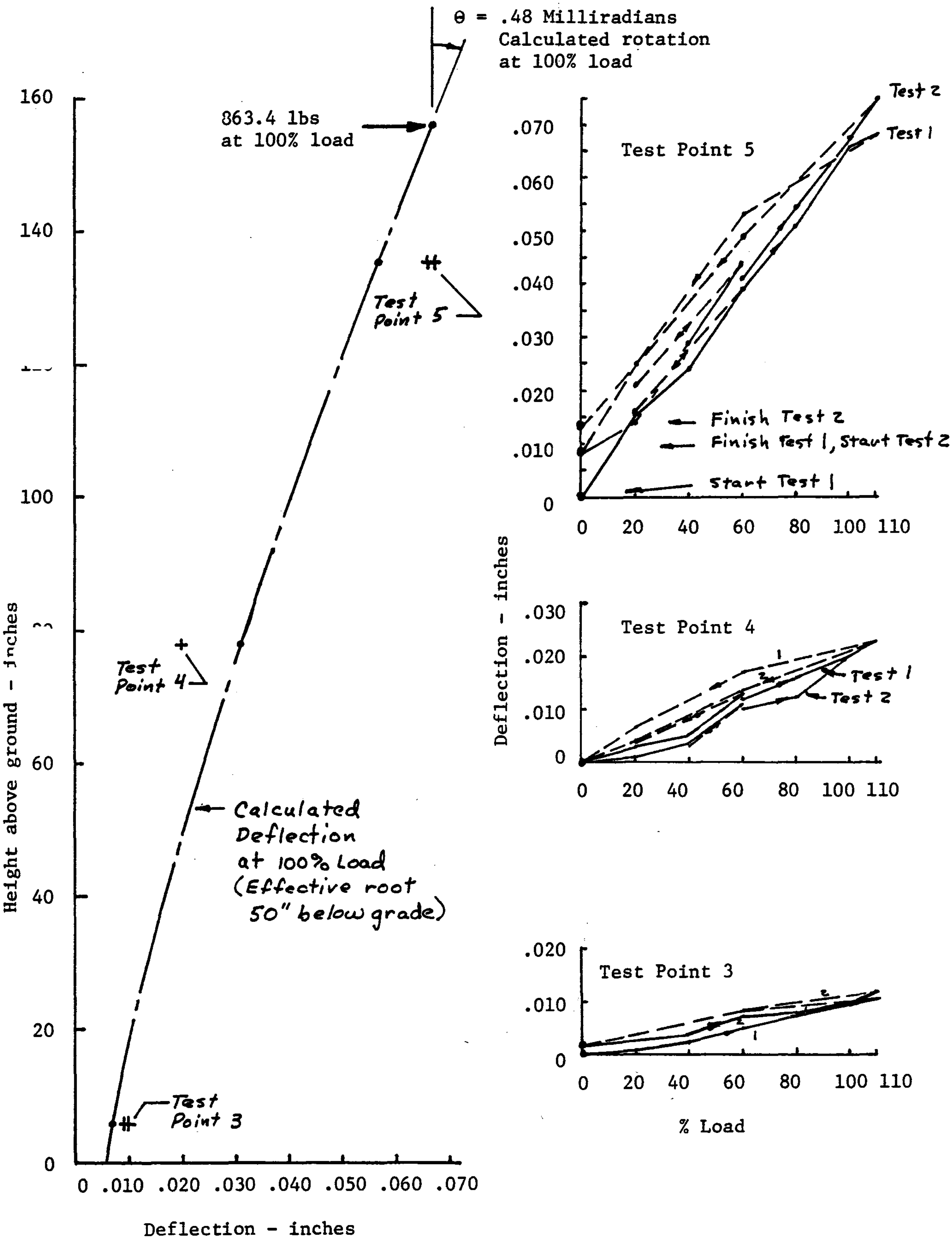


Figure 9.7-40 Pedestal Deflections

9.7.2.2.4 Foundation Deflections

Foundation deflections were measured during the three major wind load tests on heliostat #1, the Elevation Axis Test (90 mph wind), the Cross Elevation Axis Test (90 mph wind), and the Azimuth Axis Test (50 mph wind). The deflections were measured with dial indicators mounted to give lateral deflections. Although this method of measurement is less desirable than directly measuring the pedestal top rotation, it can be used to roughly compare with calculated values. It also gives an indication of pedestal set due to soil plasticity. The comparison of calculated deflections not including pedestal set, with test values including pedestal set, is presented in the above test sections in Figures 9.7-23, 9.7-31, and 9.7-40 respectively. These comparisons show fairly good correlation, assuming the effective pedestal root (fixed point) is 50" below grade.

Pedestal set values in terms of tip rotation have been estimated from the test results by taking the difference in the start and finish "zero" readings of the indicators located uppermost on the pedestal, assuming the pedestal pivots about a point 50" below grade, and computing the theoretical end rotation. The uppermost dial indicator was used, as it should be the most sensitive and accurate reading. Even though all the tests were run on the same heliostat, the direction of loading was different in each of the three tests. The pedestal set results summarized in Table 9.7-27 should be viewed as approximate values only, as the setups for taking the data was actually too crude to obtain accurate data.

Table 9.7-27

PEDESTAL SET DUE TO WIND LOADS

Test	110% Load	Base Moment	Load Direction (Pedestal Movement)	Pedestal Set
Elevation Axis	22,525 ft lbs pure moment	22,525 ft lbs	South	Test 1 .018 mrad Test 2 .180 mrad
Cross-Elevation Test	24,005 ft lbs pure moment	24,005 ft lbs	West	.071 mrad
Azimuth Axis Test	(a) 949.7 lbs lateral load	12,346 ft lbs	North	Test 1 .043 mrad Test 2 .030 mrad
	(b) 10,447 ft lbs twist	10,447 ft lbs (base torque)	Twist	Test 1 .017 mrad Test 2 .005 mrad

9.7.2.2.5 Motor Torque Adequacy

The motor torque must be sufficient to drive the heliostat in the elevation direction against the combined effects of gravity loads and a 22 m/s (50 mph) wind. In the azimuth direction, only the 22 m/s (50 mph) wind moments must be overcome. On start-up the motors must also provide a starting torque capable of overcoming the static frictional loads as well as the gravity and wind moments. Table 9.7-28 presents the gravity and 22 m/s (50 mph) wind moments which the elevation drive motor must overcome. Table 9.7-29 presents the 22 m/s (50 mph) wind moment which the azimuth drive motor must overcome. The maximum elevation moment is 1607 kg-m (11624 ft-lb), and the maximum azimuth moment is 1313 kg-m (9497 ft-lb).

Heliostat #1 was erected at the Northrup heliostat test facility on Sept 11, 1980. Heliostats #2 and #3 were erected on Sept 23, 1980 and Sept 30, 1980 respectively. All three of these heliostats were driven by Superior Electric Co. M112-FJ326 stepper motors and TBM 105-1230 motor control translators. The torque characteristic for this motor-translator combination is shown on Figure 9.7-41. Also shown on this figure is the torque characteristic for an M112-FJ327 stepper motor and TBM 105-1218 translator. As will be explained later, a change to this latter configuration was made during the test program to overcome a torque problem.

Torque adequacy tests were performed on heliostat #1 shortly after its erection. A deficiency in both the starting torque and running torque was noted, and was determined to be caused by higher than anticipated losses in the drive unit. An interim attempt to resolve the problem was to raise the voltage in the translator on heliostat #1. Heliostats #2 and #3 were not modified and were tested with stock M112-FJ326 motors and TBM105-1230 control translators. Table 9.7-30 summarizes the stall torque results for these initial tests. Peak output torques were 1272 kg-m (9200 ft-lb) for heliostat #1, 866 kg-m (6263 ft-lb) for heliostat #2, and 1115 kg-m (8060 ft-lb) for heliostat #3. Since the requirement for elevating to a horizontal position in

TABLE 9.7-28

Elevation Drive Moment, 22 m/s (50 mph) Wind

Heliostat Elevation Angle	Gravity Moment ft-lb	Wind Moment ft-lb	Combined Moments Horiz. Wind	Combined Moments $\pm 10^{o}$ Wind
0^{o} (vert)	4253	0	4253	6660
10	4188	2407	6595	8149
20	3996	3961	7957	9126
30	3683	5130	8813	9423
40	3258	5740	8998	9804
50	2734	6546	9280	10542
60	2127	7808	9935	11624
70	1455	9497	10952	9263
80	738	6320	7058	9575
90 (horiz)	0	0	0	6320

TABLE 9.7-29

Azimuth Drive Moment, 22 m/s (50 mph) Wind

Wind Angle of Attack	Gravity Moment ft-lb	Wind Moment ft-lb
0	0	0
10	0	2407
20	0	3961
30	0	5130
40	0	5740
50	0	6546
60	0	7808
70	0	9497
80	0	6320
90 (normal)	0	0

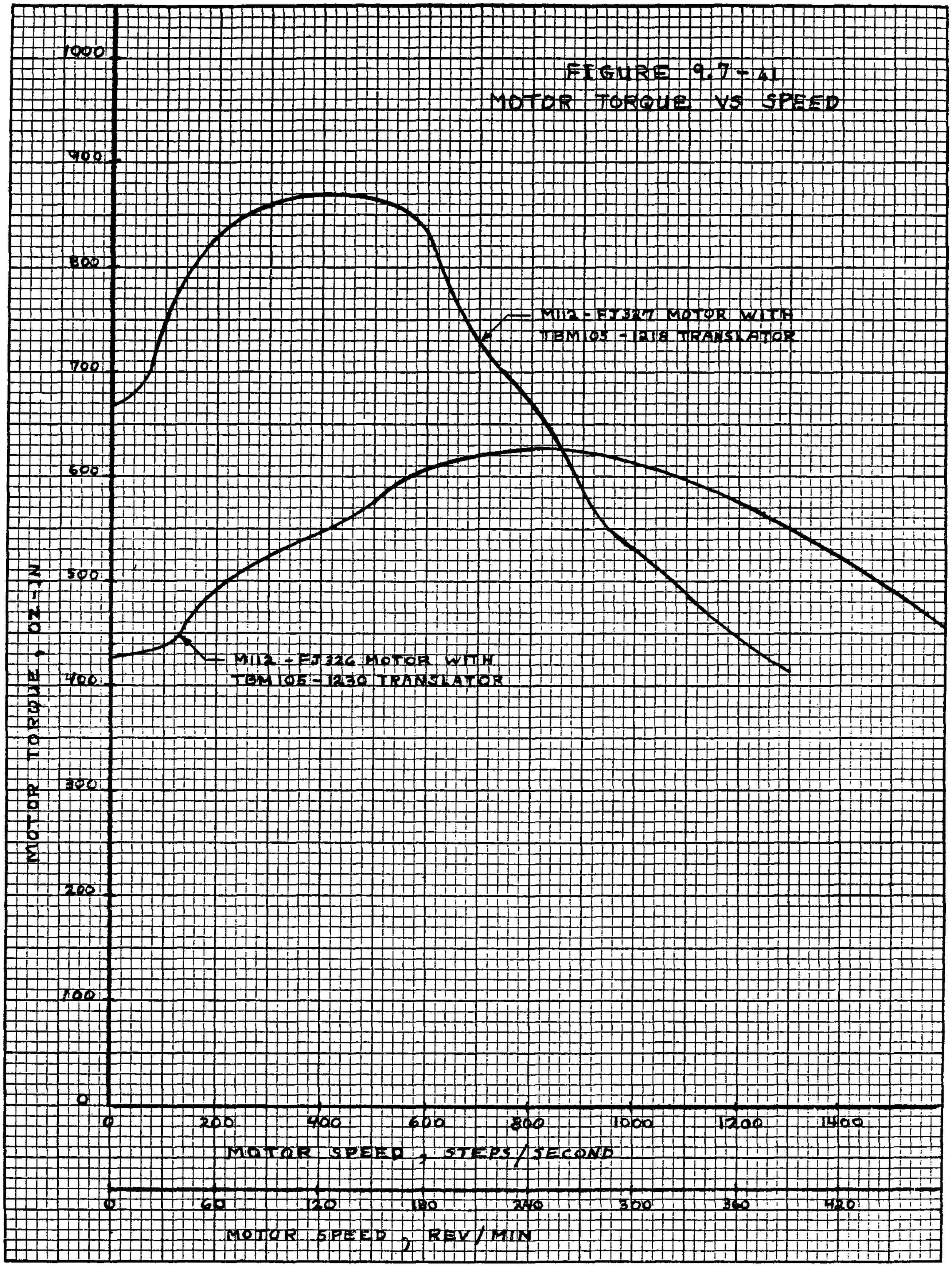


FIGURE 9.7-41
MOTOR TORQUE VS SPEED
M112-FJ327 MOTOR WITH
TBM105-1218 TRANSLATOR
M112-FJ326 MOTOR WITH
TBM105-1230 TRANSLATOR
MOTOR TORQUE, OZ-IN
1000
900
800
700
600
500
400
300
200
100
0
0
200
400
600
800
1000
1200
1400
MOTOR SPEED, STEPS/SECOND
0
60
120
180
240
300
360
420
MOTOR SPEED, REV/MIN

TABLE 9.7-30

Motor Running Torque Stall Test Results

Model M112-FJ326 Motor, Model TBM105-1230 Translator

Stepping Rate = 1000 steps/second

	Heliostat #1	Heliostat #2	Heliostat #3
Run #1	7315 ft-lb	6029 ft-lb	6413 ft-lb
Run #2	7477	6050	7241
Run #3	9200	6263	7501
Run #4	-	-	8060

Note: The heliostat #1 translator was set at a higher voltage than heliostats #2 and #3.

a 22 m/s (50 mph) wind is 1607 kg-m (11624 ft-lb), all three heliostats exhibited inadequate running torque.

The M112-FJ327 motor and TBM 105-1218 translator combination provides a significantly higher starting torque and running torque than the M112-FJ 326 motor and TBM 105-1230 combination, but must be operated at approximately one-half of the speed to realize this gain. For normal tracking operation this slower speed presents no problem. However, the slew rate for stowing is only 2.935 deg/min at a stepping rate of 500 steps/sec, so a 90 degree stow maneuver would take nearly 31 minutes. This stow time exceeds the specification requirement, but the new motor-translator combination was still selected for the deliverable heliostats since adequate torque was believed to be a more important parameter.

The new motor and translator combination was installed on heliostat #2 and a series of running torque-stall tests were conducted at stepping rates of 1000, 750, and 500 steps/sec. Table 9.7-31 presents the stall torque values measured on this test sequence. The peak value achieved was 1556 kg-m (11249 ft-lb) which is slightly lower than the 1607 kg-m (11624 ft-lb) required torque. The test was repeated on heliostat #3, and a peak torque of over 1672 kg-m (12092 ft-lb) was achieved without stalling. These two units were subsequently delivered to Sandia-Albuquerque.

All of the torque test results described thus far were running torque tests in which the motors were run continuously from a low load orientation (heliostat vertical) to a high load orientation (heliostat horizontal). The loading was obtained by water barrels hung from the ends of the trusses. Another type of test which was performed was a start torque test in which the heliostat was driven from vertical to horizontal in small angular increments, so the motor was repeatedly required to start with an ever-increasing torque requirement. The test results showed that the motor starting torque is somewhat higher than the peak running torque. The test results for the starting torque tests were performed on heliostat #2, and are presented on Table 9.7- 32.

TABLE 9.7- 31

Motor Running Torque Stall Test Results

Model M112-FJ327 Motor, Model TBM 105-1218 Translator

Heliostat	Test Number	Stepping Rate	Stall Torque
#2	1	1000 steps/sec	6871
2	2	1000	7397
2	3	1000	7368
2	4	1000	6765
2	5	750	8261
2	6	750	7990
2	7	750	8027
2	8	500	11072
2	9	500	11249
3	1	500	>12092

TABLE 9.7- 32

Motor Start Torque Test-Heliostat #2

Model M112-FJ327 Motor & TBM105-1218 Translator

Stepping Rate = 500 steps/sec

Heliostat Elevation Angle	Elevation Moment	Motor Start Result
0°(vertical)	2794 ft-lb	No stall
12.52	5283	" "
17.53	6214	" "
20.03	6662	" "
22.54	7098	" "
25.04	7520	" "
27.55	7928	" "
30.05	8320	" "
32.56	8698	" "
35.06	9057	" "
37.57	9401	" "
40.07	9725	" "
42.57	10031	" "
45.08	10318	" "
47.58	10585	" "
50.09	10833	" "
52.59	11059	" "
55.10	11265	start o.k.- some stall running
57.60	11448	start o.k.- stall during running

In addition to the basic running torque and start torque tests, an investigative test series was performed to determine the cause of the torque problem. Dynamometer tests were performed to measure the torque output of the motor, translator, microprocessor, and cabling system. These tests showed a motor output torque slightly higher than the values anticipated based on data provided by Superior Electric Co. The conclusion reached was that the problem must lie in the drive unit.

A D-C motor having a constant torque/amp characteristic was installed on each heliostat in place of the elevation stepper motor. The heliostats were elevated from a vertical position where a gravity moment of 588 kg-m (4253 ft-lb) exists, to a horizontal position where the gravity moment is zero. The D-C motor current was monitored during this elevation-up maneuver against the gravity load, and also during the elevation-down maneuver where the gravity load was assisting the motor. Figures 9.7-42 through 9.7-44 show motor current and drive input torque vs heliostat elevation angle for heliostats #1, 2, and 3 respectively. These motor current traces represent a "signature" of the frictional loss characteristics of the drive unit. The drive input stage contains a planetary gear set which provides a 460:1 speed reduction. The output stage consists of a worm and gear which provides a 40:1 speed reduction. The overall drive ratio is, therefore, 18400:1. The current traces show a high frequency input torque oscillation superimposed on a low frequency input torque oscillation. The interpretation of these cylic patterns is relatively straightforward. The low frequency characteristic is the variation in friction in the output stage caused by the engagement of the worm thread and gear teeth at different points on the tooth form. The ten discrete low frequency cycles correspond to the ten teeth of the output gear which would be encountered during the 90^{o} of motion in elevating the heliostat from a vertical to a horizontal position. Superimposed on this low frequency worm and gear tooth characteristic is a high frequency torque variation which correlates with the frequency of the planet gear rotation. In the case of the heliostat #2 trace, this

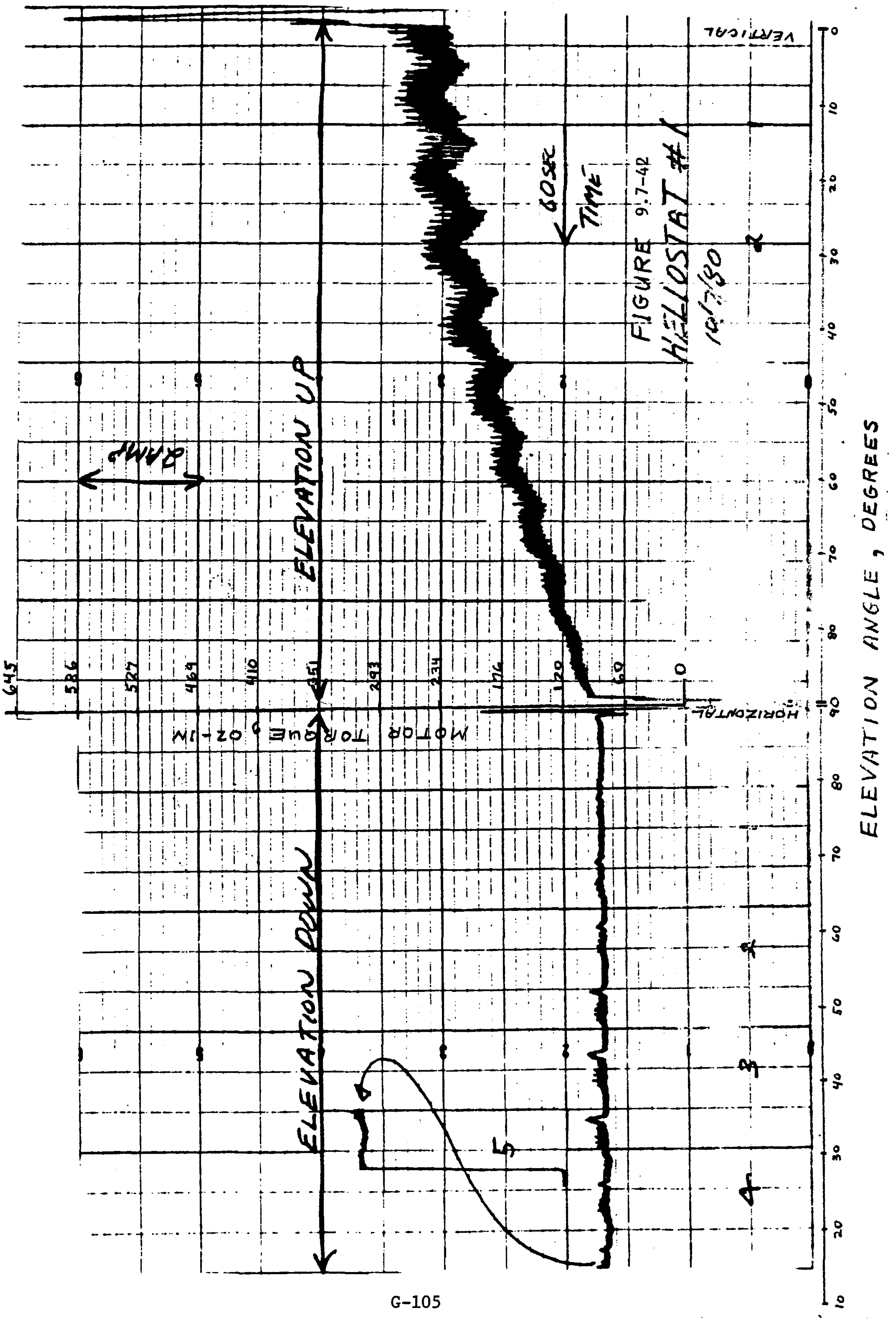
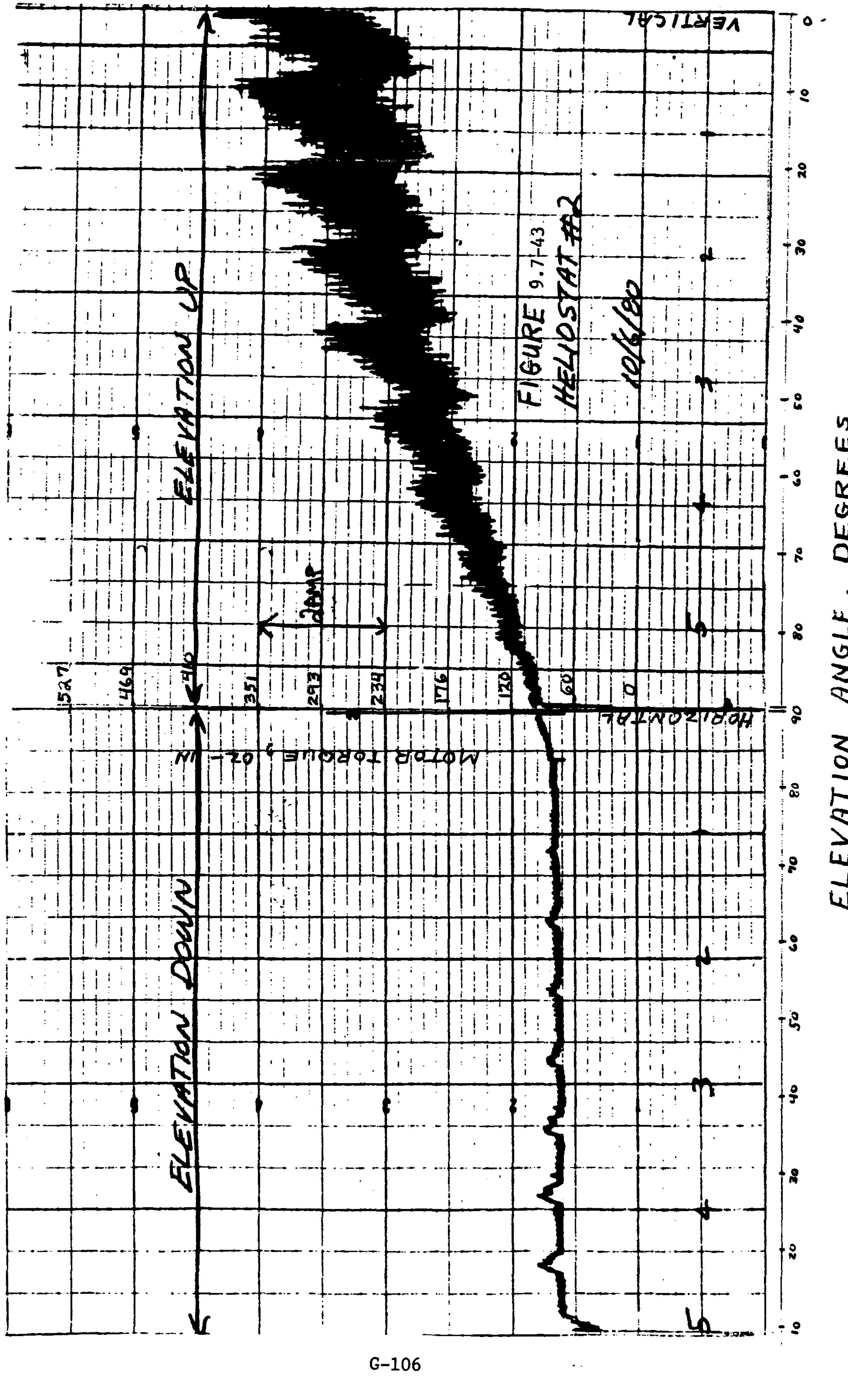


FIGURE 9.7-42
HELIOSTAT #1
10/7/80


VERTICAL
HORIZONTAL
FIGURE 9.7-43
HELIOSTAT #2
10/6/80
ELEVATION UP
ELEVATION DOWN
2AMP
527
469
410
351
293
234
176
120
60
0
MOTOR TORQUE, OZ-IN
ELEVATION ANGLE, DEGREES

