185
10/26/79

NO STOCK

SAN-1468-1(App.)

SOLAR CENTRAL RECEIVER PROTOTYPE HELIOSTAT—PHASE 1

Appendices to Final Technical Report for September 30, 1977—June 24, 1978

October 1978

Work Performed Under Contract No. EG-77-C-03-1468

Energy Systems Programs Department
General Electric Company
Schenectady, New York

MASTER

U.S. Department of Energy

Solar Energy

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SOLAR CENTRAL RECEIVER PROTOTYPE HELIOSTAT PHASE I

Appendices to
FINAL TECHNICAL REPORT

30 SEPTEMBER 1977 — 24 JUNE 1978

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GENERAL ELECTRIC

ENERGY SYSTEMS PROGRAMS DEPARTMENT
SCHENECTADY NEW YORK

MASTER

PREPARED FOR
UNITED STATES DEPARTMENT OF ENERGY
SOLAR ENERGY DIVISION
UNDER CONTRACT EG-77-C-03-1468

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APPENDIX A
DESIGN COMPLIANCE WITH DOE 001 SPECIFICATION

APPENDIX B
GENERAL ELECTRIC HELIOSTAT PARTS LIST AND DRAWINGS

APPENDIX C
**SPECULAR SOLAR TRANSMITTANCE
AND REFLECTANCE MEASUREMENTS**

APPENDIX D
**PRELIMINARY DRAFT – DESIGN SPECIFICATION
FOR CONCEPTUAL DESIGN OF AUTOMATIC
FOUNDATION MACHINE**

APPENDIX E
**INGERSOLL-RAND CRITIQUE OF GE
AUTOMATIC FOUNDATION MACHINE CONCEPT**

APPENDIX F
**APPENDIX TO SECTION 4.0 –
CONTROLS AND DRIVES**

APPENDIX "A"

Design Compliance With 001 Specification Solar Central Receiver Prototype Heliostat Requirements

<u>001 Paragraph</u>	<u>Requirement</u>	<u>Compliance</u>
3.1.1.1	Availability 0.97 (daytime)	YES - The operating times and conditions (max 12 hours/day, slow movement) are not severe for the heliostat and controller. Careful selection of components and circuit designs insured compliance with this requirement.
3.1.1.2	Interchangeability	YES - The system design is the same for all field positions with complete parts interchangeability for all units. The system is field assembled by two persons and has been designed for ease of maintenance, these factors insure the satisfaction of this requirement.
3.1.1.3	Electrical Transients	YES - Protective grids and arrestors are incorporated into the power distribution system, blower, and controls equipment to tolerate internal and external transients.
3.1.2	Environmental	YES - The enclosure design satisfies all section 3.1.2 requirements.
3.1.2.1.2	Operational Limit	DEFINE - The heliostat assembly, enclosure and control electronics have been designed to operate in the temperature range of -20°F to +120°F, with no known wind speed limit with the reflector in any of its operating positions (0-360° Az, -5° +80° El). All components of the design have been selected to operate within these limits. The enclosure assembly is the only component that must

001 <u>Paragraph</u>	<u>Requirement</u>	<u>Compliance</u>
3.1.2.1.2	(Continued)	withstand the wind environment. The life cycle of this system is 30 years.
3.1.2.1.3	Stowage Initiation	DEFINE - Stowage due to environmental factors is not a consideration in an enclosed heliostat system.
3.1.2.1.4	Wind Rise Rate 0.1M/S ² (1.3 mph/min)	YES - This is not a factor in an enclosed heliostat system.
3.1.2.1.5	Survival Wind 40 M/S (90 mph)	YES - The enclosure material selection, construction and internal pressurization has been chosen to satisfy these requirements.
3.1.2.1.7	Dust Devils Dust & Wind at 17 M/S (40 mph)	YES - See 3.1.2.1.5.
3.1.2.2	Temperature -30°C to +50°C (-20°F to +120°F)	YES - See 3.1.2.1.2
3.1.2.3	Earthquake Seismic Zone 3	YES - The heliostat foundation pipe cross-sectional design and material have been chosen to satisfy this requirement.
3.1.2.4	Snow Environment 250 Pa (5 lb/ft ²)	YES - See 3.1.2.1.5
3.1.2.5	Rain Environment Average annual 750 mm (30 in.) Max - 24 hours 75 mm (3 in.)	YES - See 3.1.2.1.5
3.1.2.6	Ice Environment 50 mm (2 in.)	YES - See 3.1.2.1.5
3.1.2.7	Hail diameter 25 mm (1 in) s.g. 0.9 velocity 23 M/S (75 fps)	YES - See 3.1.2.1.5
3.1.2.8	Sandstorm Test per Mil-Std-810B, Method 510	YES - See 3.1.2.1.5
3.1.2.9	Lightning (for Inyokern, Ca.) Direct hit - single unit loss Adjacent Strike - minimize damage to unit protect controller	YES - The power distribution network, blower and controls equipment are protected from lightning by proper grounding and the use of arrestors.