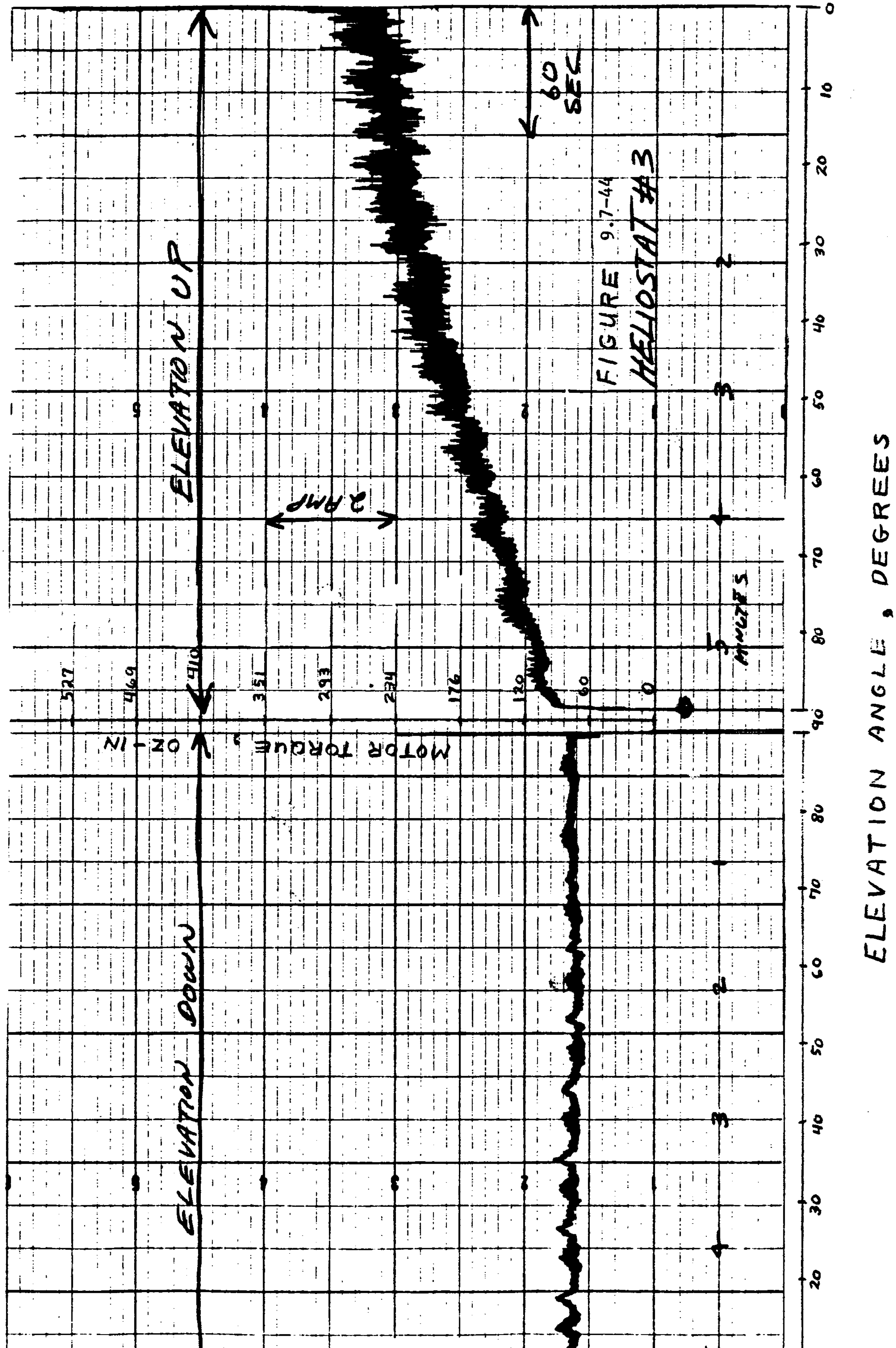


FIGURE 9.7-44
HELIOSTAT #3
ELEVATION UP
ELEVATION DOWN
60 SEC
2 AMP
MOTOR TORQUE, OZ-IN
527
469
410
351
293
234
176
120
60
0
MINUTES
ELEVATION ANGLE, DEGREES

planet gear rotational torque variation has an amplitude of 130-150 oz-in which represents approximately 50% of the total torque requirement. Interestingly, if a lower bound is drawn on each of these cyclic patterns, it will be noted that all 3 of the heliostats exhibit a nearly identical torque vs elevation angle characteristic at the lower bound. Furthermore, the drive efficiency at the lower bound is approximately 20.0% versus a theoretical efficiency of 20.4% (55% theoretical planetary efficiency x 37% theoretical worm-gear efficiency). The small difference between the actual and theoretical is probably due to the seal drag at the planetary input shaft. Hence, the lower bound of the torque trace represents a close match with the theoretical torque prediction, and the high frequency torque oscillations above this boundary is an abnormal phenomenon caused by the planetary stage. This problem is currently being researched by Winsmith. One theory is that under a drive load, the worm and gear tooth contact zone experiences a separation force which causes worm shaft bending. Since the rotating ring gear is attached to the end of the worm shaft, any worm shaft bending is reflected as a shift in the concentricity of the rotating ring gear relative to the fixed ring gear (some out-of-plane angular misalignment of the two ring gears also occurs). This concentricity shift is further worsened by any worm shaft bearing deflection. With a concentricity off-set, each of the planet gears could experience a binding action which would peak at the point of maximum concentricity off-set and then drop-off as this point is passed. This theory is substantiated by the sinusoidal nature of the input torque variations, by the cylic frequency rate which matches the planetary gear half-cyle frequency, and by the fact that the amplitude varies with the output load and tooth forces. The apparent conflicting piece of data is that when the heliostat is being lowered from a horizontal to a vertical position, the same gravity moments are encountered, but the high torque oscillations are absent. However, in reality this is not a conflicting piece of data because on elevating the heliostat the tooth reactive forces are necessarily higher since the load plus high frictional loads must be overcome, whereas the load assists the motor when the heliostat is lowered.

In summary, a higher-than-anticipated drive friction was encountered which required a change to a higher torque motor. This new motor provides sufficient torque to start and operate with the combined loads of the gravity moment and worst case 50 mph wind moments. The sacrifice which was made is a slow slew speed; the required maximum torques can only be achieved at a slew rate near 3 deg/min.

9.7.2.3 Operations and Accuracy Tests

Operations and tracking accuracy tests were performed informally on the three heliostats installed in Hutchins during the Sept. 12 to Oct. 30 period and on the two heliostats installed at the Albuquerque CRTF during the Nov. 11-20 period. Formal testing for the "Second Generation Heliostat" program evaluation began Dec 4 with the "Control System Operational Modes" test.

9.7.2.3.1 "Test 1 - Control System Operational Modes"

The objective of the control system operational mode test is to "Determine whether heliostats can perform such required functions as tracking, stowing, and assuming a commanded orientation." (ref. "Second Generation Heliostat Test Plan, p. 1)

Three sets of tests were performed over the two day period of Dec. 4 and 5th to demonstrate the control capability of the heliostat hardware and software. These were tests 1.3.1 Standard Modes, 1.3.2 Special Modes, and 1.3.4 Control Drive Repeatability.

Test 1.3.1 Standard (Control) Modes

In separate operational tests each heliostat was operated through the mode sequences of a normal operating day.

a. Stow to Standby Line Bottom
b. Standby Line Bottom to Standby Line Top
c. Standby Line Top to Target Tracking
d. Target Tracking to Standby Line Top
e. Standby Line Top to Stow

Both heliostats demonstrated full compliance with the test requirements.

Test 1.3.2 Special Control Modes

In separate operational tests each heliostat was operated at slew speed to the extremes of both elevation and azimuth travel to evaluate individual slew rates, combined slew rates, limit switch functional status, and establish limit switch base positions. Both heliostats properly traversed in commanded slew directions in all tests. No 1 heliostat primary limit switches limited up, down, east, and west travel properly. No. 2 heliostat primary limit switches limited up, down, and east travel properly, but the west travel was stopped by the back up limit switch before the primary was reached. A bracket bent in shipping was found to be the cause. After restoring the bracket position normal west limit control was demonstrated.

Test 1.3.4 Control/Drive Repeatability

The control/drive repeatability test consists of up to 10 operational cycles between stow positions and an initial commanded position established by a laser image on a target located 250 ft behind the test heliostat. (3 inches on the laser target = 1 mrad).

During the initial sequence, between "vertical stow" and the "control command position", repeatability was demonstrated within .25 inches (0.08 mrad) in "no wind"conditions and 1.75 inches (0.58 mrad) when winds sufficient to toggle azimuth backlash were present. Throughout this sequence the pedestal was shaded.

During the second sequence, between "horizontal stow" and the "control command position", repeatability was demonstrated within a 2 inch x 2 inch (.67 mrad x .67 mrad) envelope. Pedestal bending from periods of solar exposure between "horizontal stow" and the "test" position is believed responsible for the slightly increased inaccuracy. It should be noted that this pedestal solar exposure is not a normally encountered condition during tracking for the basic configuration Northrup II heliostat.

9.7.2.3.2 Beam Centroid Pointing Accuracy

The objective of the "Beam Centroid Pointing Accuracy" test is to "measure beam centroid pointing error with the Beam Characterization System (BCS) while tracking the sun". The compliance with the specification beam pointing requirement is 1.5 mrad for each axis (equivalent to axis pointing of 0.75 mrad) is defined by the performance in this BCS monitored test.

Baseline beam centroid pointing accuracy testing was performed with both heliostats Dec 12 (Day 347) and Dec 18 (Day 353). Summarized numerical results are shown in Tables 9.7-33 (Dec 12) and 9.7-34 (Dec 18). Graphic plots for Dec 12 are shown in Figures 9.7-45 and 9.7-46 and for Dec 18 are shown in Figures 9.7-47 and 9.7-48.

The baseline tracking accuracy data indicated #2 heliostat to be within specification limits, 0.2597 mrad rms elevation error and 0.5532 mrad rms azimuth error. The #1 heliostat was beyond limit for the elevation error, 1.0270 mrad rms elevation error and 0.5442 mrad rms azimuth error. Correlation of the elevation error patterns for morning and afternoon against elevation angle show repeating patterns for #2 and a hysteresis effect between am elevation and pm elevation for #1. This generally correlates with the tilt data difference between the two heliostats (#1 tilt = 1.81 mad; #2 tilt = 0.27 mrad).

The Dec. 18, 1980 data confirmed the characteristic tracking performance pattern of higher accuracy for #2 heliostat than #1. The final point for each heliostat was with low sun angles and illustrates the increasing atmospheric refraction effect on the sun's apparent position at low sun angles. A correction model for the atmospheric refraction has been incorporated in the software subsequent to these tests.

The negative offset of azimuth data sets on Dec. 18 is believed to be the result of a slow clock. Current practice is to set the computer clock with WWV time each morning.

Table 9.7-33

Baseline Beam Centroid Pointing Accuracy

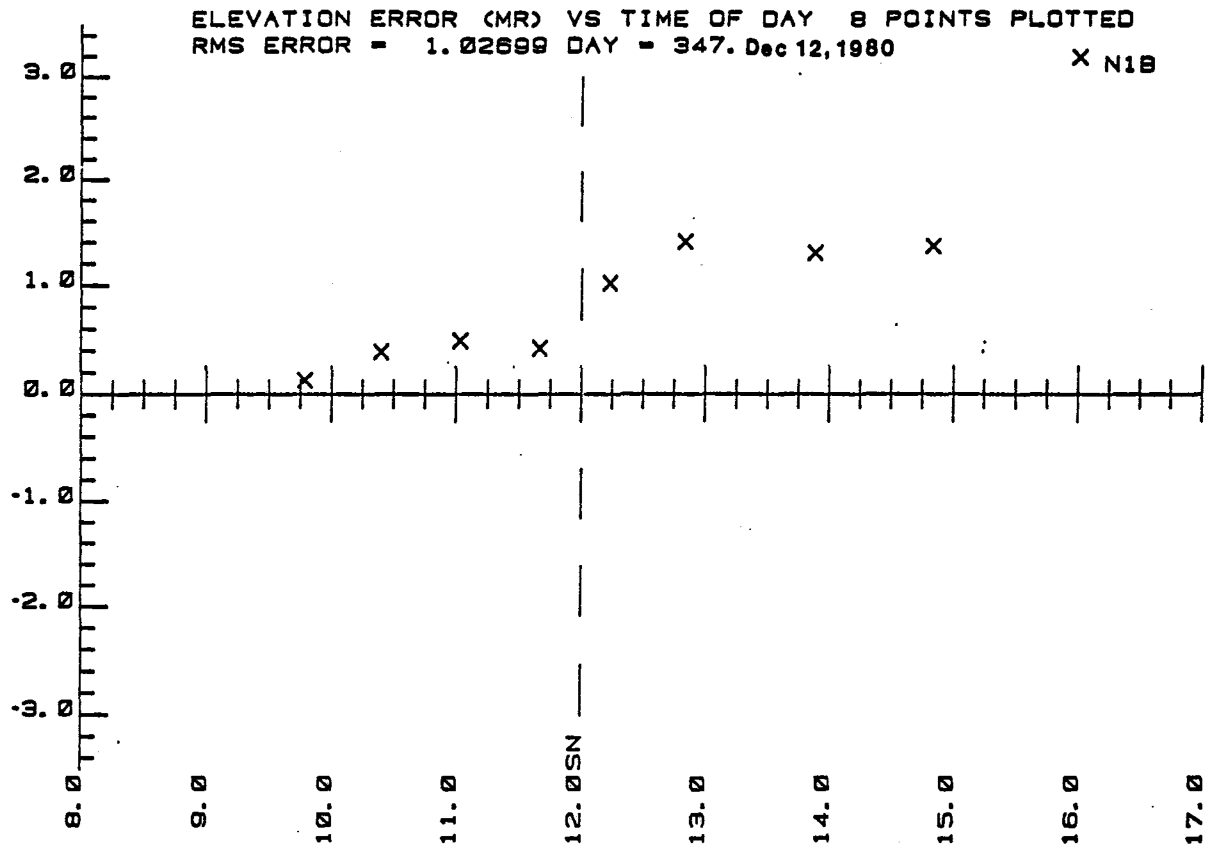
For Second Generation Northrup Heliostats

a) N-1 CRTF Heliostat (171.38, 1016.37, 102.88 target coordinates)

Dec 12 (Day 347)

Time	Azimuth Axis		Elevation Axis	
	Angle degrees from West	Mean Axis Pointing Error for 30 Data Points, mrad	Angle, degrees from Vertical	Mean Axis Pointing Error for 30 Data Points, mrad
9:45-9:48	100.96	-1.40	15.88	0.13
10:22-10:25	96.69	-0.22	17.39	0.39
10:59-11:03	92.41	-0.31	18.41	0.49
11:38-11:41	87.31	-0.59	18.86	0.42
12:12-12:15	83.10	0.28	18.78	1.02
12:48-12:50	78.72	0.47	18.23	1.41
13:51-13:54	71.27	-0.26	16.10	1.30
14:48-	65.11	1.05	13.01	1.37
RMS For Full Day		0.5442		1.0270

Figure 9.7-45 No 1 Northrup Heliostat - Dec 12, 1980



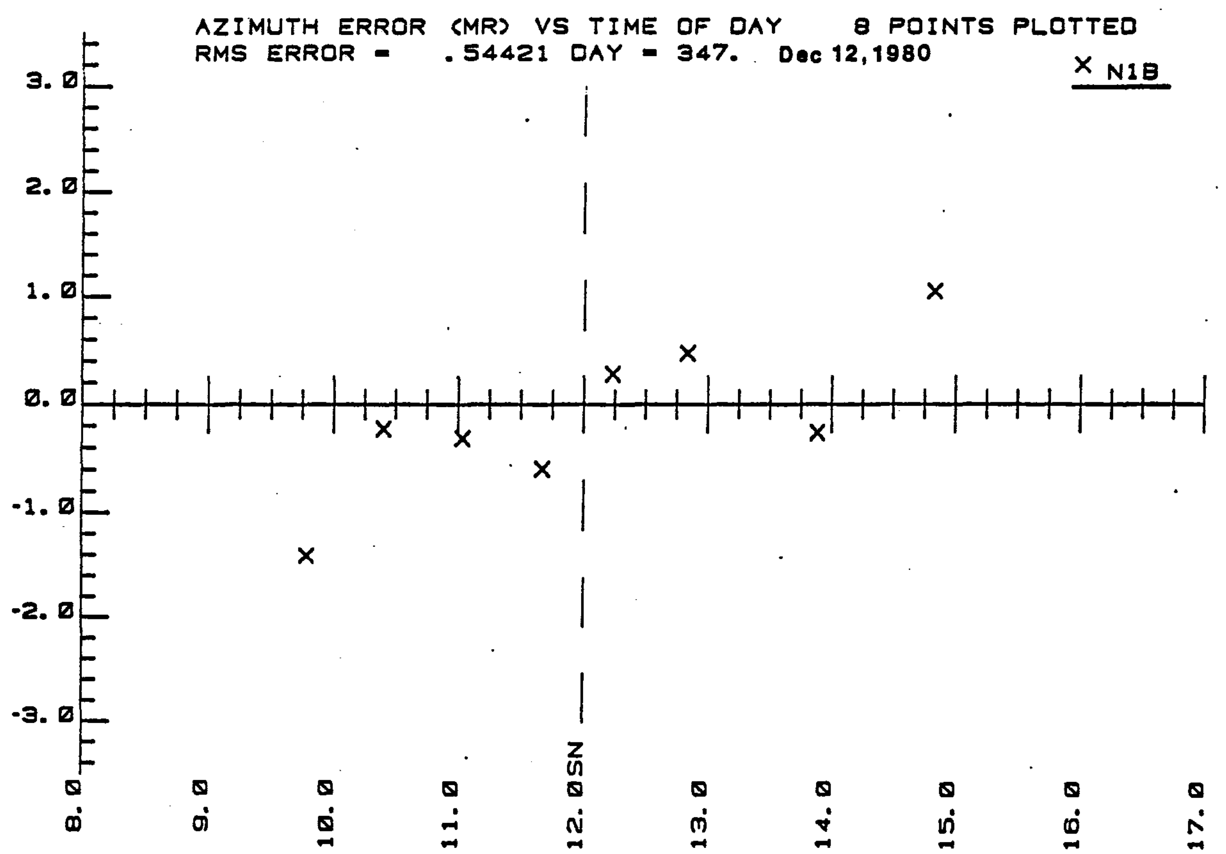


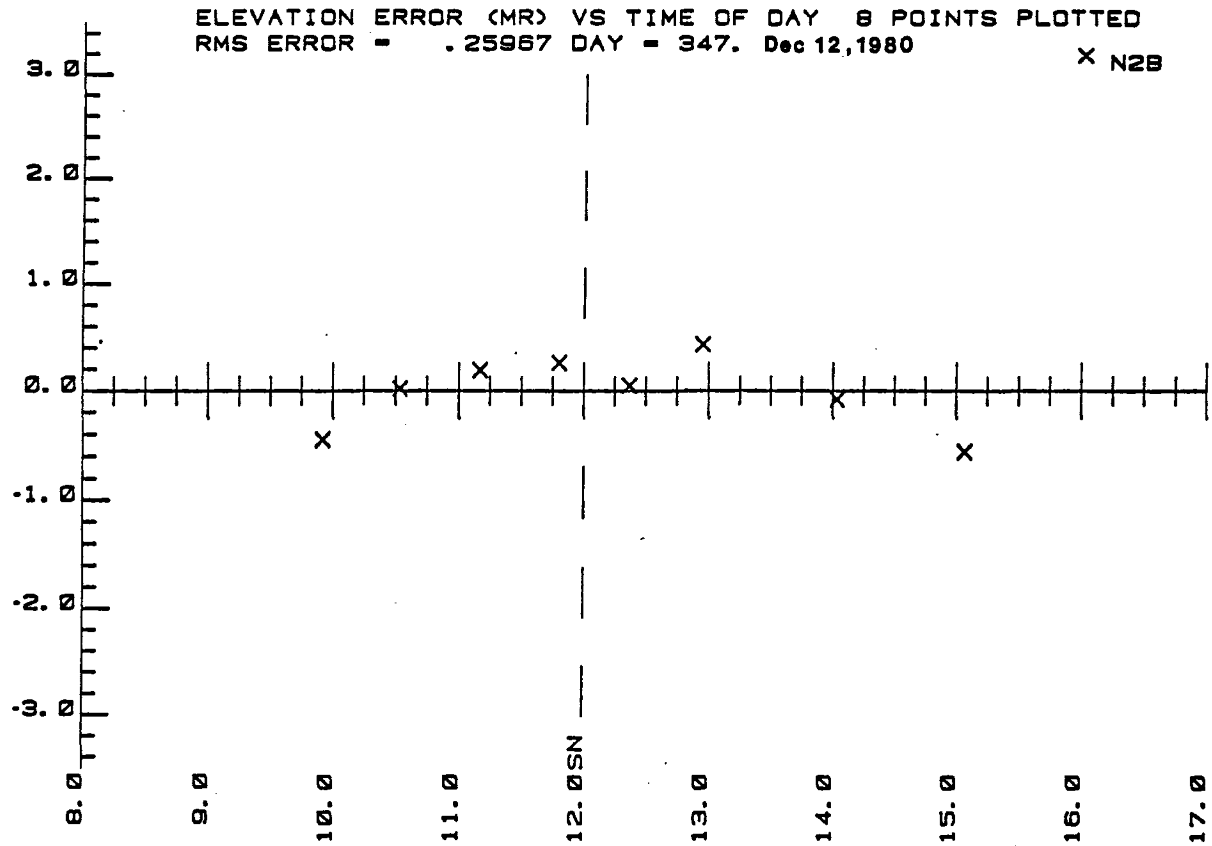
Table 9.7-33

b) N-2 CRTF Heliostat (-65.26, 769.55, 107.36 target coordinates)

Dec 12 (Day 347)

Time	Azimuth Axis		Elevation Axis	
	Angle, degrees from West	Mean Axis Point Error For 30 Data Points, mrad	Angle, degrees from Vertical	Mean Axis Pointing Error for 30 Data Points, mrad
9:53- 9:56	107.72	-1.06	16.78	-0.44
10:30- 10:34	103.36	-0.71	18.33	+0.02
11:08- 11:11	98.86	-0.72	19.36	+0.19
11:46- 11:49	94.13	-0.52	19.88	+0.26
12:20- 12:23	89.86	-0.38	19.88	+0.05
12:55- 12:57	85.57	-0.15	19.42	+0.43
14:00- 14:03	77.79	-0.36	17.33	-0.08
15:02- 15:05	71.17	-0.22	13.96	-0.56
RMS For Full Day		.5532		.2597

Figure 9.7-46 No. 2 Northrup Heliostat December 12, 1980



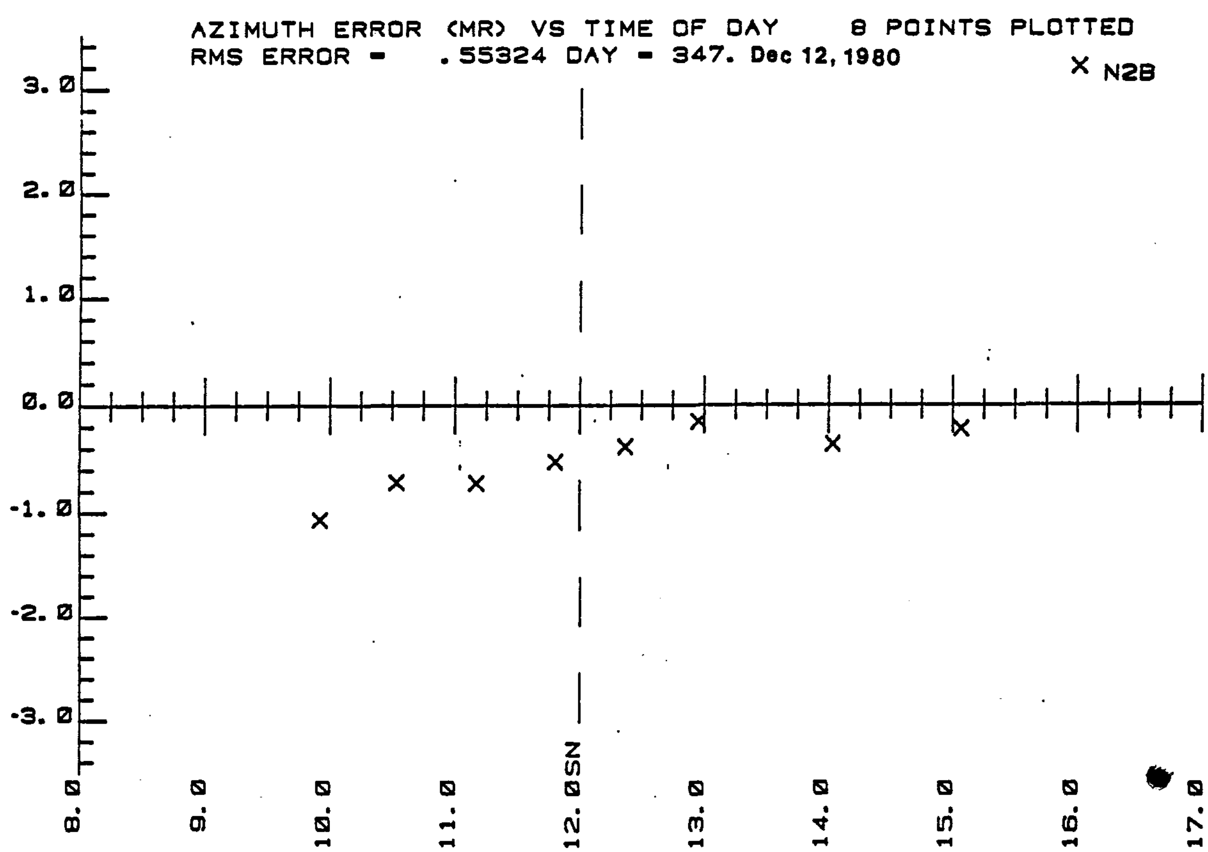


Table 9.7-34

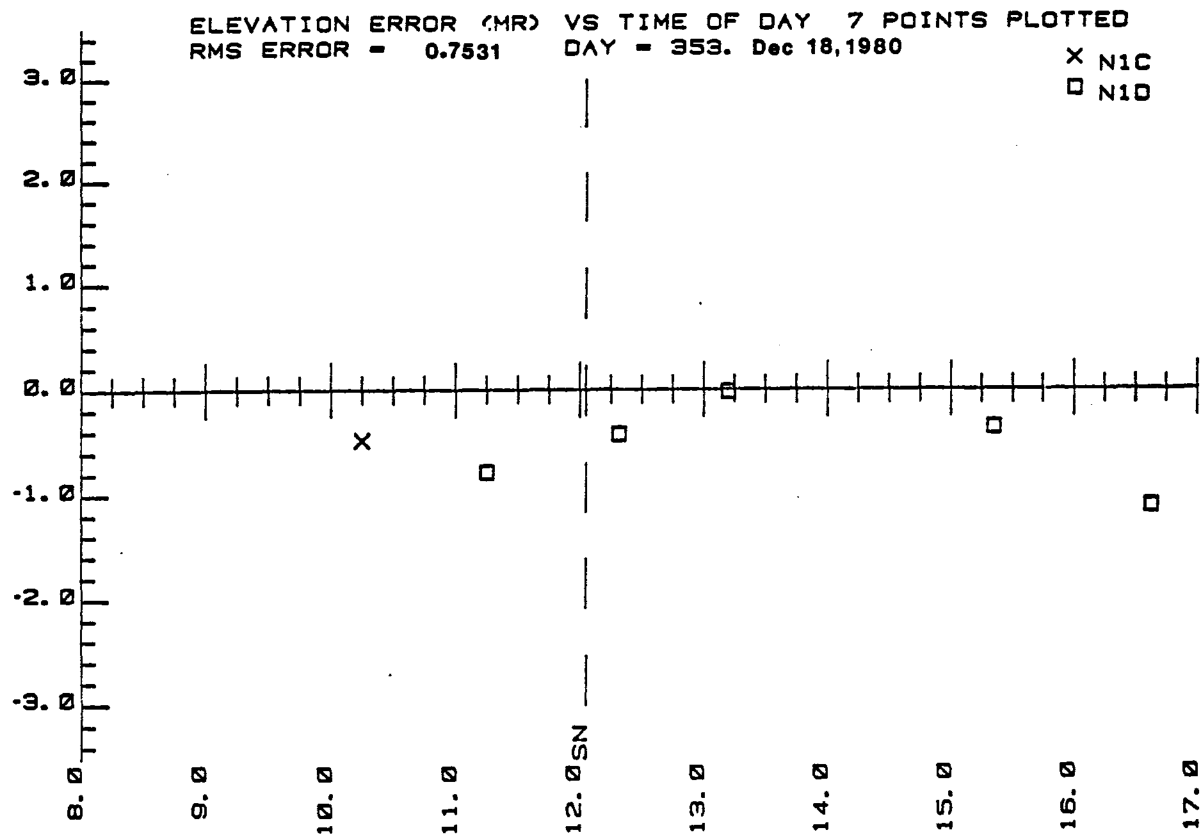
Baseline Beam Centroid Pointing Accuracy For Second Generation Northrup Heliostats

(a) N-1 CRTF Heliostat (171.38, 1016.37, 102.88 target coordinates)

Dec 18, 1980 (Day 353)

Time	Azimuth axis		Elevation axis	
	Angle, degrees from West	Mean Axis Pointing Error for 30 Data Points, mrad	Angle, degrees from Vertical	Mean Axis Pointing Error for 30 Data Points, mrad
10:13-10:16	98.038	-0.76	16.821	-0.47
11:13-11:17	90.773	-0.53	18.446	-0.78
12:17-12:23	82.863	-0.63	18.623	-0.42
13:10-13:13	76.368	-1.37	17.579	- .02
15:19-15:23	62.447	- .53	11.021	- .36
16:36-16:39	55.685	.69	4.511	-1.11
RMS First 5 sets		.9292		.5663
RMS All 6 sets		.9005		.7531

Figure 9.7-47 No. 1 Northrup Heliostat Dec 18, 1980



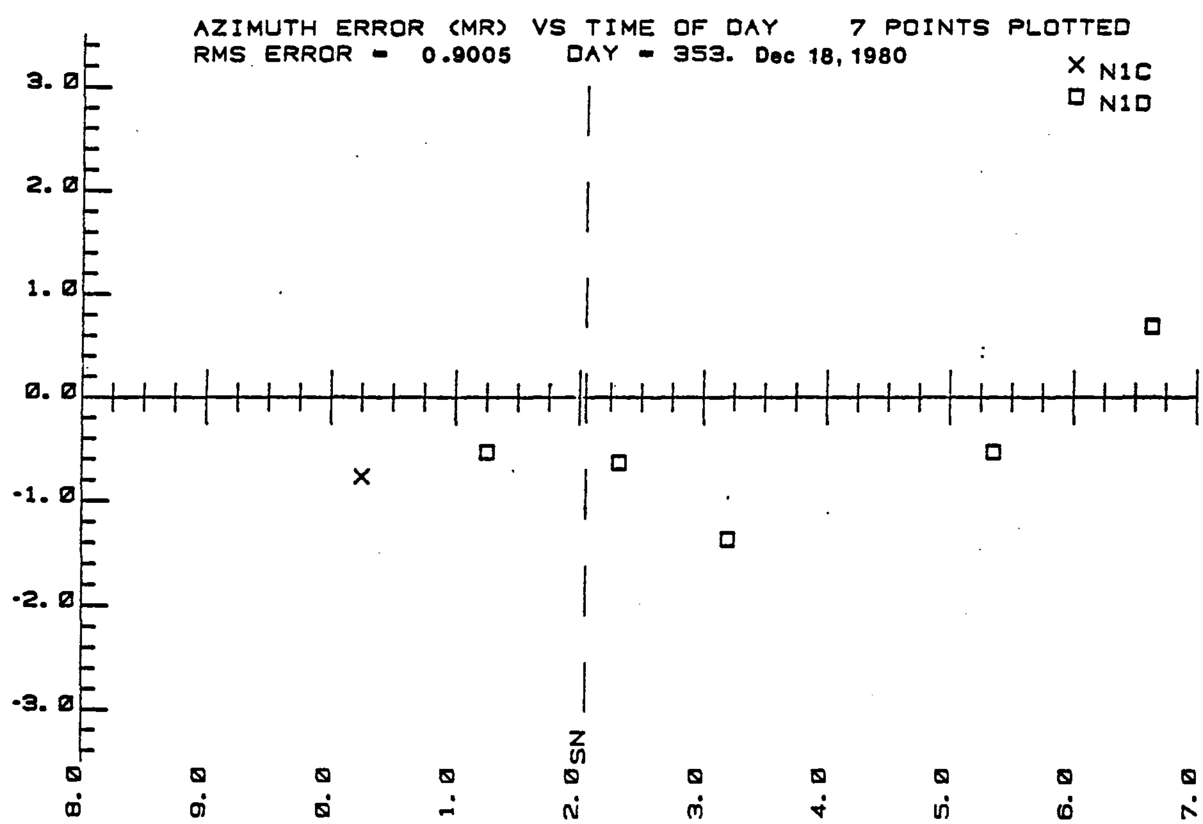


Table 9.7-34

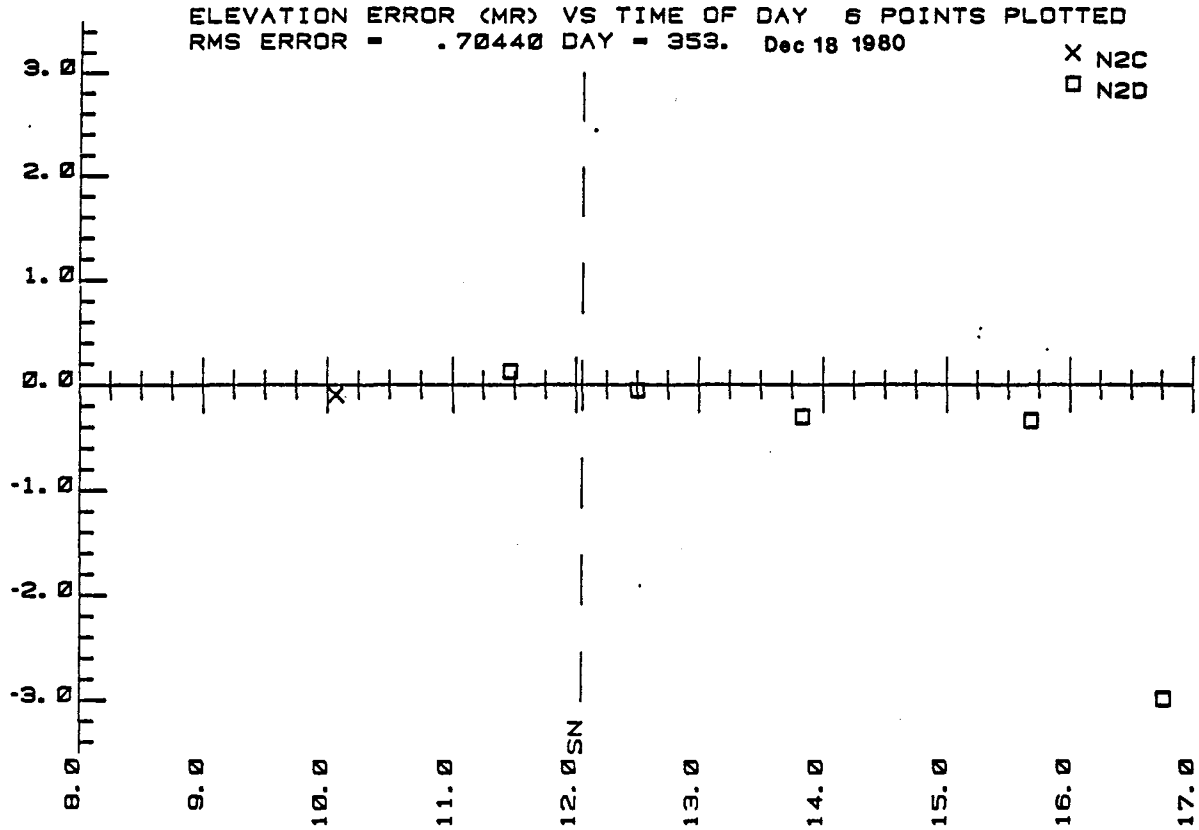
Baseline Beam Centroid Pointing Accuracy For Second Generation Northrup Heliostats

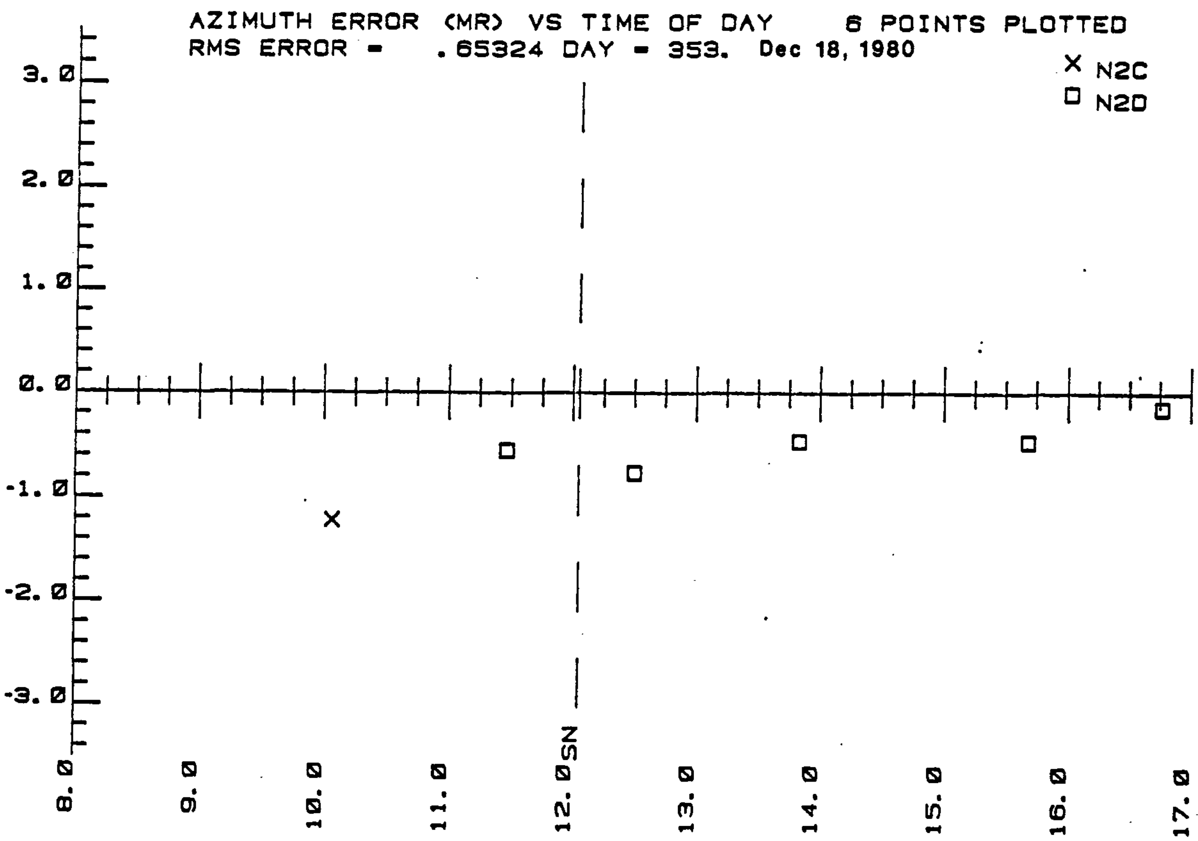
(b) N-2 CRTF Heliostat (-65.26, 769.55, 107.36 target coordinates)

Dec 18, 1980 (Day 353)

Time	Azimuth axis		Elevation axis	
	Angle, degrees from West	Mean Axis Pointing Error for 30 Data Points, mrad	Angle, degrees from Vertical	Mean Axis Pointing Error for 30 Data Points, mrad
10:02-10:05	106.93	-1.21	16.94	-0.09
11:25-11:29	96.99	-0.55	19.49	0.13
12:28-12:31	89.23	-0.76	19.70	-0.05
13:48-13:51	79.57	- .46	17.81	- .30
15:39-15:42	67.69	- .46	11.20	- .34
16:44-16:47	62.22	- .14	5.37	-2.99
RMS First 5 sets		.8250		0.2666
RMS all 6 sets		.6532		.7044

Figure 9.7-48 No 2 Northrup Heliostat Dec 18, 1980





9.7.2.3.3 Beam Quality

Initial "Beam Quality" tests were run on both heliostats Dec. 10,1980. The focal beam pattern for both heliostats was more diffuse than the "helios model" beam generated for the individual heliostats and the test time. Near-noon charts for the 90% power contour with the "helios model" points overlaid are shown in Figures 9.7-49 (No. 1 Northrup heliostat) and 9.7-50 (No. 2 Northrup heliostat).

Inspection of the mirror modules revealed a "built-in convex cant" of up to 1.4 mrad between the two facets of a single module. Inspection of the assembly tables indicated a position shift from the original alignment which caused the out of flat cant.

A design change decision to build in a concave cant matched to the slant range was made and implemented. Replacement modules were built and installed on both heliostats at CRTF. Beam quality data with a canted facet heliostat was taken Feb 5, 1981 on No. 2 heliostat. The 90% contour and 90% "helios" model plots are shown in Figure 9.7-51. Numerical data from the beam quality tests are summarized in Table 9.7-35. The gain in image size achieved by the canted facet mirror modules is quantified by the reduction in size of the 90 percent contour footprint from 19.88-19.97 m^2 in the Dec 10 test to 14.3-15.5 m^2 in the Feb. 5th test. The contour still exceeds the specified helios model by 1.5 m^2. Refinement of the "Y Direction" canting procedure is expected to improve this value.

PWR CONTOUR

TEST TIME
DEC 10, 1980 11: 3: 49. 19
FILE NAME - CF345C: : 50
MAXIMUM FLUX =
.2565665E+00 W/SQ CM
TOTAL POWER =
.4265793E+05 WATTS
SOLAR INSOLATION =
.9690000E-01 W/SQ CM
CENTROID REL. TO A.P.
X = .23547 METERS
Y = .26251 METERS

POWER CONTOUR OF 90 %
ISO CONTOUR OF 10.0 %

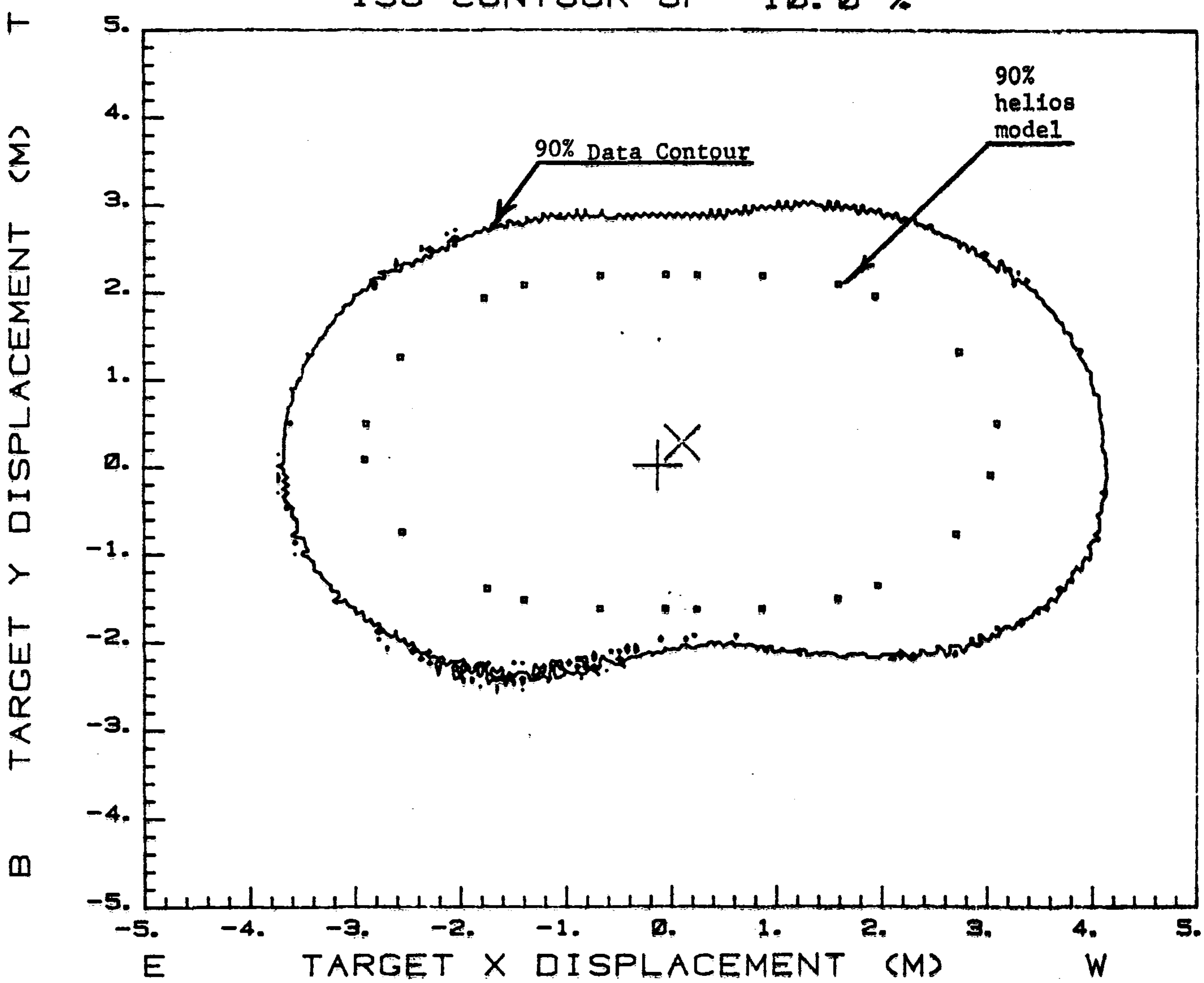


Fig. 9.7-49 "Beam Quality" Comparison Northrup #1

PWR CONTOUR

TEST TIME
DEC 10, 1980 11:22:56.17
FILE NAME - CF345D::51
MAXIMUM FLUX =
.3338382E+00 W/SQ CM
TOTAL POWER =
.4106595E+05 WATTS
SOLAR INSOLATION =
.9630001E-01 W/SQ CM
CENTROID REL. TO A.P.
X = 0.00000 METERS
Y = -.48126 METERS

POWER CONTOUR OF 90 %
ISO CONTOUR OF 13.0 %

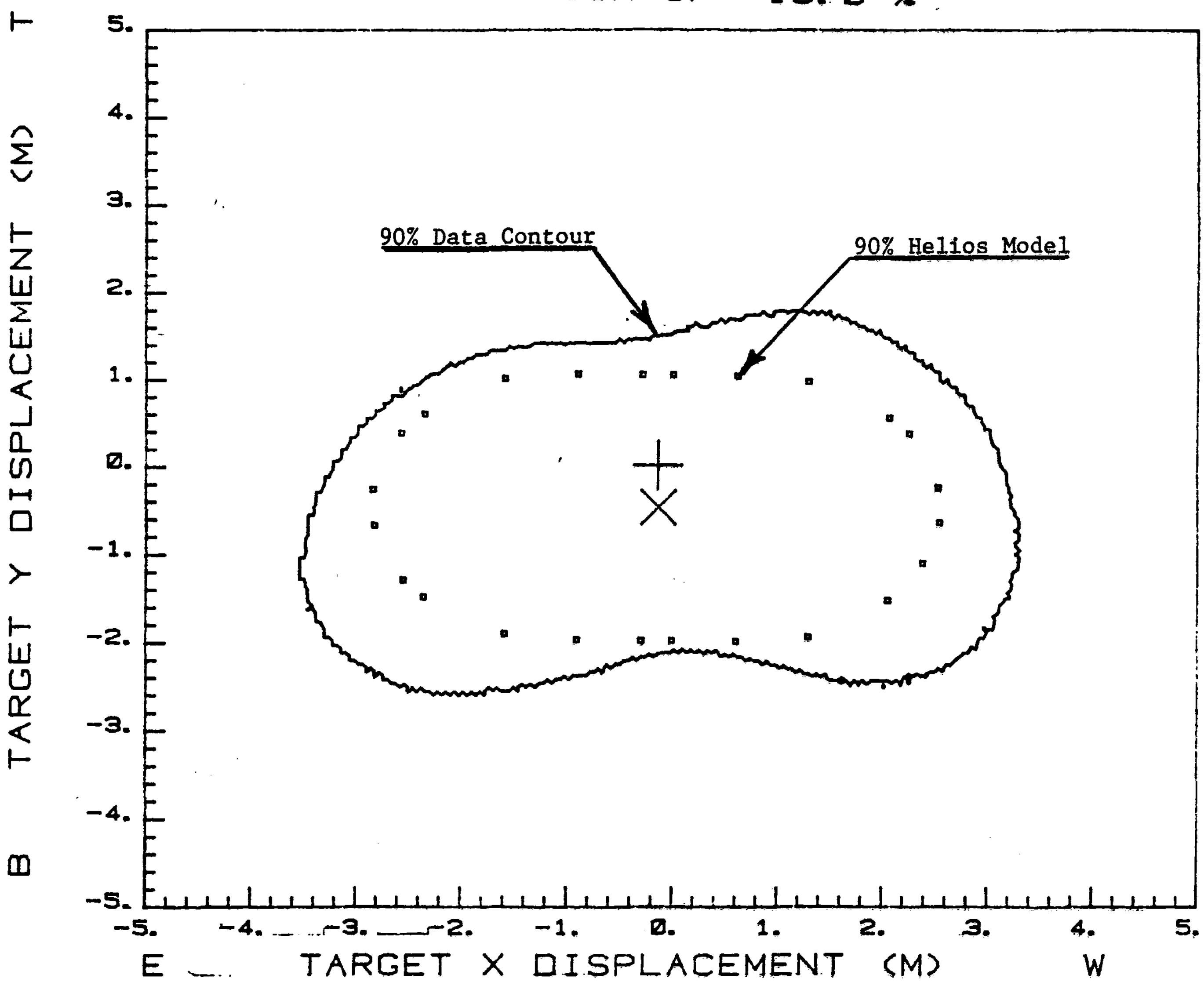


Figure 9.7-50 "Beam Quality" Comparison Northrup #2

PWR CONTOUR

TEST TIME
FEB 5, 1981 15:11:53.23
FILE NAME - CFØ36B::62
MAXIMUM FLUX =
.5428509E+00 W/SQ CM
TOTAL POWER =
.345443E+05 WATTS
SOLAR INSOLATION =
.9460001E-01 W/SQ CM
CENTROID REL. TO A.P.
X = -.34290 METERS
Y = -.59821 METERS

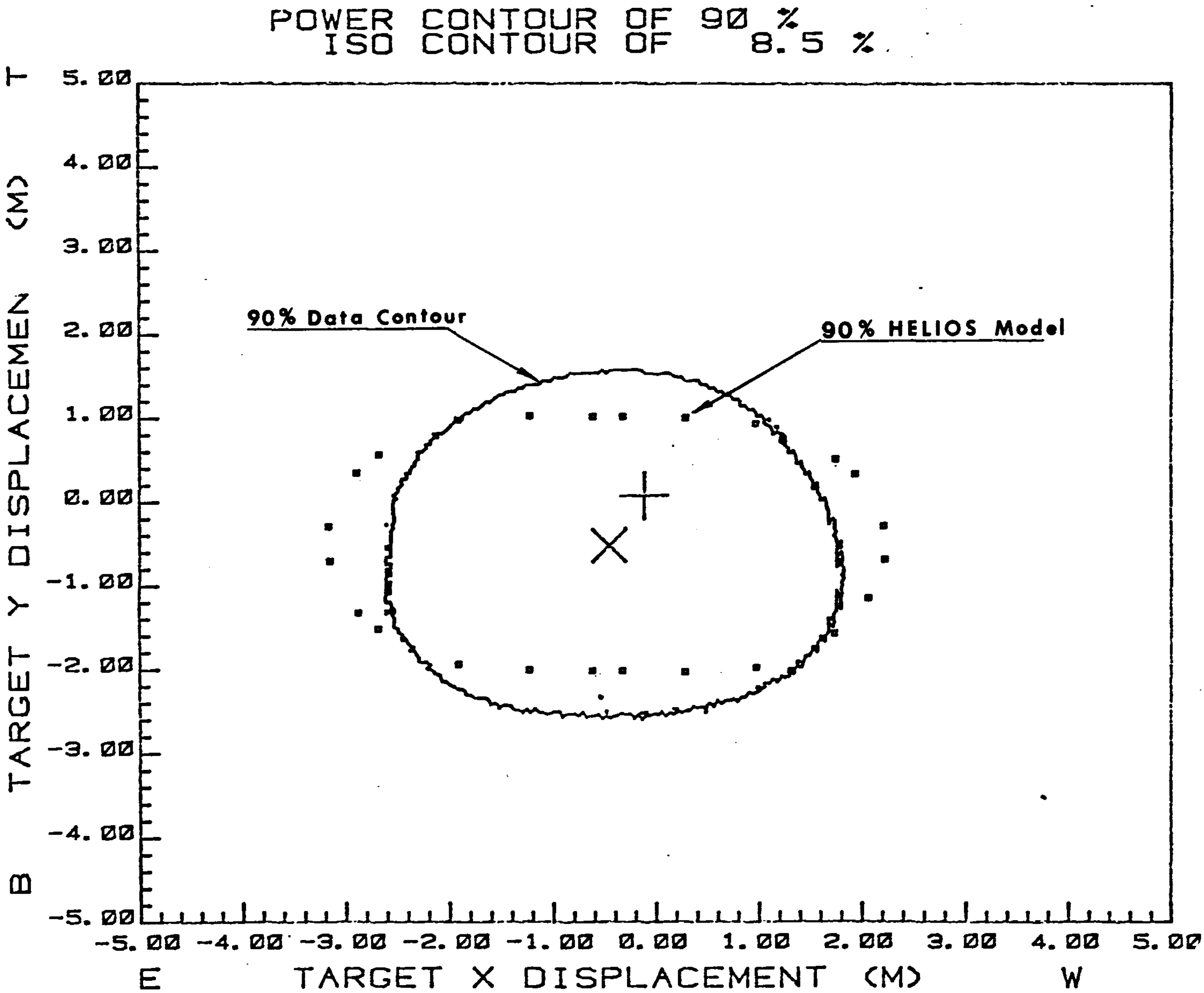


Figure 9.7-51 "Beam Quality "Northrup #2 Canted Modules

Table 9.7-35 "Beam Quality" Data Summary

Heliostat & Test time	Total Power kwt	Insolation w/m^2	Max Flux, w/m^2	90% Power Contour Area	Helios Model 90% Contour Area
No 1- Dec 10 11:03:49	42.658	969	2565.7	31.488	18.096
No 1-Dec 10 15:16:14	34.101	794	1980.2	30.345	17.887
No 2- Dec 10 11:22:56	41.066	963	3338.4	19.967	12.737
No 2-Dec 10 14:53:14	34.487	863	3060.2	19.877	12.968
No 2- Feb 5 11:28:41	40.544	1022	5192.0	15.528	not available
No 2- Feb 5 15:11:53	34.544	946	5428.5	14.299	12.797

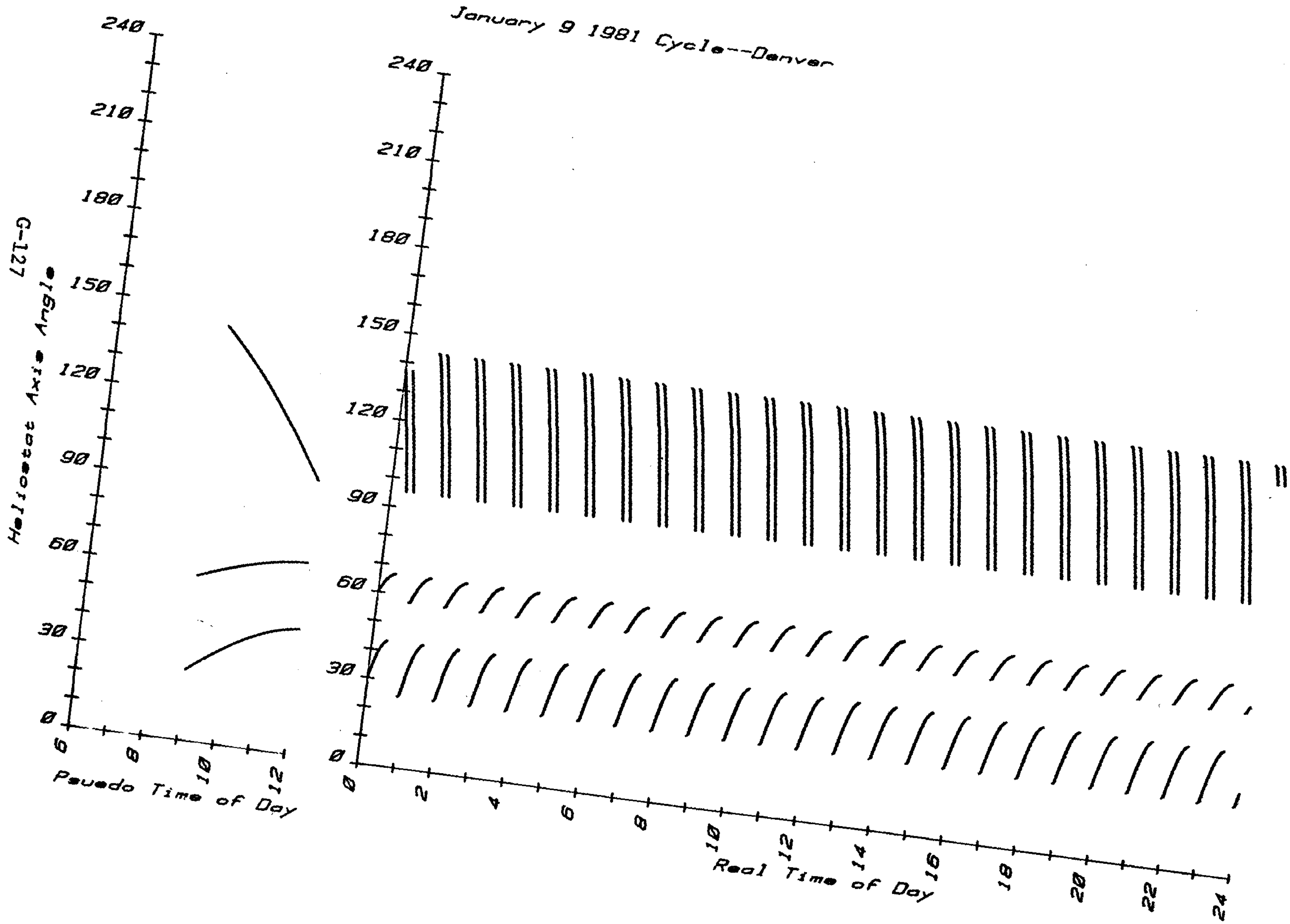
9.7.2.3.4 Life Cycle Tests

Life cycle testing software was developed on the bench test electronics unit in Littleton and incorporated in the CRTF Software Jan. 12. Either 1 or 2 heliostats are operated in a simulated half day cycle which spans a $\pm$ 67 degree range in elevation and a $\pm$ 50 degree range in azimuth every hour.