<u>Paragraph</u>	<u>Requirement</u>	<u>Compliance</u>												
		The heliostat itself is grounded through the foundation pipe and this should prevent a direct hit from spreading to adjacent units.												
3.2	Heliostat performance 95% reflected energy on target	YES - Production Heliostats satisfy this requirement.												
3.2.1	Operational Periods Spring & Fall Equinox 8:00 a.m. to 4:00 p.m. Winter Solstice 9:00 a.m. to 3:00 p.m. Summer Solstice 6:00 a.m. to 6:00 p.m.	YES - This design is fully capable of operating for the periods of time stated in this paragraph. The controls and drives have sufficient movement to track the sun through the hours indicated for the field described in paragraph 3.2.2.1 and 3.2.3.1.												
3.2.2.1	Target	DEFINE - Vertical cylinder 17 M diameter by 25 M height, centered 250 M above the ground.												
3.2.3.1	Field Positions	<table> <tr> <td>DEFINE</td> <td>North of <u>Tower</u></td> <td>East of <u>Tower</u></td> </tr> <tr> <td></td> <td>A 1200 M</td> <td>430 M</td> </tr> <tr> <td></td> <td>B 800 M</td> <td>860 M</td> </tr> <tr> <td></td> <td>C -400 M</td> <td>430 M</td> </tr> </table>	DEFINE	North of <u>Tower</u>	East of <u>Tower</u>		A 1200 M	430 M		B 800 M	860 M		C -400 M	430 M
DEFINE	North of <u>Tower</u>	East of <u>Tower</u>												
	A 1200 M	430 M												
	B 800 M	860 M												
	C -400 M	430 M												
3.3	Drive & Control System <ul style="list-style-type: none"> ● Redirect collector field insolation to receiver throughout the day ● Provide flexible operation ● Respond to emergency commands and main plant control 	YES - The controls and drives design fully satisfies these requirements. Sufficient accuracy is provided to redirect the reflected energy to the target. The field control is segregated into groups of heliostats representing $\leq 10\%$ of the total field. These groups will be oriented to reflect sunlight within 180 seconds from being commanded by the central control. Sun tracking will be open loop. Provision shall be included for automatic calibration, individual failure reporting to the central control and manual control override for use during maintenance operations.												
3.3.1.1	Availability Fail Safe During Power Outage	YES - The heliostat is mechanically designed to move to a fail position in the event of loss of drive.												

001 <u>Paragraph</u>	<u>Requirement</u>	<u>Compliance</u>
3.3.1.3	Limit Controls Equipment & personnel protection where necessary	YES - The design of the controls and drives has limit controls as required for the safety of personnel and the protection of the equipment.
3.3.2.1	Tracking - Maintain reflected beam on target thru operating period	YES - See Section 3.3
3.3.2.2	Acquisition (Beam on Command) - Groups ($\leq$ 10% of field) shall respond to commands within 180 seconds	YES - See Section 3.3
3.3.2.3	Synthetic Tracking • continuous tracking during intermittent clouds	YES - See Section 3.3
3.3.2.4	Offset Pointing - Independent control of groups of heliostats	YES - See Section 3.3
3.3.2.5	Normal Shutdown - Control groups of heliostats to stowage	YES - See Section 3.3
3.3.2.6	Receiver/Stowage - Traverse - control beams during start up and shutdown - independent control of group movements	YES - See Section 3.3
3.3.3.1	Manual Control • Local control of heliostat	YES - See Section 3.3
3.3.3.2	Calibration & Checkout • Provide accuracy check on command	YES - See Section 3.3
3.3.4.1	Failure Indication - Status Report to central control	YES - See Section 3.3
3.3.4.2	Emergency Shutdown • Upon command reduce incident power on receiver to 3% of initial value	YES - See Section 3.3