The cycle count is recorded on the same type plot used during tracking operation where the lines are composed of plotted points for each tracking update. Figure 9.7-52 shows a typical plot for dual heliostat cycling showing the twenty four operating cycles and the simulation cycle.

As of Feb. 4, 1981 heliostat #2 had operated 380 cycles without any problems being encountered.

Figure 9.7-52 Life Cycle Test Chart for 2 Heliostats



APPENDIX H

MANUFACTURING

This appendix includes the following:

OVERALL SUMMARY

CBS No. ______ DESCRIPTION ______

QUANTITY PER HELIOSTAT	PART NO.	DESCRIPTION	COST PER UNIT: DIRECT MATERIAL	COST PER UNIT: DIRECT LABOR	COST PER HELIOSTAT: DIRECT MATERIAL		COST PER HELIOSTAT: DIRECT LABOR		EQUIPMENT COST
1	CBS4410	Reflective Unit			960	36	15	48	9,161,000
1	CBS4420	Drive Unit			1,318	39	76	82	54,262,000
1	CBS4430	Controls			233	48	10	47	680,000
1	CBS4440	Foundation			309	40	4	50	1,464,000
1	CBS4450	Heliostat Support			450	84	10	96	6,640,000
					3,272	47	118	23	72,207,000

SUMMARY   CBS NO. 4410   Reflective Unit

DESCRIPTION

QUANTITY PER HELIOSTAT	PART NO.	DESCRIPTION	COST PER UNIT: DIRECT MATERIAL		COST PER UNIT: DIRECT LABOR		COST PER HELIOSTAT: DIRECT MATERIAL		COST PER HELIOSTAT: DIRECT LABOR		EQUIPMENT COST
12	12-100	Mirror Module Assy	79	28	1	29	951	36	15	48	9,161,000
36	12-010-0021	Stud		13	--	--	4	68	--	--	----
72	12-010-0022	Flat Washer		01	--	--		72	--	--	----
36	12-010-0023	Jam Nut		02	--	--		72	--	--	----
72	12-010-0024	Spherical Nut-Washer		04	--	--	2	88	--	--	----
							960	36	15	48	9,161,000

ASSEMBLY DETAILS

PART NO. 12-100 DESCRIPTION Mirror Module Assy CBS 4410

QUANTITY PER ASSEMBLY	PART NO.	DESCRIPTION	TYPE	DIRECT MATERIAL WEIGHT LENGTH, ETC. PER PC	PER ASSY.	COST PER LB,FT,ETC.	COST PER ASSY.		DIRECT LABOR HOURS PER 100PC	LABOR RATE		COST PER PC		COST PER ASSY		EQUIPMENT COST
1		Substrate Assy				$31.94 ea	31	94					28		28	2,131,000
2	0115	Mirror Facet Assy				11.72 ea	23	44					27		54	4,158,000
1	0116	Backing Plate	Steel		43.5#	.27/#	11	75	.14	4	49		01		01	809,000
14 oz	0154	Silicone	#4			9.50/#	8	31							---	---
4 oz		Adhesive				2.08/#		52							---	---
1	0103	Center Molding	Foam		4 ft	.12/ft		48							---	---
1 oz	0156	Adhesive, Rubber				.98/#		06							---	---
2	0106	Molding, End	P.P. Steel	0.22#	.44#	.35/#		15	.04	4	49		01		02	
																91,000
4	0105	Molding, Side	P.P. Steel	0.34#	1.36#	.35/#		48	.06	4	49		01		04	
4	0107	Corner	P.P. Steel	0.01#	.04#	.35/#		01	.02	4	49		01		04	37,000
6 oz		Sealant				5.50/#	2	06							---	
1		Center Trim	P.P. Steel		0.24#	.35/#		48	.08	4	49		01		01	37,000
		Assemble					---	---	7.84	4	49		35		35	1,898,000
							79	28						1	29	9,161,000

ASSEMBLY DETAILS

PART NO. ____________ DESCRIPTION Substrate Assy ____________ CBS 4410

QUANTITY PER ASSEMBLY	PART NO.	DESCRIPTION	TYPE	DIRECT MATERIAL: WEIGHT GAUGE, ETC. PER PIECE	WEIGHT GAUGE, ETC. PER ASSY.	COST PER LB,FT,ETC.	COST PER ASSY.	DIRECT LABOR: HOURS PER 100PC	LABOR RATE	COST PER PC	COST PER ASSY	EQUIPMENT COST
7	0131	Web	P.P. Steel	3.6#	25.2#	.35/#	8 82	.04	4 49	01	07	181,000
14	0132	Stiffener	P.P. Steel	0.1#	1.4#	.33/#	46					37,000
2	0121a	End Channel	P.P. Steel	1.2#	2.4#	.35/#	84	.07	4 49	01	02	60,000
20	0151	Rivet	-----			.05ea	1 00				---	---
1	0113	Backing Plate	P.P. Steel	43.5#	43.5#	.35/#	15 23	.14	4 49	01	01	809,000
2	0141	Rectangular Tube	P.P. Steel	7.5#	15#	.33/#	4 95	.07	4 49	01	02	60,000
4	0142	Floating Nut	-----			.03ea	12				--	---
4 oz.		Adhesive	-----			2.08/#	52				--	---
		Assemble					---	3.54	4 49	16	16	984,000
							31 94				28	2,131,000

ASSEMBLY DETAILS

PART NO. 12-100-0115 DESCRIPTION Mirror Facet Assy CBS 4410

QUANTITY PER ASSEMBLY	PART NO.	DESCRIPTION	DIRECT MATERIAL TYPE	WEIGHT LENGTH, ETC. PER PIECE	WEIGHT LENGTH, ETC. PER ASSY.	COST PER LB,FT,ETC.	COST PER ASSY.	DIRECT LABOR HOURS PER 100PC	LABOR RATE	COST PER PC	COST PER ASSY	EQUIPMENT COST
1		Glass	Low-iron Float	48 x 72		.43/ft^2	10 32				---	
.06 oz		Silver				$15/oz	90					4,158,000
.05 gal		Paint				$10/gal	50	6.00	4 49	27	27	
							11 72				27	4,158,000

NOTE: Each facet also requires .02 ounces of copper which has negligible cost.

SUMMARY   CHS 4420
N

D...e Unit
DESCRIPTION

QUANTITY PER HELIOSTAT	PART NO.	DESCRIPTION	COST PER UNIT DIRECT MATERIAL	COST PER UNIT DIRECT LABOR	COST PER HELIOSTAT DIRECT MATERIAL	COST PER HELIOSTAT DIRECT LABOR	EQUIPMENT COST
1		Drive & Motor Assy.	1307 43	76 07	1307 43	76 07	54,262,000
12	12-010-0018	Lockwashers	04	----	24	----	----
12	12-010-0019	Nut, Hex	06	----	72	----	----
1		Cable Assy			10 00	75	
					1318 39	76 82	54,262,000

ASSEMBLY DETAILS

PART NO. ______ DESCRIPTION Drive and Motor Assy CBS 4420

QUANTITY PER ASSEMBLY	PART NO.	DESCRIPTION	TYPE	DIRECT MATERIAL: WEIGHT LENGTH, ETC. PER PIECE	DIRECT MATERIAL: WEIGHT LENGTH, ETC. PER ASSY.	DIRECT MATERIAL: COST PER LB, FT, ETC.	DIRECT MATERIAL: COST PER ASSY.	DIRECT LABOR: HOURS PER 100PC	DIRECT LABOR: LABOR RATE	DIRECT LABOR: COST PER PC	DIRECT LABOR: COST PER ASSY	EQUIPMENT: COST
1	12-300	Drive Unit Assy					850 34				73 82	53,362,000
12	12-010-0017	Stud	Steel			$.26 ea.	3 12				---	
5.2 gal		Oil				8.75/gal	45 50				---	
4	12-600-0668	Limit Sw.				3.06 ea.	12 25				---	
4	12-600-0669	Limit Sw.				3.42 ea.	13.68				---	
	12-010-0011	Stepper Motor				$150 ea.	300 00				---	
2	12-010-0012	Flexible Coupling				$1.10 ea	2 20				---	
2	12-010-0013	Keyway				.01 ea	02				---	
8	12-010-0014	Bolt, Hex Hd.				.02 ea	16				---	
8	12-010-0015	Lockwasher				.01 ea	08				---	
8	12-010-0016	Nut, Hex				.01 ea	08				---	
1		Cable Assy					80 00	50	4 49		2 25	
							1307 43				76 07	53,362,000
									Assembly Line			200,000
									Paint			700,000
												54,262,000

ASSEMBLY DETAILS

PART NO. 12-300 DESCRIPTION Drive Unit Assy. CBS 4420

QUANTITY PER ASSEMBLY	PART NO.	DESCRIPTION	DIRECT MATERIAL: TYPE	DIRECT MATERIAL: WEIGHT LENGTH, ETC. PER PIECE	DIRECT MATERIAL: WEIGHT LENGTH, ETC. PER ASSY.	DIRECT MATERIAL: COST PER LB,FT,ETC.	DIRECT MATERIAL: COST PER ASSY.	DIRECT LABOR: HOURS PER 100PC	DIRECT LABOR: LABOR RATE	DIRECT LABOR: COST PER PC	DIRECT LABOR: COST PER ASSY	EQUIPMENT: COST
1	651137-85	GITS Expansion Ch				$20 ea	20 00				---	---
2	15118	Key				.01 ea	02				---	---
12	13336	Lockwasher				.01 ea	12				---	---
12	11870	Bolt				.01 ea	12				---	---
1	651137-84	Mounting Plate	(Eliminated in production design)									
1	-86	Copper Tubing	3/16 O.D.			.18 ea	18				---	---
2	15710	Key				.03 ea	06				---	---
5	11210	Pipe Plug ½				.09 ea	45				---	---
6	11208	Pipe Plug ¼				.07 ea	42				---	---
24	10548	Spirol Pin				.01 ea	24				---	---
8	20314	Tor. Needle B'rg				.45 ea	3 60				---	---
12	11868	Bolt				.03 ea	36				---	---
16	11281	Cap Screw				.07 ea	1 12				---	---
24	11241	Cap Screw				.05 ea	1 20				---	---
4	5908	Oil Seal				.19 ea	76				---	---
2	10241	Retaining Ring				.15 ea	30				---	---

ASSEMBLY DETAILS

PART NO. 12-300 DESCRIPTION Drive Unit Assy. CBS 4420

QUANTITY PER ASSEMBLY	PART NO.	DESCRIPTION	DIRECT MATERIAL TYPE	WEIGHT LENGTH, ETC. PER PIECE	WEIGHT LENGTH, ETC. PER ASSY.	COST PER LB,FT,ETC.	COST PER ASSY.	DIRECT LABOR HOURS PER 100PC	LABOR RATE	COST PER PC	COST PER ASSY	EQUIPMENT COST
2	10240	Retaining Ring				$ .08 ea	16				---	---
2	20313	Ball Brg.				3.38 ea	6 76				---	---
2	651137-67	Gasket, Plan.				.61 ea	1 22				---	---
2	651137-63	Gasket, Plan				.44 ea	88				---	---
4	20311	Timken Cone				10.87 ea	43 48				---	---
4	20312	Timken Cone				5.81 ea	23 24				---	---
4	651137-56	Journal Pin	Steel	.34#	1.36#	.33/#	45	1.37	4 49	06	24	254,000
4	-55	Planet Gear	Steel	2.5#	10#	.42/#	4 20	36.30	4 49	1 63	6 52	2,030,000
2	-54	Planetary Pinion	Steel	1.5#	3#	.42/#	1 26	50.25	4 49	2 26	4 52	2,233,000
2	-72	Sec Ring Gear	Steel	8.9#	17.8#	.42/#	7 48	37.18	4 49	1 67	3 34	---
2	71	Pri Ring Gear	Steel	8.9#	17.8#	.42/#	7 48	37.18	4 49	1 67	3 34	6,296,000
2	52	Planet Drive	Casting	7#		4.00 ea	8 00	32.57	4 49	1 46	2 92	1,333,000
2	57	Planet Gear Web	Casting	7#		4.08 ea	8 16	32.40	4 49	1 45	2 90	1,433,000
2	51	Planet Cover	Casting	17#		6.08 ea	12 16	52.37	4 49	2 35	4 70	2,535,000
2	50	Planet Housing	Casting	13#		6.00 ea	12 00	23.73	4 49	1 07	2 14	1,012,000
2	59	H.S. Worm	Steel C1117	82.8#	165.6#	45.5¢/#	75 35	115.42	4 49	5 18	10 36	9,839,000

ASSEMBLY DETAILS

PART NO. 12-300 DESCRIPTION Drive Unit Assy CBS 4420

			DIRECT MATERIAL					DIRECT LABOR				EQUIPMENT
QUANTITY PER ASSEMBLY	PART NO.	DESCRIPTION	TYPE	WEIGHT LENGTH, ETC. PER PIECE	WEIGHT LENGTH, ETC. PER ASSY.	COST PER LB,FT,ETC.	COST PER ASSY.	HOURS PER 100PC	LABOR RATE	COST PER PC	COST PER ASSY	COST
4	30178	Oil Seal				$10.00 ea	40 00				---	---
3	30177	"O" Ring				.03 ea	09				---	---
24	651137-70	Spacer	(Eliminated in production design)									
24	13339	Lock Washer				.02 ea	48				---	---
24	13338	Lock Washer				.01 ea	24				---	---
38	13337	Lock Washer				.01 ea	38				---	---
24	11878	Bolt				.14 ea	3 36				---	---
12	11879	H.H. Bolt				.07 ea	84				---	---
26	11871	H.H. Bolt				.02 ea	52				---	---
1	651137-66	Gasket				1.07 ea	1 07				---	---
1	-65	Gasket				1.77 ea	1 77				---	---
1	-64	Gasket				1.44 ea	1 44				---	---
2	20315	Ball Bearing	(Eliminated in production design)									
1	651137-60	Worm Support	Casting			1.12 ea	1 12	17.43	4 49	78	78	558,000
1	41	S.S. Gear - Elev.	Casting		217#	114.80 ea	114 80	86.67	4 49	3 89	3 89	6,270,000
1	44	S.S. Bearing, In	(Eliminated in production design)									
1	43	S.S. Bearing, Out	(Eliminated in production design)									

ASSEMBLY DETAILS

PART NO. 12-300 DESCRIPTION Drive Unit Assy CBS 4420

QUANTITY PER ASSEMBLY	PART NO.	DESCRIPTION	DIRECT MATERIAL: TYPE	WEIGHT LENGTH, ETC. PER PIECE	WEIGHT LENGTH, ETC. PER ASSY.	COST PER LB, FT, ETC.	COST PER ASSY. ($)	(¢)	DIRECT LABOR: HOURS PER 100PC	LABOR RATE ($)	(¢)	COST PER PC ($)	(¢)	COST PER ASSY ($)	(¢)	EQUIPMENT: COST
1	651137-42	S.S. Bearing Ring	Casting	45#		$22.50 ea	22	50	37.37	4	49	1	68	1	68	1,337,000
1	40	Elevation Housing	Casting	229#		111.07 ea	111	07	45.13	4	49	2	03	2	03	5,250,000
1	73	Plug, Azi, Gear				.16 ea		16							---	---
12	11869	Bolt				.06 ea		72							---	---
1	11209	Pipe Plug 3/8				.08 ea		08							---	---
2	30176	Oil Seal				10.00 ea	20	00							---	---
6	651137-69	Stud	Thr.Stk.			.38 ea	2	28	.05	4	49		--		---	---
1	87	Dust Shield				8.33 ea	8	33							---	---
1	62	Gasket				1.83 ea	1	83							---	---
1	61	Worm Support	Casting			1.12 ea	1	12	17.43	4	49		78		78	---
1	651137-46	S.S. Gear Azi	Casting	176#		87.42 ea	87	42	81.72	4	49	3	67	3	67	6,270,000
1	49	S.S. Bearing, Ring	(Eliminated in production design)													
1	48	S.S. Bearing-Clamp	(Eliminated in production design)													
1	47	S.S. Cover	Casting	48#		24.00 ea	24	00	25.30	4	49	1	14	1	14	901,000
1	45	Azimuth Housing	Casting	297#		128.84 ea	128	84	44.80	4	49	2	01	2	01	5,250,000
2	1109	Elbow				.24 ea		48	---						---	---
2	651137-58	Clamping Disc	C1117	1.3#	2.6#	25.7¢/#		67	7.93	4	49		36		72	561,000

ASSEMBLY DETAILS

PART NO. 12-300 DESCRIPTION Drive Unit Assy CBS 4420

QUANTITY PER ASSEMBLY	PART NO.	DESCRIPTION	TYPE	DIRECT MATERIAL: WEIGHT LENGTH, ETC. PER PIECE	WEIGHT LENGTH, ETC. PER ASSY.	COST PER LB,FT,ETC.	COST PER ASSY.		DIRECT LABOR: HOURS PER 100PC	LABOR RATE		COST PER PC		COST PER ASSY		EQUIPMENT COST
140		Balls	3/4 D			$.20 ea	28	00								
2		Plugs				2.00 ea	4	00								
.05 gal		Prime				10.00/gal		50								
.05 gal		Paint				20.00/gal	1	00	26.5	4	49	1	19	1	19	
		Assemble							333	4	49	14	95	14	95	
							850	34						73	82	53,362,000

SUMMARY   CBS 4430 N.   Controls

DESCRIPTION

QUANTITY PER HELIOSTAT	PART NO.	DESCRIPTION	COST PER UNIT DIRECT MATERIAL	COST PER UNIT DIRECT LABOR	COST PER HELIOSTAT DIRECT MATERIAL	COST PER HELIOSTAT DIRECT LABOR	EQUIPMENT COST
1		Control Assy	233 00		233 00	10 47	680,000
16	12-010-0025	Bolt-Hex Hd.	02	-----	32	-----	-----
16	12-010-0026	Lockwasher	01	-----	16	-----	-----
					233 48	10 47	680,000

ASSEMBLY DETAILS

PART NO. No Drawing DESCRIPTION Control Assy CBS 4430

QUANTITY PER ASSEMBLY	PART NO.	DESCRIPTION	DIRECT MATERIAL TYPE	WEIGHT LENGTH, ETC. PER PIECE	WEIGHT LENGTH, ETC. PER ASSY.	COST PER LB,FT,ETC.	COST PER ASSY.	DIRECT LABOR HOURS PER 100PC	LABOR RATE	COST PER PC	COST PER ASSY	EQUIPMENT COST
1		Rack Assy	Steel		30#	$.30/#	9 00	66.7	4 49	2 99	2 99	500,000
		Electronics										
		Microprocessor					30 00					
		Translators					150 00					180,000
		Power Supply					42 00					
		Assembly					-- --	166.7	4 49		7 48	
		Gasket	Foam		5 Ft.	.10/Ft	50				---	---
.05 gal		Prime				10.00/gal	50				---	
.05 gal		Paint				20.00/gal	1 00				---	
							233 00				10 47	680,000

SUMMARY CBS NO. 4440

Foundation
DESCRIPTION

QUANTITY PER HELIOSTAT	PART NO.	DESCRIPTION	COST PER UNIT DIRECT MATERIAL	COST PER UNIT DIRECT LABOR	COST PER HELIOSTAT DIRECT MATERIAL	COST PER HELIOSTAT DIRECT LABOR	EQUIPMENT COST
1	M-101	Pile Assy	309 40	4 50	309 40	4 50	1,464,000
					309 40	4 50	1,464,000

ASSEMBLY DETAILS

PART NO. M-101 DESCRIPTION Pile Assy CBS 4440

QUANTITY PER ASSEMBLY	PART NO.	DESCRIPTION	TYPE	DIRECT MATERIAL: WEIGHT LENGTH, ETC. PER PIECE	WEIGHT LENGTH, ETC. PER ASSY.	COST PER LB,FT,ETC.	COST PER ASSY.	DIRECT LABOR: HOURS PER 100PC	LABOR RATE	COST PER PC	COST PER ASSY	EQUIPMENT COST
1	M-101-5	Pipe	Steel	850#	850#	$ .30/#	255 00	40.0	4 49		1 80	504,000
1	M-101-1	Flange	Steel					3.3	4 49		15	480,000
				91#	91#	.40/#	36 40					
1	M-105	Flange, E.O.	Steel					3.3	4 49		15	480,000
		Assemble	-----					26.7	4 49		1 20	
0.6 gal		Primer	HD-230			10.00/gal	6 00	---				
0.6 gal		Paint	DE-500			20.00/gal	12 00	26.7	4 49		1 20	
							309 40				4 50	1,464,000

SUMMARY CBS 4450 N.

Heliostat Support
DESCRIPTION

QUANTITY PER HELIOSTAT	PART NO.	DESCRIPTION	COST PER UNIT DIRECT MATERIAL	COST PER UNIT DIRECT LABOR	COST PER HELIOSTAT DIRECT MATERIAL	COST PER HELIOSTAT DIRECT LABOR	EQUIPMENT COST
2	12-200-0220	Torque Tube Assy.	126 02	2 56	252 12	5 12	1,094,000
4	12-200-0210	Truss Assy.	38 58	1 13	154 32	4 52	2,300,000
8	12-200-0201	Truss Cross Brace	3 66	1 13	29 28	88	23,000
4	12-200-0202	Truss Lower Brace	3 51	1 13	14 04	44	23,000
4	12-200-0223	Rivet	03	-- --	12	-- --	
32	12-200-0225	Rivet	03	-- --	96	-- --	
					450 84	10 96	3,440,000
		Paint System					3,200,000
							6,640,000

ASSEMBLY DETAILS

PART NO. 12-200-0220 DESCRIPTION Torque Tube Assy. CBS 4450

QUANTITY PER ASSEMBLY	PART NO.	DESCRIPTION	TYPE	DIRECT MATERIAL: WEIGHT LENGTH, ETC. PER PIECE	WEIGHT LENGTH, ETC. PER ASSY.	COST PER LB,FT,ETC.	COST PER ASSY.	DIRECT LABOR: HOURS PER 100PC	LABOR RATE	COST PER PC	COST PER ASSY	EQUIPMENT: COST
1	0224	Torque Tube	Steel	310.2#	310.2#	$ .30/#	93 06	26.7	4 49		1 20	441,000
2	0222	Support Bracket	Steel	17#	34#	.30/#	10 20	0.8	4 49	04	08	173,000
1	0221	Flange	Steel	42#	42#	.40/#	16 80	1.7	4 49		08	480,000
		Assemble	-----					13.3	4 49		60	
0.2 gal	0226	Primer	HD-230			10.00/gal	2 00				---	
0.2 gal	0227	Paint	DE-500			20.00/gal	4 00	13.3	4 49		60	
							126 06				2 56	1,094,000

ASSEMBLY DETAILS

PART NO. 12-200-0210 DESCRIPTION Truss Assy. CBS 4450

QUANTITY PER ASSEMBLY	PART NO.	DESCRIPTION	DIRECT MATERIAL TYPE	WEIGHT LENGTH, ETC. PER PIECE	WEIGHT LENGTH, ETC. PER ASSY.	COST PER LB,FT,ETC.	COST PER ASSY.		DIRECT LABOR HOURS PER 100PC	LABOR RATE		COST PER PC	COST PER ASSY		EQUIPMENT COST
1		Top Chord	Steel		44.5#	$ .30/#	13	35	1.7	4	49			08	
1		Bottom Chord	Steel		37.1#	.30/#	11	13	1.7	4	49			08	689,000
		Web	Steel		32#	.30/#	9	60	8.3	4	49			37	393,000
		Assemble	-----						6.7	4	49			30	1,218,000
0.15 gal		Primer	HD-230			10.00/gal	1	50						---	
0.15 gal		Paint	DE-500			20.00/gal	3	00	6.7	4	49			30	
							38	58					1	13	2,300,000

ASSEMBLY DETAILS

PART NO. 12-200-0201 DESCRIPTION Truss-Cross Brace CBS 4450

QUANTITY PER ASSEMBLY	PART NO.	DESCRIPTION	DIRECT MATERIAL					DIRECT LABOR				EQUIPMENT
			TYPE	WEIGHT LENGTH, ETC. PER PIECE	WEIGHT LENGTH, ETC. PER ASSY.	COST PER LB,FT,ETC.	COST PER ASSY.	HOURS PER 100PC	LABOR RATE	COST PER PC	COST PER ASSY	COST
1	0201	Cross Brace	Steel		11.2#	$ .30/#	3 36	0.8	4 49		04	23,000
.01 gal		Primer	HD-230			10.00/gal	10	---			---	
.01 gal		Paint	DE-500			20.00/gal	20	1.6	4 49		07	
							3 66				11	23,000

ASSEMBLY DETAILS

PART NO. 12-200-0202 DESCRIPTION Truss - Lower Brace CBS 4450

QUANTITY PER ASSEMBLY	PART NO.	DESCRIPTION	TYPE	DIRECT MATERIAL: WEIGHT LENGTH, ETC. PER PIECE	WEIGHT LENGTH, ETC. PER ASSY.	COST PER LB,FT,ETC.	COST PER ASSY.	DIRECT LABOR: HOURS PER 100PC	LABOR RATE	COST PER PC	COST PER ASSY	EQUIPMENT: COST
1	202	Lower Brace	Steel		10.7#	$ .30/#	3 21	0.8	4 49		04	23,000
.01 gal		Primer	HD-230			10.00/gal	10				---	
.01 gal		Paint	DE-500			20.00/gal	20	1.6	4 49		07	
							3 51				11	23,000

MIRROR PRODUCTION

PRODUCTION ROUTING & DIRECT LABOR COST SUMMARY

PRODUCT: ______ PART: MIRROR PART NO.: ______

DRAWING NO.: ______ DATE: 2/5/80 SHEET 1 of ______

CBS	OPERATION NO.	OPERATION DESCRIPTION	MACHINE OR AUXILLARY EQUIP	SET UP	RUN	TOTAL TIME	NUMBER OPERATORS	AVG WAGE RATE	TOTAL LABOR COST	FLOOR SPACE
4411		UNLOAD GLASS	UNLOADER & TRANSFER DECK				2	4.49		
4411		TRIM EDGES	EDGE & END SEAMER							
4411		WASH	WASHER/DRYER				2	4.49		
4411		TRANSFER	ACCUM./ACCEL. CONVEYOR							
4411		90° TRANSFER	90° TRANSFER DEVICE							
4411		LOAD	LOADER							
							2	4.49		
		MIRROR COATING	MIRROR SILVERING LINE				5	4.49		
							11 per line per shift			

Direct Labor Summary

Mirror Module

Part	Operation	Quantity Per Day	Hours Per 100 pc	Operators Shift 1	Operators Shift 2
Mirror Backing Sheet	Shear	2400	.14	½	0
End Pieces	Form	4800	.07	½	0
Backing Sheet	Shear	2400	.14	½	0
Mounting Bracket	Form	4800	.07	½	0
Mounting Bracket w/nuts	Staking	4800	.14	1	0
Stiffeners	Form	33600	----	0	0
Webs	roll-form	16800	.04	½	½
Edge Molding	roll-form	9600	.06	1	0
Edge Molding	roll-form	4800	.04	1/3	0
Center Trim	Form	2400	.08	1/3	0
Corner	Form	9600	.02	1/3	0
Web Assy	Bond	16800	.04	½	½
Grease Sheet	Grease	2400	.56	1	1
Substrate Assy		2400	3.36	6	6
Module Assy		2400	4.48	8	8
Final Assy		2400	2.24	4	4
Unload		2400	1.12	2	2
				27	22

Direct Labor Summary

Drive Unit

Part	Quantity Per Day	Hours Per 100 pc	Hours Per Day	No. Of Operators	Operators Shift 1	Shift 2	Shift 3
Gear Cover	200	25.30	51	8	3	3	2
Bearing Ring	200	37.37	75	11	4	4	3
Gear-Elev.	200	86.67	173	26	9	9	8
Gear-Azi	200	81.72	163	24	8	8	8
Worm	400	115.42	462	69	23	23	23
Housing-Elev	200	45.13	90	14	5	5	4
Housing-Azi	200	44.80	90	14	5	5	4
Frame	400	32.57	130	20	7	7	6
Cover	400	52.37	209	31	11	11	9
Housing	400	23.73	95	14	5	5	4
Web	400	32.40	130	20	7	7	6
Ring Gear-Pri	400	37.18	149	22	8	8	6
Ring Gear-Sec	400	37.18	149	22	8	8	6
Planet Gear	800	36.30	290	44	15	15	14
Pinion	400	50.25	201	30	10	10	10
Stud	1200	.05	1	1	1	0	0
Worm Support	400	17.43	70	11	4	4	3
Journal Pin	800	1.37	11	2	1	1	0
Clamping Disc	400	7.93	32	5	2	2	1
Paint	200	26.50	53	8	4	4	0
Assemble Drive	200	400.00	800	100	50	50	0
Drive Unit Assy	200			496	190	189	117

Direct Labor Summary

Controls

Part	Quantity Per Day	Hours Per 100 pc	Operators Shift 1
Control Assy	200	166.7	50
Cable Assy	200	16.7	5
Limit Switch Assy	200	16.7	5
Cable Assy	200	50.0	15
			75

Direct Labor Summary

Structural Parts

Part	Operation	Quantity Per Day	Hours Per 100 pc	Shift 1	Shift 2
Flange, Opening	Fab	200	3.3	1	--
Flange, Top	Fab	200	3.3	1	--
Pile	Form	200	26.7	4	4
	Weld	200	13.3	2	2
Assemble	Weld	200	26.7	4	4
Paint	Load	200	13.3	2	2
	Unload	200	13.3	2	2
Flange, End	Fab	400	1.7	1	--
Bracket	Fab	800	0.8	1	--
Torque Tube	Form	400	13.3	4	4
	Weld	400	13.3	4	4
Assemble	Weld	400	13.3	4	4
Paint	Load	400	6.7	2	2
	Unload	400	6.7	2	2
Chord, Top	Form	800	1.7	1	1
Chord, Bottom	Form	800	1.7	1	1
Web	Weld	800	5.0	3	3
	Form	800	3.3	2	2
Assemble	Asm	800	3.3	2	2
	Weld	800	3.3	2	2
Paint	Load	800	3.3	2	2
	Unload	800	3.3	2	2
Cross Brace	Form	1600	0.8	1	1
Paint	Load	1600	0.8	1	1
	Unload	1600	0.8	1	1
Lower Brace	Form	800	0.8	1	--
Paint	Load	800	0.8	1	--
	Unload	800	0.8	1	--
Control Box	Undefined	200	66.7	20	--
				75	48

HELIOSTAT MIRROR MODULE PRODUCTION EQUIPMENT COST

MIRROR PROCESSING LINE
(DESIGN NO 2.)

SHEET 1 OF 1

MACHINE NAME	NUMBER REQUIRED	INVOICE PRICE	TRANSPORTATION COST	UNLOADING AND INSTALLATION - REMODELING AND COST	ESTIMATED MACHINE LIFE YEARS/UNITS	AVERAGE YEARLY MAINTENANCE COST	TOTAL COST
UNLOADER & TRANSFER DECK	2	$45K	$2.25K	$3.2K	10+ yrs.	$2K	$101K
EDGE & END SEAMER	2	$140K	$7K	$14K	10+ yrs.	$7K	$322K
WASHER/DRYER	2	$30K	$1.5K	$1.5K	10+ yrs.	$1.5K	$66K
ACCUM. & ACCEL. CONVEYOR	2	$30K	$1.5K	$1.5K	10+ yrs.	$1.2K	$66K
90° TRANSFER	2	$20K	$1.0K	$1K	10+ yrs.	$1K	$44K
LOADERS	2	$50K	$2.5K	$2.2K	10+ yrs	$2.2K	$110K
MIRROR SILVERING LINE	2	$1,000 K (2630K)	$50K (131.5K)	$100K (246.5 K)	10+ yrs.	$35K	$2300K
WATER TREATMENT	1	$1,000K	$50K	$100K	20yrs	$50K	$2300K
		3630K	[illegible]	[illegible]	[illegible]		

PRODUCTION EQUIPMENT COST

WEBS

SHEET ________ OF ________

MACHINE NAME	NUMBER REQUIRED	INVOICE PRICE	TRANSPORTATION COST	UNLOADING AND INSTALLATION REMODELING AND COST	ESTIMATED MACHINE LIFE YEARS/UNITS	AVERAGE YEARLY MAINTENANCE COST	TOTAL COST
Pay-off reel	2	12 (24)	1 (2)	1.2 (2.4)			
Roll-former	2	45 (90)	2.2 (4.4)	4 (8)			
Cut-off Machine	2	21 (42)	1 (2)	2 (4)			
Run-out table	2	1.5 (3)	--	--			
		159	8	14			181

PRODUCTION EQUIPMENT COST

STIFFENERS

SHEET ________ OF ________

MACHINE NAME	NUMBER REQUIRED	INVOICE PRICE	TRANSPORTATION COST	UNLOADING AND INSTALLATION REMODELING AND COST	ESTIMATED MACHINE LIFE YEARS/UNITS	AVERAGE YEARLY MAINTENANCE COST	TOTAL COST
Pay-out reel	1	12	1	1.2			
40-ton press	1	20	1	2			
		32	2	3			37

PRODUCTION EQUIPMENT COST

END PIECE

SHEET__________OF__________

MACHINE NAME	NUMBER REQUIRED	INVOICE PRICE	TRANSPORTATION COST	UNLOADING AND INSTALLATION REMODELING AND COST	ESTIMATED MACHINE LIFE YEARS/UNITS	AVERAGE YEARLY MAINTENANCE COST	TOTAL COST
Pay-off reel	1	12	1	1.2			
100-ton press	1	40	2	4			
		52	3	5			60

PRODUCTION EQUIPMENT COST

BACKING SHEET

SHEET ____________ OF ____________

MACHINE NAME	NUMBER REQUIRED	INVOICE PRICE	TRANSPORTATION COST	UNLOADING AND INSTALLATION REMODELING AND COST	ESTIMATED MACHINE LIFE YEARS/UNITS	AVERAGE YEARLY MAINTENANCE COST	TOTAL COST
Coil Holder	1	49	2.5	2			
Coil Car	1	18	.7	2			
Leveler	1	200	5	20			
Special Cut-off	1	375	7	37			
Special Stacker	1	75	3.5	7			
Run-out Table	1	4	1	--			
		721	20	68			809

PRODUCTION EQUIPMENT COST

MOUNTING BRACKET

SHEET ______ OF ______

MACHINE NAME	NUMBER REQUIRED	INVOICE PRICE	TRANSPORTATION COST	UNLOADING AND INSTALLATION REMODELING AND COST	ESTIMATED MACHINE LIFE YEARS/UNITS	AVERAGE YEARLY MAINTENANCE COST	TOTAL COST
Pay-out reel	1	12	1	1.2			
100-ton press	1	40	2	4			
		52	3	5			60

PRODUCTION EQUIPMENT COST

SUBSTRATE ASSY

SHEET ____________ OF ____________

MACHINE NAME	NUMBER REQUIRED	INVOICE PRICE	TRANSPORTATION COST	UNLOADING AND INSTALLATION REMODELING AND COST	ESTIMATED MACHINE LIFE YEARS/UNITS	AVERAGE YEARLY MAINTENANCE COST	TOTAL COST
Web Assy							
Adhesive Dispenser	1	20	1	1			
Stapler	1	10	1	1			
Run-out table	1	30					
Substrate Asm							
Conveyor	1	920					
		980	2	2			984

PRODUCTION EQUIPMENT COST

MIRROR BACKING SHEET

SHEET ____________ OF ____________

MACHINE NAME	NUMBER REQUIRED	INVOICE PRICE	TRANSPORTATION COST	UNLOADING AND INSTALLATION REMODELING AND COST	ESTIMATED MACHINE LIFE YEARS/UNITS	AVERAGE YEARLY MAINTENANCE COST	TOTAL COST
Coil Holder	1	49	2.5	2			
Coil Car	1	18	.7	2			
Leveler	1	200	5	20			
Special Cut-off	1	375	7	37			
Special Stacker	1	75	3.5	7			
Run-out Table	1	4	1	--			
		721	20	68			809

PRODUCTION EQUIPMENT COST

MODULE ASSY

SHEET ______ OF ______

MACHINE NAME	NUMBER REQUIRED	INVOICE PRICE	TRANSPORTATION COST	UNLOADING AND INSTALLATION REMODELING AND COST	ESTIMATED MACHINE LIFE YEARS/UNITS	AVERAGE YEARLY MAINTENANCE COST	TOTAL COST
Grease Dispenser	1	50	3	5			
Module Assy Conveyer	1	1240					
Final Assy Conveyer	1	600					
		1890	3	5			1898

PRODUCTION EQUIPMENT COST

EDGE MOLDING

SHEET ____________ OF ____________

MACHINE NAME	NUMBER REQUIRED	INVOICE PRICE	TRANSPORTATION COST	UNLOADING AND INSTALLATION REMODELING AND COST	ESTIMATED MACHINE LIFE YEARS/UNITS	AVERAGE YEARLY MAINTENANCE COST	TOTAL COST
Pay-off reel	1	12	1	1.2			
Roll-former	1	45	2.2	4			
Cut-off Machine	1	21	1	2			
Run-out Table	1	1.5					
		80	4	7			91

PRODUCTION EQUIPMENT COST

CORNER - MOLDING

SHEET__________ OF__________

MACHINE NAME	NUMBER REQUIRED	INVOICE PRICE	TRANSPORTATION COST	UNLOADING AND INSTALLATION REMODELING AND COST	ESTIMATED MACHINE LIFE YEARS/UNITS	AVERAGE YEARLY MAINTENANCE COST	TOTAL COST
Pay-out reel	1	12	1	1.2			
40-ton press	1	20	1	2			
		32	2	3			37

PRODUCTION EQUIPMENT COST

CENTER TRIM

SHEET______ OF______

MACHINE NAME	NUMBER REQUIRED	INVOICE PRICE	TRANSPORTATION COST	UNLOADING AND INSTALLATION REMODELING AND COST	ESTIMATED MACHINE LIFE YEARS/UNITS	AVERAGE YEARLY MAINTENANCE COST	TOTAL COST
Pay-out reel	1	12	1	1.2			
40-ton press	1	20	1	2			
		32	2	3			37

LABOR AND EQUIPMENT ESTIMATING SHEET

Page No. ____

CBS Number: 4420 | Part: Drive Cover | Part No.: 651137-41

Date: 10/20/80 | Qty./Heliostat: 1 | Sheet No.: 1 Of 1

OPER. NO.	OPERATION DESCRIPTION	PRODUCTION ESTIMATE – MACHINE – Min/Pc	MACHINE – Hrs/100 Pc @	LABOR – GRADE	LABOR – Hrs/100 PC	LABOR – $/Hour	MACHINERY & EQUIPMENT	EQUIPMENT – Qt.	EQUIPMENT – Est. Cost
010	Face	5					NC Chucker	~~3~~ 2	~~1,500,000~~ 800,000
	~~Turn [illegible] I.D.~~	~~5~~					Installation		~~[illegible]~~ 20,000
	~~Bore 19.[illegible] I.D.~~	~~4~~					Transportation		~~15,000~~ 4,000
	~~Bore Recess & 30° Angle~~	~~10~~							
	– 1 Oper / ~~2 Machines~~		~~[illegible]~~		~~[illegible]~~		Heat Treat	1	60,000
			8.33		8.33		Installation		3,000
020	Transport				.250		Transportation		2,000
	Face		8.33		8.33				
~~030~~	~~Face To Length~~	~~5~~					~~NC Chucker~~	~~3~~	~~700,000~~
	~~Machine 30° Angle At~~	~~10~~					~~Installation~~		~~30,000~~
	~~18.000 Dia [illegible] Length~~						~~Transportation~~		~~6,000~~
	~~C'Bore 12.25 Dia .125 Deep~~	~~[illegible]~~	~~36.667~~		~~11.333~~				
	~~1 Oper / 2 Machines~~						Grinder	1	200,000
	Transport				.250		Installation		10,000
~~040~~	~~Transport~~				~~[illegible]~~		Transportation		2,000
050	Drill (12) .531 Dia & Burr	2	3.333		3.333		Multi Spindle Drill		— 0 —
	Scrap Loss 4%		3.800		3.800			Use Excess	
	Inspection				1.000			Capacity in	
								Other Areas	
	Total				~~[illegible]~~				

25.30

LABOR AND EQUIPMENT ESTIMATING SHEET

Page No. ____

CBS Number: 4420 **Part:** Bearing Retainer Ring **Part No.:** 651139-42

Date: 10/20/80 **Qty./Heliostat:** 1 **Sheet No.:** 1 **Of** 2

OPER. NO.	OPERATION DESCRIPTION	PRODUCTION ESTIMATE — MACHINE: Min/Pc	MACHINE: Hrs/100 Pc @	LABOR: GRADE	LABOR: Hrs/100 PC	LABOR: $/Hour	MACHINERY & EQUIPMENT	EQUIPMENT: Qt.	EQUIPMENT: Est. Cost
010	Face	3					NC Chucker	3	900,000
	Bore 17.250 I.D.	6					Installation		30,000
	Bore 18.0018 I.D.	7					Transportation		6,000
	Bore 18.380 I.D.	5							
	Chamf .09 x 45°	1	35.100		17.500				
	- 1 Oper / 2 Machines								
020	Transport				250				
030	Face To Length	3					NC Chucker	2	600,000
	Turn 21.125 O.D.	3					Installation		20,000
	Turn 19.000 O.D.	7					Transportation		4,000
	Chamf 30°	2	25.000		12.500				
	- 1 Oper / 2 Machines								
040	Transport				250				

LABOR AND EQUIPMENT ESTIMATING SHEET

CBS Number: 4420 Part: Bearing Retainer Ring Part No.: 651137-42

Date: 10/30/80 Qty./Heliostat: 1 Sheet No.: 2 Of 2

OPER. NO.	OPERATION DESCRIPTION	PRODUCTION ESTIMATE – MACHINE – Min/Pc	PRODUCTION ESTIMATE – MACHINE – Hrs/100 Pc @	PRODUCTION ESTIMATE – LABOR – GRADE	PRODUCTION ESTIMATE – LABOR – Hrs/100 PC	PRODUCTION ESTIMATE – LABOR – $/Hour	MACHINERY & EQUIPMENT	EQUIPMENT – Qt.	EQUIPMENT – Est. Cost
050	Drill (12) .531 Dia &	2	3.333		3.333		Multi Spindle Drill		-0-
	Burr						Installation	Use Excess	
							Transportation	Capacity in	
	Scrap Loss 4%		2.533		2.533			Other Areas	
	Inspection				1.[illegible]				
							HEAT TREAT	1	60,000
	Total				37.366		INSTALLATION		3,000
							TRANSPORTATION		2,000
							GRINDER	1	200,000
							INSTALLATION		10,000
							TRANSPORTATION		2,000

LABOR AND EQUIPMENT ESTIMATING SHEET

Page No. ____

CBS Number: 4420 Part: ELEVATION GEAR Part No.: 651137-41

Date: 11/3/80 Qty./Heliostat: 1 Sheet No.: 1 Of 2

OPER. NO.	OPERATION DESCRIPTION	PRODUCTION ESTIMATE: MACHINE Min/Pc	MACHINE Hrs/100 Pc @	LABOR GRADE	LABOR Hrs/100 PC	LABOR $/Hour	MACHINERY & EQUIPMENT	EQUIPMENT Qt.	EQUIPMENT Est. Cost
010	FACE	3					NC CHUCKER	3	900,000
	BORE 12.504 I.D.	5					INSTALLATION		30,000
	TURN 16.500 DIA	3					TRANSPORTATION		6,000
	TURN 16.000 DIA	4							
	TURN 15.747 DIA	4							
	CHAMF .13 X 45°	0.5	32.500						
	-1 OPER / 2 MACHINES				16.250				
015	TRANSPORT				.500				
020	FACE TO LENGTH	4					NC CHUCKER	2	600,000
	TURN 18.000 DIA	5					INSTALLATION		20,000
	TURN 16.256 DIA	5					TRANSPORTATION		4,000
	CHAMF .13 X 45°	0.5	24.167						
	-1 OPER / 2 MACHINES				12.083				
025	TRANSPORT				.500				
030	CUT WORM TEETH	120	200.000				GEAR HOBBER	18	4,140,000
	-1 OPER / [illegible] MACHINES				20.000		INSTALLATION		180,000
							TRANSPORTATION		36,000

LABOR AND EQUIPMENT ESTIMATING SHEET

Page No. ____

CBS Number: 4420 **Part:** Elevation Gear **Part No.:** 65 1137-41

Date: 11/3/80 **Qty./Heliostat:** 1 **Sheet No.:** 2 **Of** 2

OPER. NO.	OPERATION DESCRIPTION	PRODUCTION ESTIMATE – MACHINE: Min/Pc	MACHINE: Hrs/100 Pc @	LABOR: Grade	LABOR: Hrs/100 PC	LABOR: $/Hour	MACHINERY & EQUIPMENT	EQUIPMENT: Qt.	EQUIPMENT: Est. Cost
040	Drill & Tap (12) 5/8 -11 Holes	3	5.000		5.000		Multi Spindle Drill	1	11,000
							Installation		5,000
050	Drill & Tap (12) 5/8 -11 Holes	3	5.000		5.000		Transportation		2,000
	Scrap Loss 4%		10.667		10.667				
	Inspection	10			16.667		Heat Treat	1	60,000
							Installation		3,000
							Transportation		2,000
	Total				86.667				
							Grinder	1	200,000
							Installation		10,000
							Transportation		2,000

LABOR AND EQUIPMENT ESTIMATING SHEET

Page No. ____

CBS Number: 4420   Part: Azimuth Gear   Part No.: 65/1137-46

Date: 11/21/80   Qty./Heliostat: 1   Sheet No.: 1 Of 2

OPER. NO.	OPERATION DESCRIPTION	PRODUCTION ESTIMATE – MACHINE Min/Pc	MACHINE Hrs/100 Pc @	LABOR GRADE	LABOR Hrs/100 PC	LABOR $/Hour	MACHINERY & EQUIPMENT	EQUIPMENT Qt.	EQUIPMENT Est. Cost
010	Face	3					NC Chucker	3	900,000
	Bore 1.3756 I.D.	4					Installation		30,000
	Turn 4.506 Dia	8					Transportation		6,000
	Turn 17.875 Dia	5	33 333						
	-1 Oper/2 Mach				16 667				
015	Transport				500				
020	Face To Length	3					NC Chucker	2	600,000
	Turn 16.000 Dia	5					Installation		21,000
	Chamf .13 X 45°	.5					Transportation		4,000
	-1 Oper/2 Mach		14 167		7 083				
025	Transport				500				
030	Cut Worm Teeth	120	200 000				Gear Hobber	18	4,140,000
	-1 Oper/6 Machines				20 000		Installation		180,000
							Transportation		36,000

H-45

LABOR AND EQUIPMENT ESTIMATING SHEET

Page No. ____

CBS Number: 4420 Part: Azimuth Gear Part No.: 651137-46

Date: 11/21/80 Qty./Heliostat: 1 Sheet No.: 2 Of 2

OPER. NO.	OPERATION DESCRIPTION	PRODUCTION ESTIMATE MACHINE Min/Pc	MACHINE Hrs/100 Pc @	LABOR GRADE	LABOR Hrs/100 PC	$/Hour	MACHINERY & EQUIPMENT	EQUIPMENT Qt.	Est. Cost
040	Drill + Tap (6) 3/4-10	3	5.000		5.000		Multi Spindle Drill	1	70,000
							Installation		5,000
050	Drill + Tap (16) 3/8-16	3	5.000		5.000		Transportation		2,000
	Scrap Loss 4%				10.240				
							Heat Treat	1	60,000
	Inspection	10			16.667		Installation		5,000
							Transportation		2,000
	Total				81.717				
							Grinder	1	200,000
							Installation		10,000
							Transportation		2,000

LABOR AND EQUIPMENT ESTIMATING SHEET

Page No. ____

CBS Number: 4420 | Part: WORM | Part No.: 651137-59

Date: 11/21/80 | Qty./Heliostat: 2 | Sheet No.: 1 Of 2

OPER. NO.	OPERATION DESCRIPTION	PRODUCTION ESTIMATE MACHINE Min/Pc	MACHINE Hrs/100 Pc @	LABOR GRADE	LABOR Hrs/100 PC	LABOR $/Hour	MACHINERY & EQUIPMENT	EQUIPMENT Qt.	EQUIPMENT Est. Cost
010	FACE	1					NC BAR MACHINE	5	1,500,000
	TURN O.D.	3					INSTALLATION		50,000
	DRILL, TAP & C' BORE	3					TRANSPORTATION		10,000
	TURN 3.437 DIA	3							
	TURN 2.393 DIA	3							
	TURN 2.016 DIA	2							
	CHAMFER	.5							
	CUT-OFF	2	29.167						
	- USE PRE-HEAT								
	TREATED NITRIDING STEEL								
	- 1 OPER / 2 MACHINES				14.583				
015	TRANSPORT				.500				
020	FACE TO LENGTH	1					NC CHUCKER	3	900,000
	CENTER	.5					INSTALLATION		30,000
	TURN 3.437 DIA	3					TRANSPORTATION		6,000
	TURN 2.393 DIA	3							
	CHAMFER	.5	13.333		13.333				

LABOR AND EQUIPMENT ESTIMATING SHEET

Page No. ____

CBS Number: 4420   Part: WORM   Part No.: 65 1137-59

Date: 11/21/80   Qty./Heliostat: 2   Sheet No.: 2 Of 2

OPER. NO.	OPERATION DESCRIPTION	PRODUCTION ESTIMATE – MACHINE – Min/Pc	MACHINE – Hrs/100 Pc @	LABOR – GRADE	LABOR – Hrs/100 PC	LABOR – $/Hour	MACHINERY & EQUIPMENT	EQUIPMENT – Qt.	EQUIPMENT – Est. Cost
030	CUT WORM	86					THREAD GRINDER	30	4,350,000
	- 2 CUTS						INSTALLATION		300,000
	CHAMFER WORM EDGE	18					TRANSPORTATION		60,000
	- NOT SHOWN ON PRINTS		170.000						
	-1 OPER / 6 MACHINES				28.333				
040	GRIND THREAD	30	50.000				O. D. GRINDER	9	1,800,000
	-1 OPER / 2 MACHINES				25.100		INSTALLATION		90,000
							TRANSPORTATION		18,000
050	GRIND 2,3765 DIA	6							
	- 2 PLACES								
	GRIND 2.000 DIA	3	15.000		15.000		GRINDER	3	600,000
							INSTALLATION		30,000
	NITRIDE						TRANSPORTATION		6,000
	- LOAD / UNLOAD				2.000				
	SCRAP LOSS 4%								
	INSPECTION	10			16.667		HEAT TREAT		82,500
							INSTALLATION		4,500
	TOTAL				115.416		TRANSPORTATION		2,500