3.4	Enclosure <ul style="list-style-type: none"> • Sufficient to maintain performance in operating environment 	YES - The foundation design is fully compliant with supporting the overall environmental requirements stated in 3.1.2. The foundation bag gives the enclosure a firm anchor to ground and the foundation pipe not only provides for earthquake survival but also provides the rigidity necessary to meet aiming accuracy requirements implicit in 3.2.
3.5	Physical Characteristics <ul style="list-style-type: none"> • enclosure spacing must allow for maintenance • heliostat shall have safe position • ease of maintenance • 30 year life cycle 	YES - Minimum spacing between heliostats of 9.7 M allows for maintenance. Mechanical fail safe and enclosure protect heliostat and allow for safe stowage. Design is easily maintainable and predicated on 30 year life.
3.6	Reliability <ul style="list-style-type: none"> • high reliability 	YES - The overall design is based on high reliability. The cost of acquisition vs. the cost of ownership were traded off to determine the optimum reliability desired of the original equipment.
3.7	Maintenance <ul style="list-style-type: none"> • Enclosure Surface Cleaning • Ease of Maintenance 	YES - The enclosure surface is capable of being easily cleaned. The present maintenance plan does not include scheduled cleaning. Maintenance can be performed by personnel of normal skills, with standard tools equipment.
3.8	Materials Processes, Parts <ul style="list-style-type: none"> • Standard parts and processes 	YES - The design conforms to this requirement to the extent that it is cost effective.
3.9	Electrical Transients <ul style="list-style-type: none"> • Line surge 	YES - See Section 3.1.1.3
3.11	Interchangeability	YES - See Section 3.1.1.2.
3.12	Safety <ul style="list-style-type: none"> • minimize hazards • include fail safe • provide safe stow • provide local control override • provide hazard indication and fault signal • comply with safety and OSHA regulations 	YES - The overall system design is fully compliant with the safety requirements of this paragraph.

APPENDIX "B"

GE Heliostat Parts List and Drawings

LOH-11 Heliostat Assembly

LOH-11.1 Heliostat Assembly Dimensions

LOH-111 Reflector Assembly

LOH-111.2 Strut Assembly

- LOH-111.2.2 Lgth. Adj. Cap
- 111.2.3 Tube
- 111.2.4 Handwheel & Socket Ball
- 111.2.5 Cable
- 111.2.6 Cable Swege Conn.
- 111.2.7 End Cap

LOH-111.3 Sh. 1 & Sh. 2 Tensioning Device Sub-Assembly Hub Tensioning Assembly

- LOH-111.3.2 Reflector Hub
- 111.3.3 Speed Handle
- 111.3.4 Washer
- 111.3.5 Tension Spring
- 111.3.6 Wire Collar

LOH-111.4 Reflective Surface Assembly

- LOH-111.4.2 Reflective Surface
- 111.4.3 Load Strap, Corner
- * 111.4.4 Adhesive
- 111.4.5 Corner Beam
- 111.4.6 Reinforcement Patch

* LOH-111.5 Sun Sensor

- * LOH-111.5.2 (4) Quadrant Silicon Sun Sensor
- * 111.5.3 Housing (Plastic)
- * 111.5.4 Amplifier
- * 111.5.5 (8) Pin Wire Connector Cable

LOH-111.6 Elevation Drive Hub

LOH-111.6.2 Pivot Shaft

LOH-112 Heliostat Pedestal Shipping Assembly

LOH-112.2 Yoke Assembly

LOH-112.2.2 Yoke Detail

- LOH-112.2.2.2 Flanged Brgs.
- 112.2.2.3 Brg. Mount
- 112.2.2.4 Tube

LOH-112.2.3 King Post

LOH-112.2.4 Radial Thrust Brg.

LOH-112.2.5 Radial Bearing

LOH-112.2.6 Elevation Mtr. Support Brkt

* LOH-112.2.6.2 1/4 Dia. x 1" Lg. Roll Pin

* LOH-112.2.6.3 1/4-20 x 1" Lg. S.H.C.S.

LOH-112.2.7 Mtr. Pivot Brkt. (Azimuth & Elevation)

LOH-112.2.7.2 Pivot Pin

LOH-112.2.7.3 Brkt.

LOH-112.3 Azimuth Drive Hub Detail

* LOH-112.3.2 Keeper

112.3.3 Drive Hub

* LOH-112.4 Controller

LOH-112.5 Azimuth & Elevation Drive Motor & Detector

LOH-112.6 Wiring Harness

LOH-112.7 Lower Support

* LOH-112.7.2 Alignment Pin

LOH-112.7.3 Support Pipe

LOH-112.8 Foundation Pipe

LOH-112.8.2 Alignment Pin

LOH-112.8.3 Pipe

LOH-12 Enclosure Assembly

LOH-12.2 Enclosure Entrance

LOH-12.3 Ported Vertical Panel

LOH-12.4 Vertical Panel

LOH-12.5 Top Panel

LOH-12.6 Enclosure Foundation

LOH-12.7 Ground Cloth

LOH-12.8 Zipper

* LOH-12.9 Blower Assembly

* LOH-12.9.2 Blower

* LOH-12.9.3 Blower Control

* LOH-12.9.4 Filter

* LOH-12.9.5 Duct

* LOH-12.9.6 Flange

* No Drwg's to Date or No Drwgs. Req'd.

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B-5

2nd
Sheet

B-6

B-7

ENGINEERING APPROVAL				HELIOSTAT ASSEMBLY DIMENSIONS		GE ESPD	
ISSUE							
MECH. ENG.	1	2	3				
PROG. MGR.							
DATE	21 Mar 78			DRAWN BY: J. F. ... 3/7/78		SCALE 1/32	REV.
						LOH-11.1	

B-8

NOTES:

1. HUB TENSIONING ASSY WILL HAVE ELEV. DRIVE HUB ASSEMBLED TO IT AND SHIPPED AS PART OF SUPPORT AND DRIVE ASSY.

ITEM NO.	QTY	DRWG. NO.	DESCRIPTION	WT
6	1	LOH-111.6	ELEVATION DRIVE HUB	
5	1	LOH-111.5	SUN SENSOR	
4	1	LOH-111.4	REFLECTIVE SURFACE ASSY	3.7
3	1	LOH-111.3	HUB-TENSIONING ASSY	2.5
2	8	LOH-111.2	STRUT ASSY	1.0
1		ASSEMBLY	—	2.1

ENGINEERING APPROVAL				LIST OF MATERIALS			
MECH. ENG.	ISSUE	2	3	REFLECTOR ASSEMBLY	GE		
PROD. MGR.	DATE	11/11/71		LOH-111	ESPD		
					LOH-111

B-9

LOH-111.2.7	7	1	END CAP	ALUM. CASTING - FORGING	
LOH-111.2.6	6	2	CABLE SWEDGE CONN.	PURCHASED	
LOH-111.2.5	5	1	CABLE	WT1 GA	
LOH-111.2.4	4	1	ROD WITH BALL	STL.	
LOH-111.2.3	3	1	TUBE - 166.9" LG X 2.75 DIA X .035" WALL	6061-T6 ALUM. 1/2" LG X 63.5 MM DIA X .809 MM WALL	
LOH-111.2.2	2	1	LENGTH ADJ. CAP	ALUM. CASTING - FORGING	
LOH-111.2.1	1	1	ASSEMBLY		
DRWG NO	ITEM NO.	QTY.	DESCRIPTION	MATERIAL	WGT

LIST OF MATERIALS

STRUT ASSEMBLY - PROTOTYPE		LOH-111.2	
GENERAL ELECTRIC		ENERGY SYSTEMS PROGRAMS DEPT.	
ROCKFORD, ILL., U.S.A.		LOH-111.2	