HELIOSTAT MIRROR MODULE PRODUCTION EQUIPMENT COST

WORM (Heat Treat)

SHEET 1 OF 1

MACHINE NAME	NUMBER REQUIRED	INVOICE PRICE	TRANSPORTATION COST	UNLOADING AND INSTALLATION REMODELING AND COST	ESTIMATED MACHINE LIFE YEARS/UNITS	AVERAGE YEARLY MAINTENANCE COST	TOTAL COST
Induction heater Work Station OL-204	1	$9.5K	$.5K	$.5K	10+ yrs.	$.5K	$10.5K
Weld Scanner 30" stroke (OL-103)	1	$23K	$.5K	$1.5K	10+ yrs	—	$25K
Quench System	1	$16K	$.5K	$.5K	10+ yrs	$1K	$17K
Cooling System	1	$6K	$.5K	$.5K	10+ yrs	$.5K	$7K
Power Source 100KW, 10K HZ.	1	28K	$.5K	$1.5K	10+ yrs.	—	$30K
		82.5K	2.5K	4.5K			

84.[illegible]

LABOR AND EQUIPMENT ESTIMATING SHEET

Page No. ____

CBS Number: 4420 Part: ELEVATION HOUSING Part No.: 651137-40

Date: 11/1/80 Qty./Heliostat: 1 Sheet No.: 1 Of 2

OPER. NO.	OPERATION DESCRIPTION	PRODUCTION ESTIMATE MACHINE Min/Pc	MACHINE Hrs/100 Pc @	LABOR GRADE	LABOR Hrs/100 PC	LABOR $/Hour	MACHINERY & EQUIPMENT	EQUIPMENT Qt.	EQUIPMENT Est. Cost
010	MILL BOTTOM FACE	5					INTEGRATED MANUFACTURING SYSTEM	1	5,000,000
	DRILL & REAM (2) .812 HOLES	2					OR TRANSFER LINE		
	- USE FOR LOCATION								
	DRILL (4) .412 DIA HOLES	1	13.333						
	- INDEX FIXTURE								
020	MILL TO 26.5 DIM	2							
	BORE 1.504 DIA	5							
	BORE 1.711 DIA & CHAMF 15°	2							
	DRILL & TAP (4) 3/8-16 HOLES	2							
	DRILL & TAP (1) NPT 1/2-13	1	20.000				(CONTROLLING TIME)		
	- ROTATE FIXTURE								
030	MILL FACE TO 4.375 DIM	10							
	BORE 19.005 DIA & }	10							
	BORE 19.752 DIA }	(10)							
	CHAMF .09 X 45°	2							
	DRILL & TAP (12) 1/2-13 HOLES	2	40.000				(2 STATIONS)		
	- INDEX TABLE								
040	MILL FACE TO 8.250 DIM	5							
	BORE 5.125 DIA	12							
	DRILL & TAP (4) 3/8-16 HOLES	2							
	MILL FACE TO 10.812 DIM	(5)							

LABOR AND EQUIPMEN. .STIMATING SHEET

Page No. ____

CBS Number: 4420 | Part: ELEVATION HOUSING | Part No.: 65 1137-40

Date: 11/1/80 | Qty./Heliostat: 1 | Sheet No.: 2 Of 2

OPER. NO.	OPERATION DESCRIPTION	PRODUCTION ESTIMATE — MACHINE: Min/Pc	MACHINE: Hrs/100 Pc @	LABOR: GRADE	LABOR: Hrs/100 PC	LABOR: $/Hour	MACHINERY & EQUIPMENT	EQUIPMENT: Qt.	EQUIPMENT: Est. Cost
	DRILL .500 DIA	(3)							
	DRILL & TAP (4) 1/4-20 HOLES	(2)	31.667				(2 STATIONS)		
	- INDEX TABLE								
050	DRILL & TAP (1) 1/2 NPT	2	3.333						
	- INDEX TABLE								
	DRILL & TAP (1) 1/2 NPT	2	3.333						
	SCRAP LOSS 4%		5.133		5.133				
	2 OPER / LINE				24.000		ASSUMED ONE LINE COULD PRODUCE		
							200 ELEVATION HOUSINGS / 3 SHIFTS		
	INSPECTION				16.000				
	TOTAL				45.133				

LABOR AND EQUIPMENT ESTIMATING SHEET

Page No. ____

CBS Number: 4420 Part: Azimuth Housing Part No.: 651137-45

Date: 11/1/80 Qty./Heliostat: 1 Sheet No.: 1 Of 2

OPER. NO.	OPERATION DESCRIPTION	PRODUCTION ESTIMATE: MACHINE Min/Pc	MACHINE Hrs/100 Pc @	LABOR GRADE	LABOR Hrs/100 PC	LABOR $/Hour	MACHINERY & EQUIPMENT	EQUIPMENT Qt.	EQUIPMENT Est. Cost
010	Face	5					Integrated Machining Center or	1	5,000,000
	Bore 17.502 Dia	(10)					Transfer Line		
	Bore 18.000 Dia	5							
	Bore 18.504 Dia	10							
	Face Step	5	41.667						
	- Index Table								
020	Spot Face	3							
	Bore 5.127 Dia	12							
	C'Bore 6.875	3							
	Drill & Tap (8) 3/8-16 Holes	2	33.333						
	- Index Table								
030	Mill Face To 3.755 Dim	5							
	Bore 1.504 Dia	7							
	C'Bore 1.711 Dia & 15° Chmf	3							
	Drill & Tap (4) 3/8-16 Holes	2	28.333						
	-Index Table								

LABOR AND EQUIPMENT ESTIMATING SHEET

Page No. ____

CBS Number: 4430 Part: Azimuth Housing Part No.: 651189-45

Date: 11/1/80 Qty./Heliostat: 1 Sheet No.: 2 Of 2

OPER. NO.	OPERATION DESCRIPTION	PRODUCTION ESTIMATE — MACHINE Min/Pc	MACHINE Hrs/100 Pc @	LABOR GRADE	LABOR Hrs/100 PC	LABOR $/Hour	MACHINERY & EQUIPMENT	EQUIPMENT Qt.	EQUIPMENT Est. Cost
050	Drill & Tap (12) 5/8 - 11 Holes	2							
	(12) 1/2 - 13	(2)							
	(1) 3/8 NPT	2							
	(1) 1/2 NPT	2	10.000						
–	Scrap Loss 4%		4.800		4.800				
	2 Oper / Machine				24.000		Assumed One Line Running		
	Inspection				16.000		3 Shifts		
	Total				44.800				

LABOR AND EQUIPMENT ESTIMATING SHEET

Page No. ____

CBS Number: 4420 Part: Planetary Frame Part No.: 651139-52

Date: 11/3/80 Qty./Heliostat: 2 Sheet No.: 1 Of 2

OPER. NO.	OPERATION DESCRIPTION	PRODUCTION ESTIMATE: MACHINE Min/Pc	MACHINE Hrs/100 Pc @	LABOR GRADE	LABOR Hrs/100 PC	LABOR $/Hour	MACHINERY & EQUIPMENT	EQUIPMENT Qt.	EQUIPMENT Est. Cost
010	Face	2					NC Chucker	4	720,000
	Bore 1.637 Dia	8					Installation		20,000
	Chamf .06 x 45°	0.5					Transportation		8,000
	Cut Off	3	22.500						
	-1 Oper/2 Machines				11.250				
015	Transport				.250				
020	Face to Length	3	5.000		5.000		NC Chucker	1	180,000
							Installation		5,000
025	Transport				.250		Transportation		2,000
								3	300,000
030	~~Rough Mill 5.00 Radius~~						Mill	~~[illegible]~~	~~[illegible]~~
	~~Side 1~~	~~4~~					Installation		~~[illegible]~~ 15,000
	~~Side 2~~	~~4~~					Transportation		~~[illegible]~~ 6,000
	Finish Mill								
	Side 1	4							
	Side 2	4	~~40.000~~ 13.333		6.667				
	1-Oper/2 Machines				~~[illegible]~~				
040	Transport				.250				

LABOR AND EQUIPMENT ESTIMATING SHEET

Page No. ____

CBS Number: 4430 **Part:** Planetary Frame **Part No.:** 651137-52

Date: 11/3/80 **Qty./Heliostat:** 2 **Sheet No.:** 2 **Of** 2

OPER. NO.	OPERATION DESCRIPTION	PRODUCTION ESTIMATE — MACHINE Min/Pc	MACHINE Hrs/100 Pc @	LABOR GRADE	LABOR Hrs/100 PC	LABOR $/Hour	MACHINERY & EQUIPMENT	EQUIPMENT Qt.	EQUIPMENT Est. Cost
060	Drill & Bore (2) .627 Dia	3	5 000		5 000		Multi Spindle Drill	1	70,000
							Installation		5,000
	Scrap Loss 4%		2 900		2 900		Transportation		2,000
	Inspection				1 000				
	Total				45 900				
					32 567				

LABOR AND EQUIPMENT ESTIMATING SHEET

Page No. ____

CBS Number: 4420 Part: PLANETARY COVER Part No.: 65 1137-51

Date: 11/4/80 Qty./Heliostat: 2 Sheet No.: 1 Of 2

OPER. NO.	OPERATION DESCRIPTION	PRODUCTION ESTIMATE MACHINE Min/Pc	MACHINE Hrs/100 Pc @	LABOR GRADE	LABOR Hrs/100 PC	$/Hour	MACHINERY & EQUIPMENT	EQUIPMENT Qt.	Est. Cost
010	FACE	3					NC CHUCKER	8	1,440,000
	TURN 7.499 DIA	5					INSTALLATION		80,000
	BORE 1.250 DIA	3					TRANSPORTATION		16,000
	TURN 1.625 DIA + FACE	5							
	BORE 5.375 DIA	5							
	BORE 6.753 DIA	5							
	-1 OPER / 2 MACHINES		43.333		21.667				
020	TRANSPORT				.250				
030	FACE TO LENGTH	3					NC CHUCKER	4	720,000
	BORE 2.1257 DIA	5					INSTALLATION		40,000
	C' BORE 2.192 DIA	2					TRANSPORTATION		8,000
	CUT I.D. GROOVE	2							
	CHAMF .193 X 45°	2	23.333						
	-LOCATING PLUG ON FACE PLATE								
	-1 OPER / 2 MACHINES				11.667				
040	TRANSPORT				.250				

H-56

LABOR AND EQUIPMENT ESTIMATING SHEET

Page No. ____

CBS Number: 4420 | Part: Planetary Cover | Part No.: 651137-51

Date: 11/4/80 | Qty./Heliostat: 2 | Sheet No.: 2 Of 2

OPER. NO.	OPERATION DESCRIPTION	PRODUCTION ESTIMATE MACHINE Min/Pc	MACHINE Hrs/100 Pc @	LABOR GRADE	LABOR Hrs/100 PC	LABOR $/Hour	MACHINERY & EQUIPMENT	EQUIPMENT Qt.	EQUIPMENT Est. Cost
050	Drill (6) .406 Dia Holes	1					Multi Spindle Drill	3	210,000
	Burr	1	3.333				Installation		15,000
							Transportation		6,000
060	Drill & Tap (6) .250 Dia	2	3.333						
070	Drill & Tap (4) 1/4-20 Holes	2	3.333						
080	Drill & Tap (3) 1/4 NPT	2	3.333		13.332				
	Scrap Loss 4%		3.200		3.200				
	Inspection				2.000				
	Total				52.366				

H-57

LABOR AND EQUIPMENT ESTIMATING SHEET

Page No. ____

CBS Number: 4420 Part: PLANETARY HOUSING Part No.: 651137-50

Date: 11/4/80 Qty./Heliostat: 2 Sheet No.: 1 Of 7

OPER. NO.	OPERATION DESCRIPTION	PRODUCTION ESTIMATE: MACHINE Min/Pc	Hrs/100 Pc @	GRADE	LABOR Hrs/100 PC	$/Hour	MACHINERY & EQUIPMENT	EQUIPMENT Qt.	Est. Cost
010	FACE	8					NC CHUCKER	3	540,000
	TURN 5.124 DIA.	5					INSTALLATION		15,000
	FACE TO .627 DIA	2	16 667				TRANSPORTATION		6,000
	-1 OPER / 2 MACHINES				8 334				
020	TRANSPORT				250				
030	FACE TO LENGTH	4					NC CHUCKER	2	360,000
	BORE 7.502 DIA	3	11 667				INSTALLATION		10,000
	-1 OPER / 2 MACHINES				5 834		TRANSPORTATION		4,000
040	TRANSPORT				250				
050	DRILL & TAP (6) 3/8-16	2	3 333		3 333		MULTI SPINDLE DRILL	1	70,000
							INSTALLATION		5,000
							TRANSPORTATION		2,000
060	DRILL & SPOT FACE (8)	2	3 333		3 333				
	.406 DIA HOLES								
	SCRAP LOSS 4%		1 400		1 400				
	INSPECTION				1 800				
	TOTAL				23 734				

LABOR AND EQUIPMENT ESTIMATING SHEET

CBS Number: 4420 Part: Planetary Gear Web Part No.: 651137-57

Date: 11/4/80 Qty./Heliostat: 2 Sheet No.: 1 Of 2

OPER. NO.	OPERATION DESCRIPTION	PRODUCTION ESTIMATE — MACHINE: Min/Pc	MACHINE: Hrs/100 Pc @	LABOR: GRADE	LABOR: Hrs/100 PC	LABOR: $/Hour	MACHINERY & EQUIPMENT	EQUIPMENT: Qt.	EQUIPMENT: Est. Cost
010	Turn 7.000 I.D.	3					NC Chucker	5	900,000
	Bore 2.218 I.D.	4					Installation		25,000
	Bore 2.630 Dia	3					Transportation		10,000
	Bore 6.753 Dia & Face	4							
	Bore 5.375 & 30° Angle	3	28.333		14.167				
	-1 Oper/2 Machines								
020	Face To Length	3					NC Chucker	1	180,000
	Chamf .062 X 45°	0.5	5.833		5.833		Installation		5,000
							Transportation		2,000
025	Transport				.250				
030	Broach .500 Keyway	0.5	.833		.833		Broaching Machine	1	150,000
							Installation		5,000
035	Transport				.250		Transportation		2,000
040	Drill (6) .250 Dia Holes	2	3.333		3.333		Multi Spindle Drill	2	140,000
	& Burr						Installation		10,000
	Drill & Tap (6) 1/4-20 Holes	3	5.000		5.000		Transportation		4,000
	-Fixture To Locate From Key								
	-1 Oper/2 Machines								

LABOR AND EQUIPMENT ESTIMATING SHEET

Page No. ____

CBS Number: 4420 Part: Planetary Gear Wel[illegible] Part No.: 65 1137-57

Date: 11/4/80 Qty./Heliostat: 2 Sheet No.: 2 Of 2

OPER. NO.	OPERATION DESCRIPTION	PRODUCTION ESTIMATE — MACHINE: Min/Pc	MACHINE: Hrs/100 Pc @	LABOR: GRADE	LABOR: Hrs/100 PC	LABOR: $/Hour	MACHINERY & EQUIPMENT	EQUIPMENT: Qt.	EQUIPMENT: Est. Cost
	Scrap Loss 4%		1.733		1.735				
	Inspection				1.000				
	Total				32.399				

LABOR AND EQUIPMENT ESTIMATING SHEET

Page No. ____

CBS Number: 4420 | Part: Primary Ring Gear / Secondary Ring Gear | Part No.: 651137-71 & 72

Date: 11/3/80 | Qty./Heliostat: 2 & 2 | Sheet No.: 1 Of 2

OPER. NO.	OPERATION DESCRIPTION	PRODUCTION ESTIMATE — MACHINE: Min/Pc	MACHINE: Hrs/100 Pc @	LABOR: GRADE	LABOR: Hrs/100 PC	LABOR: $/Hour	MACHINERY & EQUIPMENT	EQUIPMENT: Qt.	EQUIPMENT: Est. Cost
010	Face	3					NC Bar Machine w/Auto Loader	5	1,250,000
	Turn 6.803 Dia	3					Installation		50,000
	Turn 6.751 Dia	2	13.333				Transportation		10,000
	- Chuck I.D.								
020	Face To Length	3					NC Chucker	5	900,000
	Bore 4.9387 Dia	4	11.667				Installation		50,000
	- 1 Oper / 2 Machines				12.500		Transportation		10,000
	- Chuck O.D.								
025	Transport				.250				
030	Cut Gear Teeth	28	46.667				Gear Hobber	16	3,680,000
	- 3 Pcs At A Time						Installation		160,000
	- 1 Oper / 6 Mach				7.778		Transportation		32,000
040	Transport				.250				

LABOR AND EQUIPMENT ESTIMATING SHEET

Page No. ____

CBS Number: 4420 | Part: Primary Ring Gear / Secondary Ring Gear | Part No.: 65 1137-71 & 72

Date: 11/3/80 | Qty./Heliostat: 2 & 2 | Sheet No.: 2 Of 2

OPER. NO.	OPERATION DESCRIPTION	PRODUCTION ESTIMATE — MACHINE: Min/Pc	MACHINE: Hrs/100 Pc @	LABOR: GRADE	LABOR: Hrs/100 PC	LABOR: $/Hour	MACHINERY & EQUIPMENT	EQUIPMENT: Qt.	EQUIPMENT: Est. Cost
050	Drill & C'Bore (6)	1	1.667		1.667		Multi Spindle Drill	2	140,000
	.281 Holes						Installation		10,000
							Transportation		4,000
060	Drill (6) .250 Holes	1	1.667		1.667				
070	Drill, C'Bore & Tap	1	1.667		1.667				
	(3) 1/4-20 Holes								
080	Heat Treat								
	Scrap Loss 4% Oper		3.067		3.067				
	010, 020, 030, 050, 060, 070								
	Inspection				8.333				
	Total				37.179				

LABOR AND EQUIPMENT ESTIMATING SHEET

Page No. ____

CBS Number: 4420 | Part: Planet Gear | Part No.: 651137-55

Date: 11/3/80 | Qty./Heliostat: 4 | Sheet No.: 1 Of 2

OPER. NO.	OPERATION DESCRIPTION	PRODUCTION ESTIMATE: MACHINE Min/Pc	MACHINE Hrs/100 Pc @	LABOR GRADE	LABOR Hrs/100 PC	LABOR $/Hour	MACHINERY & EQUIPMENT	EQUIPMENT Qt.	EQUIPMENT Est. Cost
010	FACE	1					NC MULTI SPINDLE BAR MACHINE	5	800,000
	TURN O.D.	2					INSTALLATION		25,000
	BORE I.D.	4					TRANSPORTATION		10,000
	CUT-OFF	2	15.000						
	- 1 OPER / 2 MACH				7.500				
020	TRANSMAT				.250				
030	GRIND TO LENGTH	.403	.650		.650		BLANCHARD GRINDER	~~2~~ 1	~~200,000~~ 100,000
	- 30 TO 40 PCS AT ONE TIME						INSTALLATION		~~10,000~~ 5,000
							TRANSPORTATION		~~4,000~~ 3,000
040	TRANSMAT				.250				
050	CUT GEAR TEETH	11	18.333				GEAR HOBBER	7	700,000
	- 3 TO 4 AT A TIME						INSTALLATION		35,000
	- 1 OPER / 2 MACH				9.167		TRANSPORTATION		14,000
060	TRANSMAT				.250				
070	MILL 3.0 RADIUS SIDE 1	2					MILLING MACHINE	3	300,000
	MILL 3.0 " " 2	2	6.667		6.667		INSTALLATION		15,000
	- 10 PCS AT A TIME						TRANSPORTATION		6,000

LABOR AND EQUIPMENT ESTIMATING SHEET

Page No. ____

CBS Number: 4420 Part: Planet Gear Part No.: 651139-55

Date: 11/3/80 Qty./Heliostat: 4 Sheet No.: 2 Of 2

OPER. NO.	OPERATION DESCRIPTION	PRODUCTION ESTIMATE — MACHINE Min/Pc	MACHINE Hrs/100 Pc @	LABOR GRADE	LABOR Hrs/100 PC	LABOR $/Hour	MACHINERY & EQUIPMENT	EQUIPMENT Qt.	EQUIPMENT Est. Cost
080	Heat Treat								
	Nitride								
	Load / Unload				.500				
090	Hone I.D.	1	1.667		1.667		Automatic Hone	1	15,000
							Installation		2,000
	Scrap Loss 4% 010, 030		1.669		1.669		Transportation		1,000
	050, 070, 090								
	Inspection				8.333				
	Total				36.303				

LABOR AND EQUIPMENT ESTIMATING SHEET

Page No. ____

CBS Number: 4420 **Part:** Planetary Pinion **Part No.:** 651137-54

Date: 11/4/80 **Qty./Heliostat:** 2 **Sheet No.:** 1 **Of** 2

OPER. NO.	OPERATION DESCRIPTION	PRODUCTION ESTIMATE – MACHINE – Min/Pc	MACHINE – Hrs/100 Pc @	LABOR – GRADE	LABOR – Hrs/100 PC	LABOR – $/Hour	MACHINERY & EQUIPMENT	EQUIPMENT – Qt.	EQUIPMENT – Est. Cost
010	TURN 1.389 DIA	5					NC BAR MACHINE	5	900,000
	TURN 1.147 DIA	5					INSTALLATION		25,000
	MACHINE UNDERCUT 1.063 DIA	1					TRANSPORTATION		10,000
	TURN .741/.743 GEAR O.D.	3							
	CHAMF .185 X 45°	.1							
	GEAR UNDERCUT	1							
	CUT OFF	2	31 000						
	– 1 OPER / 2 MACHINES				15 000				
015	TRANSPORT				250				
020	FACE TO LENGTH	1					NC CHUCKER	2	360,000
	GUN DRILL FOR .625 DIA	3					INSTALLATION		10,000
	GUN REAM .625 DIA	1					TRANSPORTATION		4,000
	MACHINE UNDERCUT I.D.	1							
	CHAMF .062 X 45°	0.5	10 833						
	– 1 OPER / 2 MACHINES				5 417				
030	TRANSPORT				250				
040	BROACH 3/16 KEYWAY	2	3 333		3 333		BROACHING MACHINE	1	150,000
							INSTALLATION		5,000
045	TRANSPORT				250		TRANSPORTATION		2,000

LABOR AND EQUIPMENT ESTIMATING SHEET

Page No. ____

CBS Number: 4420 | Part: Planetary Pinion | Part No.: 651137-54

Date: 11/4/80 | Qty./Heliostat: 2 | Sheet No.: 2 Of 2

OPER. NO.	OPERATION DESCRIPTION	PRODUCTION ESTIMATE – MACHINE Min/Pc	MACHINE Hrs/100 Pc @	LABOR Grade	LABOR Hrs/100 PC	LABOR $/Hour	MACHINERY & EQUIPMENT	EQUIPMENT Qt.	EQUIPMENT Est. Cost
050	Grind 1.376 Dia	2					O.D. Grinder	2	125,000
	Grind 1.1255 Dia	2	6.667		6.667		Installation		10,000
							Transportation		4,000
060	Cut Gear	14	23.333		7.778		Gear Hobber	4	600,000
	1 Oper / 3 Machines						Installation		20,000
	Scrap Loss 4%		2.967		2.967		Transportation		8,000
	Inspection				8.333				
	Total				50.245				

LABOR AND EQUIPMENT ESTIMATING SHEET

Page No. ____

CBS Number: 4420 | Part: Stud - Azimuth Drive | Part No.: 651137-69

Date: 10/20/80 | Qty./Heliostat: 6 | Sheet No.: 1 Of 1

OPER. NO.	OPERATION DESCRIPTION	PRODUCTION ESTIMATE – MACHINE Min/Pc	MACHINE Hrs/100 Pc @	LABOR GRADE	LABOR Hrs/100 PC	LABOR $/Hour	MACHINERY & EQUIPMENT	EQUIPMENT Qt.	EQUIPMENT Est. Cost
010	Cut Off & Chamf	.03	.050	1	.050	8.48	Horizontal 6 Spindle Bar Mach		— 0 —
							- Utilize Excess Capacity		
	Scrap Loss 4%		.002		.002		In Other Areas		
	Total				.052				

LABOR AND EQUIPMENT ESTIMATING SHEET

Page No. ____

CBS Number: 4420 Part: WORM SUPPORT - ELEVATION Part No.: 671137-60 & 61

Date: 11/4/80 Qty./Heliostat: 1 & 1 Sheet No.: 1 Of 1

OPER. NO.	OPERATION DESCRIPTION	PRODUCTION ESTIMATE: MACHINE Min/Pc	MACHINE Hrs/100 Pc @	LABOR GRADE	LABOR Hrs/100 PC	LABOR $/Hour	MACHINERY & EQUIPMENT	EQUIPMENT Qt.	EQUIPMENT Est. Cost
010	TURN 1.499 DIA	5	8 333				NC CHUCKER	2	360,000
							INSTALLATION		10,000
							TRANSPORTATION		4,000
020	FACE TO 0.25 DIM	3							
	TURN 3.000 DIA	2	8 333						
	- 1 OPER/2 MACHINES				8 333				
030	TRANSPORT				250				
040	DRILL (4) .406 DIA HOLES	2	3 333		3 333		MULTI SPINDLE DRILL	1	70,000
	+ BUR						INSTALLATION		5,000
050	TRANSPORT				250		TRANSPORTATION		2,000
060	MILL 2.250 RADIUS						MILLING MACHINE	1	110,000
	- 10 PCS AT A TIME	2	3 333		3 333		INSTALLATION		5,000
							TRANSPORTATION		2,000
	SCRAP LOSS 4%		933		933				
	INSPECTION				1 000				
							MACHINE QTYS REFLECT REQUIREMENTS		
					17 432		FOR BOTH PARTS.		