B-10

LOH-111.3 SH.1

REV A 5-2-78

SCALE - $\frac{1}{2} \times$
LOH-111.3 SH.2
 REV A 5-2-78

ENG APPROVALS				REFLECTOR HUB DETAIL LOH-113.1		G. E. E. S. P. D.	
ISSUE							
WGR	1						
ENG							
PROG							
WGR							
DATE	7/27/78						
DRAWN BY A. M. CAIRO 5/22/78				SCALE 1/2" = 1" NATFO		LOH 111.3.2

$\frac{3}{4}$ -10 TAP

MAT'L - ALUM. CASTING
SCALE - FULL

LOH-111.3.3

98/4/24/78

REV. -A -5-2-78

MAT'L - C.R.S.
SCALE - FULL

LOH - III.3.4

FREE LGTH. = 8

SOLID HEIGHT = 3.942"

* SIMILAR TO LEMPCO MED.
HEAVY DIE SPRING CAT. #
9-2432-2

994/2478

LOH-111.3.5

REV. A 5-2-78

B-16

MAT'L - ALUM. CASTING
SCALE - FULL

JH/12472

LOH-111 .3.6

REV. A 5-2-78

B-17

NOTE 5:

1. REFLECTIVE SURFACE ITEM 1 MAY BE FABRICATED FROM 1.5M(5FT) TO 2.1M(7FT) STOCK FOR LOW ,O MEDIUM QUANTITY PRODUCTION, FOR HIGH QUANTITY PRODUCTION FULL WIDTH MATERIAL WILL BE AVAILABLE ON COST TRADE OFF BASIS.
2. THIS AREA TO HAVE ALUMINUM COATING REMOVED FROM ITEM 2.
3. DETAIL OF LOWER FLAP MAY BE MODIFIED AT LATER DATE TO PARTIAL OR FULL FLAP SIMILAR TO SURFACE 2.

SCALE: 1/2" = 1'

(5) DIE CAST AL

LCH-1114.6	6	8	REINFORCEMENT PLY	SEE DETAIL	
LCH-1114.5	5	8	CORNER BEAM	SEE DETAIL	
LCH-1114.4	4	AR	ADHESIVE	DENSIL 1078	3
LCH-1114.3	3	8	LOAD STRAP, CORNER	MYLAR .004THK m ² (sf) TOTAL	3
LCH-1114.2	2	1	REFLECTIVE SURFACE	AL-MAR .002THK 55 m ² ()	2
			ASSEMBLY		6
DRWG. NO.	ITEM	QTY	IDENTIFICATION	DESCRIPTION	5

ENGINEERING APPROVAL	LIST OF MATERIALS		WGT
ISSUE 2 3	REFLECTOR 55" x 7"	GE	
WELL ENGR.	SURFACE ASSEMBLY	ESPD	
PROG MGR	LOH-1114		
DATE	DRAWN BY	SCALE	REQ
		LOH-1114	2-2

VIEW OF PLATTEN FACE

CONCEPT #2

SECTION A-A
ROTATED 10° C.W.

MATL - GLASS REINFORCED LEXAN

SCALE - 1/2x

NOTE:
THIS HUB ASSEMBLED TO REFLECTOR
HL-8 (LOH-1113)

ENGINEERING APPROVAL				ELEVATION DRIVE HUB		GE	
DESIGN	REV	DATE	BY	LOH-1114		ESP D	
DATE	1/1/78	1/1/78	1/1/78	DRAWN BY:		SCALE	1/2x
				1/1/78		LOH-111.6	REV A

MAT'L - DRAWN, GROUND &
POLISHED ACCURACY
ROUND
SCALE - FULL

LOH - III.6.2

HELIOSTAT PEDESTAL SHIPPING ASSY	
4/11/78	LOH-112.1
SCALE 1/3 X	LOH-112
REV A	5-2-78

B-21

TITLE YOKE ASSY LOH-112.2		GENERAL ELECTRIC ENERGY SYSTEMS PROGRAMS DEPT. SCHENECTADY, N.Y., U.S.A.	
DATE FOR	DESIGNED BY	SCALE 1/4 x	REV A
PROJECT	LOH-112.2	5-2-75

YOKE DETAIL

LOH-1123.1

DRAWN BY:

J. J. J. J. 4/5/78

G.E.