LABOR AND EQUIPMENT ESTIMATING SHEET

Page I ____

CBS Number: 4420 **Part:** Journal Pin **Part No.:** 651137-56

Date: 10/20/80 **Qty./Heliostat:** 4 **Sheet No.:** 1 **Of** 1

OPER. NO.	OPERATION DESCRIPTION	PRODUCTION ESTIMATE — MACHINE Min/Pc	MACHINE Hrs/100 Pc @	LABOR GRADE	LABOR Hrs/100 PC	$/Hour	MACHINERY & EQUIPMENT	EQUIPMENT Qt.	EQUIPMENT Est. Cost
010	Load Bar Feeder	Int							
020	Turn O.D. & Chamf	0.2	.333		.333		Horizontal 6 Spindle Bar Machine	1	160,000
	Cut Off & Chamf	0.2	.333		.333		- Installation		5,000
							- Transportation		2,000
030	Centerless Grind	0.1	.167		.167		Centerless Grinder	1	80,000
							- Installation		5,000
	Scrap Loss 4%		.033		.033		- Transportation		2,000
040	Heat Treat								
	- Load/Unload				.300				
	Total				1.366				

H-70

LABOR AND EQUIPMENT ESTIMATING SHEET

Page No. ____

CBS Number: 4420 | Part: Clamping Disc | Part No.: 651137-58

Date: 10/20/80 | Qty./Heliostat: 2 | Sheet No.: 1 Of 2

OPER. NO.	OPERATION DESCRIPTION	PRODUCTION ESTIMATE – MACHINE Min/Pc	MACHINE Hrs/100 Pc @	LABOR GRADE	LABOR Hrs/100 PC	LABOR $/Hour	MACHINERY & EQUIPMENT	EQUIPMENT Qt.	EQUIPMENT Est. Cost
005	Load Bar Stock	1					~~Overhead Jib & Sling~~	~~4~~	~~4,000~~
	- Internal To Mach. Cycle						~~Installation~~		~~2,000~~
010	Turn 2.625 Dia O.D.	1					NC Chucker	1	180,000
	Face	0.5					Installation		5,000
	Center Drill	0.5					Freight		2,000
	2' Bore 1.25	0.5							
	Cut Off	1	5.833						
	- Scrap 4%		.233						
	- 1 Oper/2 Mach				3.033				
020	Transport								
030	Face To Length	2					NC Chucker	2	360,000
	Turn 1.000 O.D.	2					Installation		10,000
	Chamf .032 × 45°	0.5	7.500				Freight		4,000

LABOR AND EQUIPMENT ESTIMATING SHEET

Page No. ____

CBS Number: 4420 Part: Clamping Disc Part No.: 651137-58

Date: 10/20/80 Qty./Heliostat: 2 Sheet No.: 2 Of 2

OPER. NO.	OPERATION DESCRIPTION	PRODUCTION ESTIMATE: MACHINE Min/Pc	MACHINE Hrs/100 Pc @	LABOR GRADE	LABOR Hrs/100 PC	LABOR $/Hour	MACHINERY & EQUIPMENT	EQUIPMENT Qt.	EQUIPMENT Est. Cost
030	- Scrap 4%		3.00						
	- 1 Oper/2 Machines				3.900				
040	Inspection				1.000				
	Total				7.933				

LABOR AND EQUIPMENT ESTIMATING SHEET

Page No. ____

CBS Number: 4420 Part: Drive & Motor Assem Part No.: 12-300

Date: 11/1/80 Qty./Heliostat: 1 Sheet No.: 1 Of 3

OPER. NO.	OPERATION DESCRIPTION	PRODUCTION ESTIMATE — MACHINE: Min/Pc	Hrs/100 Pc @	LABOR: GRADE	Hrs/ 100 PC	$/Hour	MACHINERY & EQUIPMENT	EQUIPMENT: Qt.	Est. Cost
010	Install Main Gear						Azimuth & Elevation Assembly		
	- Mount SS Retaining Rings						Line & Equipment		
	& Seals								
	- Set Main Gear								
	- Install Bearing								
	- " Outer Clamp						Labor: 50 Men/Shift		
	Ring & Gasket								
	- Install Inner Clamp								
	Ring & Gasket								
	- Install Oil Seals								
020	Mount Planetary Housing								
	- Subassemble Planetary								
	Gear Web & Primary								
	Ring Gear								
030	Install Planetary Gear								
	Web Subassembly								

LABOR AND EQUIPMENT ESTIMATING SHEET

Page No. ____

CBS Number: 4420 **Part:** Drive & Motor Assem. **Part No.:** 12-300

Date: 11/1/80 **Qty./Heliostat:** 1 **Sheet No.:** 2 **Of** 3

OPER. NO.	OPERATION DESCRIPTION	PRODUCTION ESTIMATE: MACHINE Min/Pc	MACHINE Hrs/100 Pc @	LABOR GRADE	LABOR Hrs/100 PC	LABOR $/Hour	MACHINERY & EQUIPMENT	EQUIPMENT Qt.	EQUIPMENT Est. Cost
050	Install Clamping Disc								
	- Subassemble Planetary								
	Frame								
	" Planetary Frame								
	" Planet Gear								
	" Journal Pin								
060	Install Planetary Frame								
	- Subassemble Planetary								
	Cover Assembly								
	" Cover								
	" Bearing								
	" Retainer Ring								
	" Pinion Gear								
	" Secondary Ring Gear								
070	Install Planetary Cover								
	Assembly								

LABOR AND EQUIPMENT ESTIMATING SHEET

Page No. ____

CBS Number: 4420 **Part:** DRIVE & MOTOR ASSEM **Part No.:** 12-380

Date: 11/1/80 **Qty./Heliostat:** 1 **Sheet No.:** 3 **Of** 3

OPER. NO.	OPERATION DESCRIPTION	PRODUCTION ESTIMATE MACHINE Min/Pc	Hrs/100 Pc @	LABOR GRADE	Hrs/ 100 PC	$/Hour	MACHINERY & EQUIPMENT	EQUIPMENT Qt.	Est. Cost
080	INSTALL WORM STOP,								
	EXPANSION CHAMBER,								
	MOTOR, OIL								
090	TEST								
100	PAINT						Paint Line		700,000
110	ASSEMBLE AZIMUTH DRIVE								
	TO ELEVATION DRIVE.								
							Assembly Line		200,000

HELIOSTAT CONTROLS PRODUCTION EQUIPMENT COST

MACHINE NAME	NUMBER REQUIRED	INVOICE PRICE (TOTAL)	TRANSPORTATION COST	UNLOADING AND INSTALLATION REMODELING AND COST	ESTIMATED MACHINE LIFE YEARS/UNITS	AVERAGE YEARLY MAINTENANCE COST		TOTAL COST
						PARTS	LABOR	
FLOW SOLDER MACHINE & DEGREASER HOLLIS ENGINEERING	1	10,000			15	500	1200	
SEMI-AUTOMATIC DIP INSERTER AMISTAR CORP.	1	15,900			15	250	500	
LEAD FORM MACHINE ELECTROVERT	1	3,000			15	200	500	
CLINCH & TRIM TOOL	20	~~200~~ ✓			1	—	—	
BURN-IN OVEN BEMCO	1	12,000			15	200	500	
TEST EQUIPMENT FOR MODULE REPAIR	—	8,000			15	100	500	
40 PIN & 24 PIN IC INSERTION TOOL	20	~~200~~ ✓			2	—	—	
CABLE TERMINATION EQUIPMENT AMP INC.	—	5,000			10	100	500	
μP BOARD TESTER	5	2500 (12500)			10	—	250 1250	
POWER SUPPLY TESTER	5	1500 (7500)			10	—	250 1250	
TRANSLATOR TESTER	5	1750 (8750)			10	—	250 1250	

✓ – INDIRECT MATERIALS

HELIOSTAT CONTROLS PRODUCTION EQUIPMENT COST

SHEET 2 OF 2

MACHINE NAME	NUMBER REQUIRED	INVOICE PRICE TOTAL	TRANSPORTATION COST	UNLOADING AND INSTALLATION REMODELING AND COST	ESTIMATED MACHINE LIFE YEARS/UNITS	AVERAGE YEARLY MAINTENANCE COST PARTS	AVERAGE YEARLY MAINTENANCE COST LABOR	TOTAL COST
HFC TESTER	3	1500 (4500)			10	—	150 450	
CABLE #1 TESTER	3	150 (450)			10	—	150 450	
CABLE #2 TESTER	3	150 (450)			10	—	150	
CABLE #3 TESTER	3	150 (450)			10	—	150	
CABLE #4 TESTER	3	150 (450)			10	—	150	
CABLE #5 TESTER	3	150 (450)			10	—	150	
ASSEMBLY TESTER	3	1500 (4500)			10	—	150	
BOARD STORAGE TRAYS	50	~~388~~ ✓			5	—	—	
PARTS BINS	264	~~792~~ ✓			5	—	—	
		93900						

✓ - INDIRECT MATERIALS

HELIOSTAT MATERIAL HANDLING PRODUCTION EQUIPMENT COST

ELECTRONICS

SHEET 1 OF 1

MACHINE NAME	NUMBER REQUIRED	INVOICE PRICE	TRANSPORTATION COST	UNLOADING AND INSTALLATION REMODELING AND COST	ESTIMATED MACHINE LIFE YEARS/UNITS	AVERAGE YEARLY MAINTENANCE COST	TOTAL COST
PART CAROUSEL	2	22,500 (45000)	500 (1000)	1,000 (2000)	10	500	48,000
PALLET RACKS	88 PALLET POSITIONS	4,400	500	INCLUDED IN COST	10	100	4,900
4,000 LB FORK LIFT	1	32,200	500	–	7	960	32,700
		81600	2000	2000			

85600

PRODUCTION EQUIPMENT COST

PILE ASSY

SHEET ______ OF ______

MACHINE NAME	NUMBER REQUIRED	INVOICE PRICE	TRANSPORTATION COST	UNLOADING AND INSTALLATION REMODELING AND COST	ESTIMATED MACHINE LIFE YEARS/UNITS	AVERAGE YEARLY MAINTENANCE COST	TOTAL COST
Flange, end							
1000-Ton press	1	420	20	40			
Flange, opening							
1000-ton press	1	420	20	40			
Pile							
200-ton press	1	80	8	12			
Feeder Stacker	2	40 (80)	.5	.5			
Bending rolls	2	75 (150)	.5	.5			
Seam welder	2	35 (70)	.7	.7			
Pile Assy							
Welder	2	50 (100)					
		1320	50	94			1464

PRODUCTION EQUIPMENT COST

TORQUE TUBE ASSY

SHEET ______ OF ______

MACHINE NAME	NUMBER REQUIRED	INVOICE PRICE	TRANSPORTATION COST	UNLOADING AND INSTALLATION REMODELING AND COST	ESTIMATED MACHINE LIFE YEARS/UNITS	AVERAGE YEARLY MAINTENANCE COST	TOTAL COST
Flange							
1000-Ton Press	1	420	20	40			
Bracket							
300-ton press	1	150	8	15			
		570	28	55			653

HELIOSTAT STRUCTURAL SUPPORT PRODUCTION EQUIPMENT COST

TORQUE TUBE 1/3 PLATE

SHEET 1 ______ OF ______

MACHINE NAME	NUMBER REQUIRED	INVOICE PRICE	TRANSPORTATION COST	UNLOADING AND INSTALLATION REMODELING AND COST	ESTIMATED MACHINE LIFE YEARS/UNITS	AVERAGE YEARLY MAINTENANCE COST	TOTAL COST
FEEDER STACKER	2	40,000 (80,000)	1500 (3000)	500 (1000)	10	400 800	83,000
BENDING ROLLS	2	75,000 (150,000)	500 (1000)	500 (1000)	10	1000 2000	152,000
SEAM WELDER	4	26,000 (104,000)	700 (2800)	700 (2800)	10	1000 3000	82200
ASSEMBLY JIG WELDER	2	20,000 (40000)	500 (1000)	1000 (2000)	10	500 1000	43,000
FLANGE WELD ASSEMBLY	2	25,000 (50 000)	500 (1000)	500 (1000)	10	500 1000	52000
						7800	412200
		424,000	8800	7[illegible]	440,600		

HELIOSTAT STRUCTURAL SUPPORT PRODUCTION EQUIPMENT COST

SLITTING LINE

SHEET 2 OF

MACHINE NAME	NUMBER REQUIRED	INVOICE PRICE	TRANSPORTATION COST	UNLOADING AND INSTALLATION REMODELING AND COST	ESTIMATED MACHINE LIFE YEARS/UNITS	AVERAGE YEARLY MAINTENANCE COST	TOTAL COST
PAYOFF REEL	1	49,000	600	500	10		49,500
COIL CAR	1	18,200	500	500	10		19,200
2 UNIT SLITTING MACH.	1	236,000	1000	1500	10		2[illegible],000
SCRAP REWIND	1	5,600	500	500	10		6,600
2 ARM TURNSTILE	1	28,000	600	500	10		29,100
		336,800	3200	3500		5000	$343,500

HELIOSTAT STRUCTURAL SUPPORT PRODUCTION EQUIPMENT COST

TRUSS

FLANGE LINE

SHEET 2 OF ____

MACHINE NAME	NUMBER REQUIRED	INVOICE PRICE	TRANSPORTATION COST	UNLOADING AND INSTALLATION REMODELING AND COST	ESTIMATED MACHINE LIFE YEARS/UNITS	AVERAGE YEARLY MAINTENANCE COST	TOTAL COST
STOCK REEL	1	17,250	500	500	10	500	18250
LEVELER	1	21,000	600	700	10	1000	22300
NOTCH MACHINE CO-16-48	1	52,200	1000	1000	10	2000	54200
NOTCH TABLE	1	5,200	400	200	10	100	5800
NOTCH MACHINE CO-16-30	1	50,000	1000	1000	10	1000	52000
NOTCH TABLE	1	5,200	400	200	10	100	5800
ROLL FORMER 12MW2	1	63,000	2000	1000	10	2000	66000
			5900	4600		6700	203,371

213,850

STAT STRUCTURAL SUPPORT CTION EQUIPMENT COST

TRUSS

FLANGE LINE

SHEET 3 OF

MACHINE NAME	NUMBER REQUIRED	INVOICE PRICE	TRANSPORTATION COST	UNLOADING AND INSTALLATION REMODELING AND COST	ESTIMATED MACHINE LIFE YEARS/UNITS	AVERAGE YEARLY MAINTENANCE COST	TOTAL COST
CUTOFF CO-10-10	1	37,000	600	700	10	1000	38300
ELECTRONIC COUNTER	1	11,700	300	400	10	400	12400
TOOLING (FLANGE) -ROLLS -PIECE DIES -CUTOFF		70,000	600	200	10	2500	70800
		118,700	1500	1300		3900	121,500

H-83

HELIOSTAT STRUCTURAL SUPPORT PRODUCTION EQUIPMENT COST

TUBE LINE

SHEET 4 OF ____

MACHINE NAME	NUMBER REQUIRED	INVOICE PRICE	TRANSPORTATION COST	UNLOADING AND INSTALLATION REMODELING AND COST	ESTIMATED MACHINE LIFE YEARS/UNITS	AVERAGE YEARLY MAINTENANCE COST	TOTAL COST
STOCK REEL HR-6-0	1	15000	500	500	10	500	26000
LEVELER 6R-10	1	21000	600	700	10	1000	22300
JOINTER COIL END C-11-G	1	11000	500	500	10	500	12000
FLOOR STOCK ACC. MR-10	1	65000	2000	1000	10	2000	68000
ROLL FORMER 12-MW	1	63000	2000	1000	10	2000	66000
SEAM WELDER VT-100	1	100,000	2000	1000	10	1000	103000
		275 000	7600	4700		7000	297300

OSTAT STRUCTURAL SUPPORT **UCTION EQUIPMENT COST**

TUBE LINE

SHEET 5 OF

MACHINE NAME	NUMBER REQUIRED	INVOICE PRICE	TRANSPORTATION COST	UNLOADING AND INSTALLATION REMODELING AND COST	ESTIMATED MACHINE LIFE YEARS/UNITS	AVERAGE YEARLY MAINTENANCE COST	TOTAL COST
STRAIGHTENER	1	40000	600	700	10	1000	41300
CUTOFF CO-4-8	1	22000	600	700	10	1000	23300
RUNOUT TABLE 44'	1	4200	400	200	10	100	4800
TOOLING	1	35000	600	200	10	2500	35800
		101200	2200	1800		4600	105200

HELIOSTAT STRUCTURAL SUPPORT PRODUCTION EQUIPMENT COST

TRUSS

TRUSS ASSEMBLY

SHEET 6 OF ____

MACHINE NAME	NUMBER REQUIRED	INVOICE PRICE	TRANSPORTATION COST	UNLOADING AND INSTALLATION REMODELING AND COST	ESTIMATED MACHINE LIFE YEARS/UNITS	AVERAGE YEARLY MAINTENANCE COST	TOTAL COST
WEB BENDER	1	150,000	1000	1000	10	1000	152,000
ASSEMBLY JIG -FLANGE -WEB -	1	250,000	2000	2000	10	1000	254,000
AUTOMATIC RESISTANCE WELD	1	350,000	2000	3000	10	2000	355,000
STORAGE RACKS -TRANSFER SYSTEM	1	250,000	2000	4000	10	1000	256,000
TOOLING		200,000	1000				
TOTAL SYSTEM		1,200,000	18000	10,000	10	5000	1228,000
			1,218,000				

PRODUCTION EQUIPMENT COST

CONTROL BOX

SHEET ________ OF ________

MACHINE NAME	NUMBER REQUIRED	INVOICE PRICE	TRANSPORTATION COST	UNLOADING AND INSTALLATION REMODELING AND COST	ESTIMATED MACHINE LIFE YEARS/UNITS	AVERAGE YEARLY MAINTENANCE COST	TOTAL COST
Undefined		500					
		500					

PRODUCTION EQUIPMENT COST

BRACES

SHEET ____________ OF ____________

MACHINE NAME	NUMBER REQUIRED	INVOICE PRICE	TRANSPORTATION COST	UNLOADING AND INSTALLATION REMODELING AND COST	ESTIMATED MACHINE LIFE YEARS/UNITS	AVERAGE YEARLY MAINTENANCE COST	TOTAL COST
Cross Brace							
40-ton press	1	20	1	2			
Lower Brace							
40-ton press	1	20	1	2			
		40	2	4			46

PRODU[illegible] EQUIPMENT COST

PAINT

SHEET ______ OF ______

MACHINE NAME	NUMBER REQUIRED	INVOICE PRICE	TRANSPORTATION COST	UNLOADING AND INSTALLATION REMODELING AND COST	ESTIMATED MACHINE LIFE YEARS/UNITS	AVERAGE YEARLY MAINTENANCE COST	TOTAL COST
Paint System		1,000					
Conveyor		2,200					
		3,200					

APPENDIX I

SPECIFICATION S-101

INSTALLATION OF OPEN END PIPE PILES

BECHTEL NATIONAL, INC.

March 1980

TECHNICAL SPECIFICATION

FOR

INSTALLATION OF OPEN END PIPE PILES

1. SCOPE

A. ITEMS INCLUDED

1) Installation of two open end steel pipe piles at the Central Receiver Test Facility in Albuqerque, New Mexico

2) Installation of tapered leveling shims

B. RELATED ITEMS NOT INCLUDED

1) Survey for pile location

2) Excavation, backfill and grading

3) Testing of piles

2. QUALITY STANDARDS

A. GENERAL

The contractor shall control the quality of items and services to meet the requirements of this specification, applicable codes and standards, and other contract documents

B. REFERENCED CODES AND STANDARDS

Code	Title
ASTM 252	Welded and Seamless Steel Pipe Piles

3. DESIGN REQUIRMENTS

A. PILE DESCRIPTION

1) The pile shall be fabricated of welded steel pipe in conformance with ASTM 252.

2) Pile dimensions, flange, electronic package mounting and coating shall conform to Bechtel Drawing M-101.

B. DRIVING EQUIPMENT

1) Vibratory hammers, either hydraulically or electrically driven, shall be used to drive the piles.

2) If for any reason (e.g., large rock or thick cemented layers of soil) the vibratory hammer driven pile is refused, the piles will be placed in augered holes and set in concrete grout.

4. FIELD OPERATIONS

A. PILE DRIVING

1) The piles shall be driven to satisfy the requirements of Bechtel Drawing M-102.

2) Piles shall be located as shown and driven to the plumb condition as indicated. The maximum deviation from indicated plan location shall be 152 millimeters (6 inches). The maximum deviation for piles out of plumb shall be 2 percent.

3) Piles will be driven to the depth indicated in Bechtel Drawing M-102. Maximum deviation from the indicated depth (i.e., elevation of flange above grade) shall be 51 millimeters (2 inches).

B. FLANGE LEVELING SHIM INSTALLATION

The flange leveling shims (Bechtel Drawing M-103) shall be installed in conformance with Bechtel Drawing M-102 and the following instructions.

1) Place the L.S. Starrett Co. (Athol, Mass.) Level No. 199Z, or equivalent, across a diameter of the flange-face. Rotate the level about the flange center until a level reading is obtained. Centering the bubble

within the finest gradations on this instrument will locate a line, intersecting the flange, that is level within 10 arc seconds (1/20 milliradian). Mark the two intersections of this line on the flange O.D.

2) Place two tapered leveling shims (Bechtel Drawing M-103) on the flange with one flange location hole aligned with each of the two diametrically opposed marks on the flange O.D.

3) Place three 15.9 x 51 mm (5/8 x 2 inch) bolts through the shim slots and flange holes at equally spaced locations along the shim/flange circumference to serve as concentricity guides.

4) Place 6.35 x 76 mm (1/4 x 3 inch) bolts in the two shim location holes to serve as handles for subsequent rotation of the shims.

5) Place the level across the diameter of the leveling shims perpendicular to a line connecting the two marks on the flange O.D. Note which side of the shim surface is low.

6) Rotate the two shim handles toward the low edge of the shim surface, keeping equal distances between each handle and the adjacent flange level mark as illustrated in Figure 1. If desired rotation is blocked by a concentricity guide bolt, relocate the guide bolt in the adjacent slot so as to permit continued rotation.

7) When the level, still perpendicular to a line connecting the two level marks on the flange O.D., gives a level reading; the shims are properly adjusted.

8) Replace the three concentricity guide bolts with three 102 mm (4 inch) long No. 10 American Standard Taper Pins (ANSI B5.20). Tack weld the shims in place per Bechtel Drawing M-102.

9) Remove the taper pins.

C. PILE DRIVING ATTACHMENTS

Installation of the pile driving attachment of Bechtel Drawing M-104 is illustrated in Figure 2.

The M104-1 Driving Stub is intended for attachment to the pile flange. Its purpose is to permit driving of the pile with a conventional vibratory hammer pipe driving head, which does not have sufficient bite to bridge the flange.

The M104-3 Flange Cover protects the flange mating surface from damage while the pile is driven by a vibratory hammer with a custom head, which has sufficient bite to bridge the flange. If the custom head is not available for driving the CRTF piles, the M104-1 Driving Stub will be used (with the M104-3 Flange Cover removed).

The M104=5 Cover Plate is bolted to the control electronics package opening during driving of the pile.

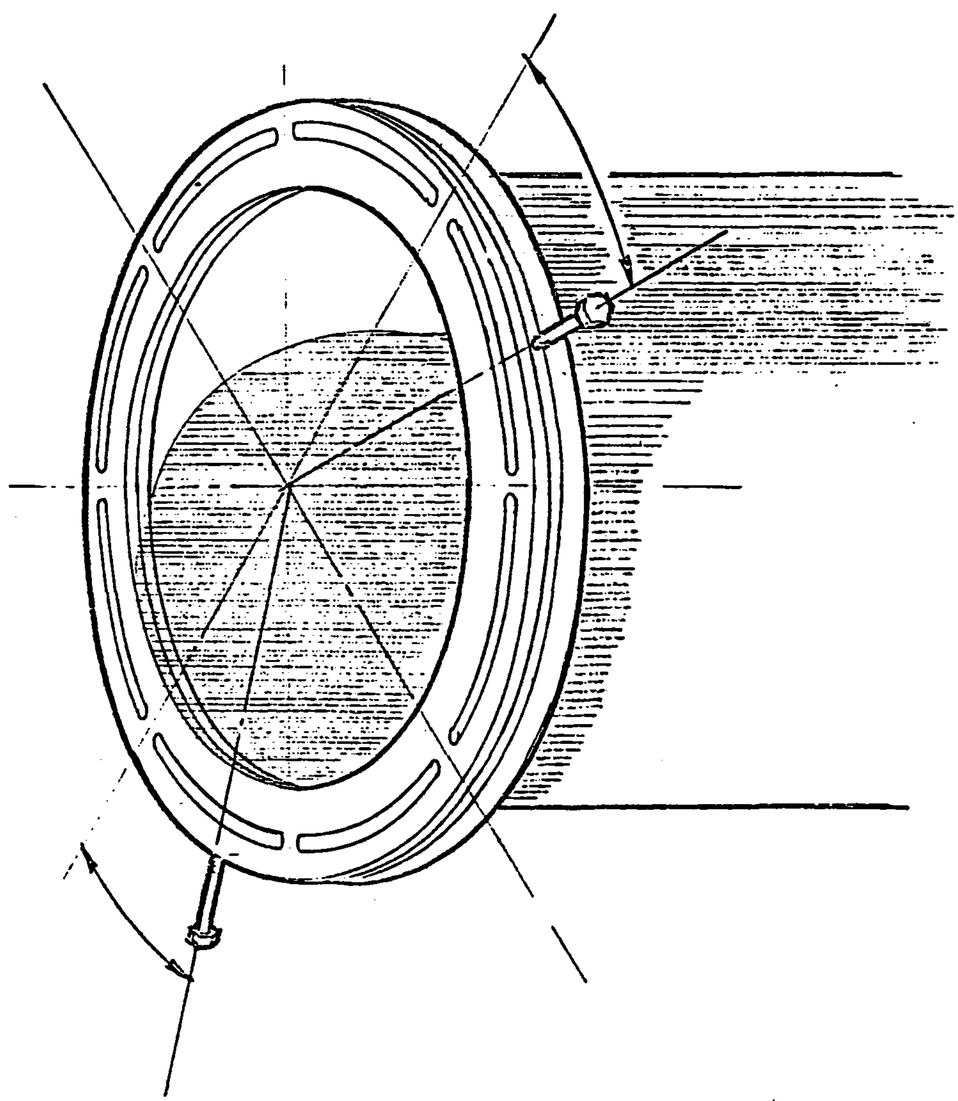


Figure 1 — TAPERED LEVELING SHIMS ADJUSTMENT

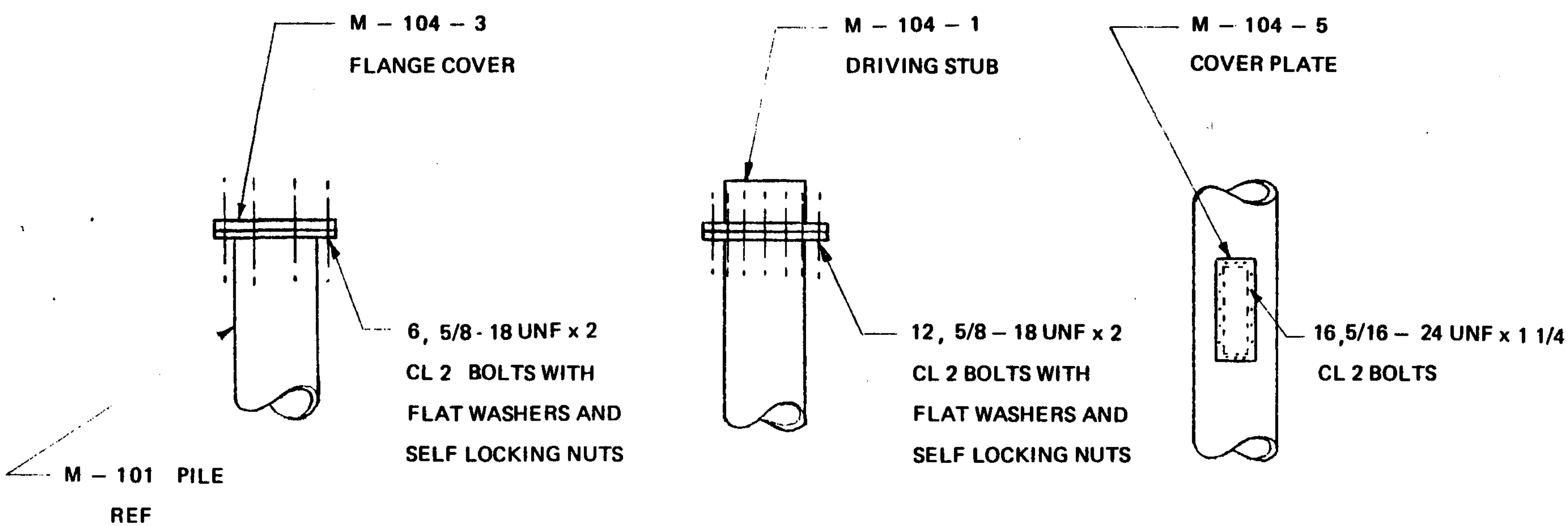


Figure 2 PILE DRIVING ATTACHMENTS

SURFACE PREPARATION, APPLICATION, AND INSPECTION

OF

PROTECTIVE COATINGS

FOR

CARBON STEEL HELIOSTAT PILES

JOB NO. 13353

SPECIFICATION S-102

Date: March 25, 1980

Prepared: Harry J. Smith
Coatings Specialist

Reviewed: [signature]
Coatings and Plastics Group Manager

Approved: [signature] Manley
Manager, Materials and Quality Services

NO.	DATE	REVISIONS

BECHTEL	MATERIALS AND QUALITY SERVICES RESEARCH AND ENGINEERING	SPEC./DOC. NO.	REV.

SURFACE PREPARATION, APPLICATION, AND INSPECTION OF PROTECTIVE COATINGS FOR CARBON STEEL HELIOSTAT PILES

CONTENTS

SURFACE PREPARATION, APPLICATION, AND INSPECTION

OF

PROTECTIVE COATINGS

FOR

CARBON STEEL HELIOSTAT PILES

1.0 SCOPE

1.1 Items Included

1.1.1 This specification covers the surface preparation and application of inorganic zinc coating to the interior surfaces, and the surface preparation and application of inorganic zinc coating and epoxy polyamide cured primer and white polyurethane topcoats to the exterior surfaces.

1.1.2 Documentation of the materials and procedures

1.1.3 Inspection and tests

1.1.4 Protection of coated surfaces

1.1.5 Environmental control equipment to provide the application and curing conditions required

1.1.6 Touch-up and repair of defective or damaged coated surfaces

1.1.7 Shop priming and finishing

1.2 Related Items Not Included

1.2.1 The following surfaces shall not be coated:

1.2.1.1 Surfaces within two inches of field welds, unless otherwise specified

1.2.1.2 Name and instruction plates, etc.

1.2.1.3 Rubber or similar nonmetallic parts

1.2.1.4 Surfaces to be completely embedded in concrete, unless otherwise specified

1.2.1.5 Prefinished metal

2.0 QUALITY STANDARDS

2.1 General

2.1.1 The Seller shall control the quality of items and services to meet the requirements of this specification, applicable codes and standards, and other procurement documents.

2.2 Referenced Codes and Standards:

Sponsor	Number	Subject
ASTM	E337-1972	Test for Relative Humidity by Wet-and-Dry-Bulb Psychrometer
SSPC	SP-1-1971	Solvent Cleaning
SSPC	SP-10-1971	Near-White Blast Cleaning
SSPC	Vis-1-1967	Pictorial Surface Preparation Standards for Painting Steel Surfaces
SSPC	PA-2-1973	Measurement of Dry Paint Thickness with Magnetic Gages

2.2.1 The Seller shall meet the specific requirements of this specification. If the requirements of this specification differ from or otherwise conflict with the normal procedures of the Seller, the requirements of this specification shall govern.

3.0 ENGINEERING DOCUMENTS

3.1 A listing of all coating materials to be used in this work which shall identify the specific products by manufacturer and catalog number in each coating system as scheduled.

3.1.1 The Seller's written procedures for storage, handling, surface, preparation, environmental control, application, touch-up and repair, curing, and inspection of the coating system shall be submitted for the Buyer's review and assignment of a status recommendation prior to use. Conflicts, if any, between the coating manufacturer's recommendations and this specification shall be brought to the attention of the Project Engineer for resolution.

4.0 MATERIALS

4.1 Material Manufacturers

4.1.1 Unless otherwise specified, all coating materials used on any one surface or piece of equipment shall be products accepted by the Buyer. Materials from different manufacturers shall not be used over each other without prior written acceptance.

4.1.2 The coating materials shall be in pre-measured units.

4.2 Inorganic Zinc Coatings

4.2.1 The following materials are acceptable:

Material	Manufacturer
Dimetcote 6	Ameron Protective Coatings Div.
Interzinc QHA 027/QHA 028	International Paint Co.
Mobilzinc 7	Mobil Chemical Co.

4.3 Epoxy Polyamide Cured Primers

4.3.1 The following materials are acceptable:

Material	Manufacturer
Amercoat 71	Ameron Protective Coatings Div.
Intergard 4400/4414	International Paint Co.
Valchem 13-R-56	Mobil Chemical Co.

4.4 Polyurethane Coatings

4.4.1 The following materials are acceptable:

Material	Manufacturer
Amercoat 450	Ameron Protective Coatings Div.
Interthane PA Series	International Paint Co.
Urethane Enamel 40 Series	Mobil Chemical Co.

4.5 Abrasive Materials

4.5.1 Abrasives for blast cleaning shall be clean and dry, furnished either in bulk or packaged, and shall be free of oil or contaminants. The particle size shall be capable of producing the specified surface profile. Cast iron or malleable iron shot shall not be used. Chilled iron shot may be used. Recirculated grit may be used. Recycled sand shall not be used.

4.6 Touch-Up Materials

4.6.1 Materials for touch-up of damaged areas of surfaces shall be the same as those originally applied, thinned according to recommendations of the manufacturer.

4.6.2 Alternate materials for touch-up may be used, subject to acceptance by the Buyer and the coating manufacturer.

4.7 Thinners, Solvents, and Cleaners

4.7.1 Thinners, solvents, and cleaners shall be as recommended by the coating material manufacturer and shall be identified by the product number or generic formulation.

5.0 SHIPPING, HANDLING AND STORAGE

5.1 Delivery and Storage

5.1.1 Coating materials shall be delivered to the place of application in the manufacturer's unopened, original containers bearing a legible product designation, batch number, and date of manufacture. Containers which are damaged to the point of jeopardizing the contents shall not be used.

5.1.2 The material shall be handled and stored in accordance with the manufacturer's latest published instructions, and shall be protected from damage, moisture, direct sunlight, and temperatures below 40F or above 100F.

5.2 Date of Materials

5.2.1 The materials shall be used within twelve months of their manufacture. The date of use shall in no case exceed the manufacturer's recommended shelf life, if such shelf life is less than twelve months.

5.2.2 Containers of coatings or components shall not be opened except for immediate use.

5.3 Handling of Coated Items

5.3.1 Coated surfaces shall be protected from damage during lifting or handling. Coated items shall be protected on non-abrasive supports during shipment and storage.

6.0 EQUIPMENT

6.1 General Requirements

6.1.1 The Seller shall provide equipment capable of regulating and controlling the conditions within the work area to the extent that the temperature of the substrate is always a minimum of 5F above the dew point. The substrate temperature during coating application and curing shall be maintained between a minimum of 55F and a maximum of 100F.

6.1.2 The spray equipment shall be as recommended by the coatings manufacturer and shall be suitably sized to the configuration of the work.

6.1.3 Spray equipment air supply lines shall be equipped with traps to remove moisture and oil.

6.1.4 For field applications, coatings listed shall comply with all air pollution control requirements applicable at jobsite.

7.0 SURFACE PREPARATION

7.1 General Requirements

7.1.1 Prior to blast cleaning or application of the topcoat, contamination shall be removed from the steel surfaces. Oil and grease shall be removed by solvent cleaning in accordance with SSPC-SP-1.

7.1.2 Surfaces to be coated shall be abrasive blast cleaned in accordance with SSPC-SP-10.

7.1.3 The surface profile of the steel cleaned by blasting shall be between 1.0 and 3.0 mils. A comparison shall be made with a Keane-Tator Profile Comparator, or Clemtex anchor profile chips, or Testex Press-O-Film, or other Buyer accepted equivalent which is appropriate to the type of abrasive material being used.

7.1.4 The abrasive mixture and the compressed air shall be clean, dry, and oil-free. Separators, in addition to oil and water extractors mounted on the compressor, shall be used in compressed air lines to remove oil and moisture from the air close to the point of use.

7.1.5 Abrasive blast cleaning shall not be performed in the immediate area where the coating or curing of coated surfaces is in progress. All surfaces and equipment which are not to be coated shall be suitably protected from abrasive blast cleaning.

7.1.6 Burrs, slivers, scabs, and weld spatter which become visible after blasting shall be removed by the Seller. Repaired areas shall have the surface profile suitably restored.

7.1.7 If rusting occurs or if the cleaned surfaces become wet or otherwise contaminated prior to coating, they shall be recleaned to the degree specified above.

7.1.8 After blast cleaning and immediately before coating, dust shall be removed with compressed air, free of oil and moisture. Vacuuming shall be used if the surface is not dust free.

8.0 MIXING AND APPLYING COATINGS

8.1 General Requirements

8.1.1 The mixing, applying, and curing of the coating material shall be in accordance with the manufacturer's latest published instructions and the requirements specified herein. When multiple component units are mixed, each component shall be mixed separately prior to the mixing of the combined materials. Only complete, pre-measured units shall be mixed. After mixing, the coating material shall be applied within the manufacturer's latest published pot life time.

8.1.2 Coating materials shall be thoroughly mixed until they are smooth and free from lumps, then strained through a 30 mesh or finer screen. Mixed material shall be agitated to keep the solids in suspension.

8.1.3 Inorganic zinc coating shall be a single coat applied over all specified ferrous surfaces, except as noted, to a dry film thickness of between 2.0 mils minimum and 4.0 mils maximum.

8.1.4 Epoxy polyamide cured primer shall be a single coat applied over all specified surfaces, except as noted, to a dry film thickness of between 1.0 mils minimum and 2.0 mils maximum.

8.1.5 White polyurethane finish shall be applied in two or more coats over all specified surfaces, except as noted, to a dry film thickness for the polyurethane of between 2.0 mils minimum and 4.0 mils maximum.

8.1.6 The total dry film thickness of the entire exterior system shall be a minimum of 5.0 mils and a maximum of 10.0 mils.

8.1.7 The curing time between coats and the final cure shall be in accordance with the manufacturer's latest published instructions.

8.1.8 The application of the coating shall be performed only when the environmental conditions meet the parameters specified in paragraphs 6.1.1 and 6.1.2 of this specification.

8.1.9 The coating materials shall not be applied when there is moisture on the surface, dust is present which can contaminate the freshly-coated surface, dirt or other detrimental materials have recontaminated the surface, or when the surface temperature of the steel is below 55F or above 100F or less than 5F above the dew point.

8.1.10 The spray equipment shall be conventional or airless and in acceptable operating condition as determined by the Seller through inspection and testing. The air supply lines shall be equipped with traps to remove moisture and oil.

8.1.11 Runs, sags, voids, drips, overspray, loss of adhesion, blistering, peeling, mudcracking, inadequate cure, or rusting of the substrate shall not be permitted.

9.0 INSPECTION AND TESTING

9.1 Surface Preparation Inspection

9.1.1 The temperature, dew point, and relative humidity shall be determined with a sling psychrometer or an accepted equal following procedures in ASTM E337. Readings are required at the start of work and every four hours or at time intervals designated by the Buyer. Alternatively, continuous monitoring shall be performed using systems established and/or reviewed by the Buyer.

9.1.2 Blast cleaned surfaces shall be compared with SSPC-Vis-1, Swedish Pictorial Standards, or accepted NACE Standards. The anchor pattern profile depth shall be verified with a Keane-Tator Profile Comparator, or Clemtex anchor pattern profile chips, or Testex Press-O-Film, or other Buyer accepted equivalent which is appropriate to the type of abrasive material being used.

9.1.3 Recirculated shot and grit used for abrasive cleaning shall be tested for the presence of oil by immersing them in water and checking for oil flotation. Tests shall be made at the start of blasting, every four hours thereafter, and at the end of blasting. If oil is evident, the contaminated abrasive shall be replaced with clean abrasive and retested before proceeding. All steel blasted after the previous satisfactory test shall be completely recleaned.

9.2 Coating Inspection

9.2.1 Surface temperature and humidity readings shall be taken every four hours.

9.2.2 The dry film thickness shall be measured with a Mikro-test FIM gage or an accepted equivalent, at five random points for each 50 square feet of surface area or at three random points on each piece less than 50 square feet in area. The testing method shall be in accordance with SSPC PA-2.

9.2.3 The film shall be visually inspected for defects such as overspray, runs, sags, mudcracking, inadequate cure or lack of adhesion. The Seller shall repair all defects according to the touch-up and repair procedures accepted by the Buyer.

9.2.4 The total dry film thickness of sags and runs shall not exceed 120 percent of the maximum specified dry film thickness nor shall it be less than 90 percent of the minimum specified dry film thickness.

10.0 REMEDIAL WORK

10.1 Touch-Up

10.1.1 Coated surfaces within the scope of this specification that have been damaged during assembly or handling shall be repaired in accordance with procedures as reviewed by the Buyer.

10.1.2 The surface profile shall be restored to meet the specified surface preparation requirements for cleanliness and profile. The periphery of a damaged area shall be feathered in with an acceptable material.

10.1.3 Precautions shall be taken to protect adjacent coated areas from damage caused by abrasive blast cleaning. The use of vacuum blast type equipment and needle guns will be permitted for abrasive blast cleaning.

UNLIMITED RELEASE

INITIAL DISTRIBUTION

UC-62d (350)

U.S. Department of Energy
600 E Street NW
Washington, D. C. 20585
Attn: W. W. Auer
G. W. Braun
K. Cherian
M. U. Gutstein
L. Melamed
J. E. Rannels

U.S. Department of Energy
San Francisco Operations Office
1333 Broadway
Oakland, CA 94612
Attn: S. D. Elliott
S. Fisk
R. W. Hughey
W. Nettleton

U.S. Department of Energy
Solar Ten Megawatt Project Office
P. O. Box 1449
Canoga Park, CA 91304
Attn: M. Slaminski

U.S. Department of Energy
Solar Ten Megawatt Project Office
5301 Bolsa Ave. MS14-1
Huntington Beach, CA 92649
Attn: R. N. Schweinberg

USAF Logistics Command
P. O. Box 33140
Wright-Patterson AFB
Ohio 45433
Attn: G. Kastanos

UCLA
900 Veteran Avenue
Los Angeles, CA 90024
Attn: F. Turner

Georgia Institute of Technology
Engineering Experiment St.
Atlanta, GA 30332
Attn: S. H. Bomar, Jr.

University of Houston
Houston
Solar Energy Laboratory
4800 Calhoun
Houston, TX 77004
Attn: A. F. Hildebrandt
L. L. Vant-Hull

U.S. Department of Interior
Water & Power Res. Service
P.O. Box 427
Boulder City, NV 89005
Attn: J. Sundberg

Acurex
485 Clyde Avenue
Mountain View, CA 94042
Attn: J. Hull

Aerospace Corporation
Solar Thermal Projects
Energy Systems Group, D-5
Room 1110
P.O. Box 92957
El Segundo, CA 90009
Attn: P. deRienzo
P. Mathur

Airesearch Manufacturing Co.
2525 West 190th Street
Torrance, CA 90509
Attn: M. G. Coombs
For: P. F. Connelly

AMFAC
700 Bishop Street
Honolulu, HI 96801
Attn: G. St. John

ARCO
911 Wilshire Blvd
Los Angeles, CA 90017
Attn: J. H. Caldwell, Jr.

Arizona Public Service
P. O. Box 21666
Phoenix, AZ 85036
Attn: D. L. Barnes
For: E. Weber

Arizona Solar Energy Commission
1700 W. Washington - 502
Phoenix, AZ 85007
Attn: R. Sears

Babcock & Wilcox
91 Stirling Avenue
Barberton, OH 44203
Attn: G. Grant
For: J. Pletcher
M. Seale

Babcock & Wilcox
P. O. Box 1260
Lynchburg, VA 24505
Attn: W. Smith

Babcock & Wilcox
20 S. VanBuren Avenue
Barberton, OH 44203
Attn: M. Wiener

Badger Energy, Inc.
One Broadway
Cambridge, MA 02142
Attn: F. D. Gardner

Battelle Pacific Northwest Labs
P. O. Box 999
Richland, WA 99352
Attn: M. A. Lind

Bechtel National, Inc.
P. O. Box 3965
San Francisco, CA 94119
Attn: E. Lam
For: J. B. Darnell
R. L. Lessley

Black & Veatch
P. O. Box 8405
Kansas City, MO 64114
Attn: C. Grosskreutz
For: J. E. Harder
S. Levy

Boeing Engineering & Construction
P. O. Box 3707
Seattle, WA 98124
Attn: R. L. Campbell
R. Gillette
J. R. Gintz

Booz, Allen & Hamilton, Inc.
8801 E. Pleasant Valley Road
Cleveland, OH 44131
Attn: W. Hahn

Brookhaven National Laboratory
Upton, NY 11973
Attn: G. Cottingham

Burns and Roe, Inc.
550 Kinderkamack Rd.
Oradell, NJ 07649
Attn: J. Willson

Burns and Roe, Inc.
185 Crossways Park Drive
Woodbury, NY 11797
Attn: R. Vondrasek

Busche Energy Systems
7288 Murdy Circle
Huntington Beach, CA 92647
Attn: K. Busche

California Public Utilities Commission
350 McAllister St., Room 5024
San Francisco, CA 94102
Attn: B. Barkovich
For: C. Waddell

Chevron Research
P. O. Box 1627
Richmond, CA 94804
Attn: L. Fraas

Chevron Oil Research
P. O. Box 446
La Habra, CA 90631
Attn: W. Peake
For: J. Ploeg
W. Stiles

Colt Industries
Trent Tube Division
East Troy, WI 53170
Attn: J. Thackray

Corning Glass Works
Advanced Products Dept.
M/S 25
Corning, NY 14830
Attn: W. M. Baldwin
A. Shoemaker

Custom Metals Enterprises, Inc.
3288 Main Street
Chula Vista, CA 92011
Attn: T. J. Bauer

Data Science Corp.
1189 Oddstad Drive
Redwood City, CA 94063
Attn: M. Liang

Electric Power Research Institute
P. O. Box 10412
Palo Alto, CA 93403
Attn: J. Bigger

El Paso Electric Company
P. O. Box 982
El Paso, TX 79946
Attn: J. E. Brown

Energy, Inc.
P. O. Box 736
Idaho Falls, ID 83401
Attn: G. Meredith

Exxon Enterprises-Solar Thermal Systems
P. O. Box 592
Florham Park, NJ 07932
Attn: P. Joy
For: D. Nelson
G. Yenetchi

Ford Aerospace
3939 Fabian Way, T33
Palo Alto, CA 94303
Attn: I. E. Lewis
For: H. Sund

Foster-Miller Associates
135 Second Avenue
Waltham, MA 02154
Attn: E. Poulin

Foster Wheeler Dev. Corp.
12 Peach Tree Hill Road
Livingston, NJ 07039
Attn: A. C. Gangadharan
For: R. Zoschak

GAI Consultants, Inc.
570 Beatty Rd.
Monroeville, PA 15146
Attn: H. Davidson

General Atomic Company
P. O. Box 81608
San Diego, CA 92138
Attn: H. A. Chiger

General Electric Company
Advanced Energy Programs
P. O. Box 8661
Philadelphia, PA 19101
Attn: A. A. Koenig

General Electric Company
1 River Road
Schenectady, NY 12345
tric Company
1 River Road
Schenectady, NY 12345
Attn: J. A. Elsner
For: R. N. Griffin
R. Horton

GM Transportation System Center
GM Technical Center
Warren, MI 48090
Attn: J. Britt

GM Corp. Harrison Rad. Division
A and E Building
Lockport, NY 14094
Attn: A. Stocker

Houston Lighting and Power
P. O. Box 1700
Houston, TX 77001
Attn: J. Ridgway

Institute of Gas Technology
Suite 218
1825 K Street, NW
Washington, D. C. 25006
Attn: D. R. Glenn

Jet Propulsion Laboratory
Building 520-201
4800 Oak Grove Drive
Pasadena, CA 91103
Attn: M. Adams
H. Bank
W. Carley
E. Cuddihy
J. Sheldon
J. Swan
V. Truscello

Kaiser Engineers, Inc.
300 Lakeside Drive
Oakland, CA 94612
Attn: I. Kornyey

Lawrence Berkeley National Laboratory
University of California
Berkeley, CA 94720
Attn: A. J. Hunt

Los Alamos National Laboratory
P. O. Box 1663
Los Alamos, NM 87545
Attn: S. W. Moore

Los Angeles Water and Power
111 North Hope Street
Los Angeles, CA 90051
Attn: B. M. Tuller
R. Radmacher

Martin Marietta Corporation
P. O. Box 179
Denver, CO 80201
Attn: P. R. Brown
A. E. Hawkins
T. Heaton
L. Oldham
H. C. Wroton

McDonnell Douglas Astronautics Co.
5301 Bolsa Avenue
Huntington Beach, CA 92647
Attn: P. Drummond
R. L. Gervais
D. A. Steinmeyer
L. Weinstein

Meridian Corporation
5515 Cherokee Avenue
Alexandria, VA 22312
Attn: B. S. Macazeer

Nielsen Engineering. & Research
510 Clyde Avenue
Mt. View, CA 94043
Attn: R. Schwind

Northrup, Inc.
302 Nichols Drive
Hutchins, TX 75141
Attn: J. A. Pietsch

ARCO Power Systems
Suite 301
7061 S. University Boulevard
Littleton, CO 80122
Attn: J. Anderson
F. Blake

Olin Corporation
275 Winchester Avenue
New Haven, CT 06511
Attn: S. L. Goldstein

OSC Department of Commerce
341 West 2d Street
San Bernardino, CA 92401
Attn: M. G. Heaviside

Pacific Gas and Electric Co.
77 Beale Street
San Francisco, CA 94105
Attn: P. D. Hindley
For: J. F. Doyle
A. Lam

Pacific Gas and Electric Co.
3400 Crow Canyon Road
San Ramon, CA 9426
Attn: H. Seielstad
For: J. Raggio

Phillips Chemical Co.
13-D2 Phillips Building
Bartlesville, OK 74004
Attn: M. Bowman

Pittsburgh Corning
800 Presque Isle Drive
Pittsburgh, PA 15239
Attn: W. F. Lynsavage

Pittsburgh Corning
723 N. Main Street
Port Allegany, PA 16743
Attn: W. J. Binder
For: R. Greene

PPG Industries, Inc.
One Gateway Center
Pittsburgh, PA 15222
Attn: C. R. Frownfelter

Public Service Co. of New Mexico
P. O. Box 2267
Albuquerque, NM 87103
Attn: A. Akhil

Research and Development
Public Service Co. of Oklahoma
P. O. Box 201
Tulsa, OK 74102
Attn: F. Meyer

Rockwell International
Energy Systems Group
8900 De Soto Avenue
Canoga Park, CA 91304
Attn: T. Springer

S. C. Plotkin & Associates
6451 West 83rd Street
Los Angeles, CA 90045
Attn: W. Raser

Safeguard Power Transmission Co.
Hub City Division
P. O. Box 1089
Aberdeen, SD 57401
Attn: R. E. Feldges

Sargent and Lundy
55 East Monroe
Chicago, IL 60603
Attn: N. Weber

Schumacher & Associates
2550 Fair Oaks Blvd., Suite 120
Sacramento, CA 95825
Attn: J. C. Schumacher

Sierra Pacific Power Co.
P. O. Box 10100
Reno, NV 89510
Attn: W. K. Branch

Solar Energy Research Institute
1617 Cole Boulevard
Golden, CO 80401
Attn: L. Duhham, TID
G. Gross
B. Gupta
D. W. Kearney
L. M. Murphy
R. Ortiz, SEIDB
J. Thornton

Solar Thermal Test Facility
User Association
Suite 1205
First National Bank East
Albuquerque, NM 87112
Attn: F. Smith

Solar Turbines International
P. O. Box 80966
San Diego, CA 92138
Attn: P. Roberts

Southern California Edison
2244 Walnut Grove Road
Rosemead, CA 91770
Attn: J. Reeves
For: C. Winarski

Southwestern Public Service Co.
P. O. Box 1261
Amarillo, TX 78170
Attn: A. Higgins

Standard Oil of California
555 Market Street
San Francisco, CA 94105
Attn: S. Kleespies

Stanford Research Institute
333 Ravenswood Avenue
Menlo Park, CA 94025
Attn: A. Slemmons

Stearns-Roger
P. O. Box 5888
Denver, CO 80217
Attn: W. Lang
For: J. Hopson

Stone & Webster Engineering Corp.
245 Summer Street
P. O. Box 2325
Boston, MA 02107
Attn: R. Kuhr

Townsend and Bottum
9550 Flair Drive
El Monte, CA 91731
Attn: R. Schwing

US Gypsum
101 S. Wacker Drive
Chicago, IL 60606
Attn: Ray McCleary

US Water & Power Resources Service
Bureau of Reclamation
Code 1500 E
Denver Federal Center
P. O. Box 25007
Denver, CO 80225
Attn: S. J. Hightower

Van Leer Plastics
15581 Computer Lane
Huntington Beach, CA 92649
Attn: Larry Nelson

Veda, Inc.
400 N. Mobile, Building D
Camarillo, CA 90310
Attn: L. E. Ehrhardt
For: W. Moore

Westinghouse Corporation
Box 10864
Pittsburgh, PA 15236
Attn: J. J. Buggy
For: R. W. Devlin
W. Parker

Winsmith
Division of UMC Industries
Springville, NY 14141
Attn: W. H. Heller

K. R. Miller, 3153
G. E. Brandvold, 4710; Attn: J. F. Banas, 4716
J. A. Leonard, 4717
B. W. Marshall, 4713; Attn: D. L. King
A. B. Maish, 4724
R. G. Kepler, 5810; Attn: L. A. Harrah, 5811
J. G. Curro, 5813
F. P. Gerstle, 5814
J. N. Sweet, 5824; Attn: R. B. Pettit and E. P. Roth
T. B. Cook, 8000; Attn: A. N. Blackwell, 8200
B. F. Murphey, 8300
C. S. Hoyle, 8122; Attn: V. D. Dunder
R. J. Gallagher, 8124; Attn: B. A. Meyer
D. M. Schuster, 8310; Attn: R. E. Stoltz, 8312, for M. D. Skibo
A. J. West, 8314
W. R. Even, 8315
R. L. Rinne, 8320
C. T. Yokomizo, 8326; Attn: L. D. Brandt
P. L. Mattern, 8342
L. Gutierrez, 8400; Attn: R. A. Baroody, 8410
D. E. Gregson, 8440
C. M. Tapp, 8460
C. S. Selvage, 8420
V. Burolla, 8424; Attn: C. B. Frost
R. C. Wayne, 8450
T. D. Brumleve, 8451
W. R. Delameter, 8451
P. J. Eicker, 8451 (5)
R. M. Houser, 8451
C. L. Mavis, 8451
W. L. Morehouse, 8451
H. F. Norris, Jr., 8451
W. S. Rorke, Jr., 8451
D. N. Tanner, 8451
S. S. White, 8451
A. C. Skinrood, 8452
W. G. Wilson, 8453
Publications Division, 8265/Technical Library Processes Division, 3141
Technical Library Processes Division, 3141 (2)
M. A. Pound, 8214, for Central Technical Files (3)

☆U.S. GOVERNMENT PRINTING OFFICE: 1981 - 791-856/326 9-II