E.S.P.D.

SCALE:

1/4x

LOH 112.2.2

REV.

8
9/2/78

ENLARGED VIEW "A"

PLASTIC FLANGED BEARING (2) REQ'D.

LOH-112.2.2.2

MAT'L - 6061-T6 ALUM.

* DESIGNATES CRITICAL DIMENSIONS

ENGINEERING APPROVAL				<u>KING POST</u>		G. E. E.S. P. D.	
ISSUE							
MECH. ENG.	1	2	3	LOH-1124.2		SCALE 1/2 x	
PROG. MGR.							
DATE	11 Apr 78			DRAWN BY A. M. Cains 4/7/78		LOH-112.2.3	REV A 5-2-78

RADIAL-THRUST BEARING LOH-112.2.4

MAT'L - NYLON

RADIAL BEARING LOH-112.2.5

MAT'L - NYLON

ENGINEERING APPROVAL			
	ISSUE		
	1	2	3
MECH. ENG.	<i>[Signature]</i>		
PROD. MGR.			
DATE	11 Apr 78		

AZIMUTH BEARING
DETAILS

LOH-1123.4

DRAWN BY:

T.J. [Signature] 4/11/78

* DESIGNATES CRITICAL DIMENSIONS

G.E.
E.S.P.D.

SCALE
FULL

LOH-112.2.4
112.2.5

REV.
A
5-2-78

MAT'L - LEXAN FOAM

ENGINEERING APPROVAL

	ISSUE	1	2	3
MECH. ENG.				
PROG. MSR.				
DATE	5 April 78			

ELEVATION MOTOR
SUPPORT BRACKET DET.

LOH-1123.3

DRAWN BY:
4/5/78

* DESIGNATES CRITICAL DIMENSIONS

G.E.
E.S.P.D.

SCALE:
FULL

LOH-112.2.6

REV.
A
5-2-78

B-26

* DESIGNATES CRITICAL DIMENSION

MAT L - LEXAN FOAM

*
"DOVE TAIL" SLIDE
SADDLE

ENGINEERING APPROVAL					MOTOR PIVOT BRKT. DETAIL LOH-112.4.6		G.E. E.S.P.D.		REV A 5-2-78	
	ISSUE		2	3						
MECH. ENG.	<i>[Signature]</i>				DRAWN BY: <i>[Signature]</i> 4/5/78		SCALE FULL	LOH-112.2.7		
PROG. MGR.										
DATE	4/11/78

PARTIAL SECTION "B-B"

ENGINEERING APPROVAL

	1	2	3
MECH. ENG.			
PROG. MGR.			
DATE	4 April 77		

AZIMUTH DRIVE
HUB DETAIL
LOH-1124.1

DRAWN BY:
J.P. [Signature] 4/4/78

G.E.
E.S.P.D.

SCALE
1/4 X

LOH-112.3

REV.
A
5-2-78

8

7

6

5

4

3

2

1

REV	DESCRIPTION	REVISIONS			DATE	BY	APPROVED
		1	2	3

NOTE:

1. BREAK AND DEBURR ALL SHARP EDGES.
2. FILLET RAD. NOT TO EXCEED .02 MAX.
3. ROUGH MACHINE LEAVING APPROX. 1/32" PER SURFACE FOR CLEAN-UP.
4. STRESS RELIEF HEAT TREAT $\pm 25^\circ \pm$ MAX. FOR 1 HOUR.
5. FINAL MACHINE.
6. MARK HOLES PRIOR TO ANODIZING.

NOTES, UNLESS OTHERWISE SPECIFIED:

PRELIMINARY INFORMATION

NOV 22 1960

DIMENSIONING AND TOLERANCING PER ASA STANDARD Y 14.5		ITEM NO.	PART NO.	DESCRIPTION		QTY.
UNLESS OTHERWISE SPECIFIED		DRAFTSMAN	DATE	PARTS LIST		XYNETICS, INC. CALIFORNIA
DIMENSIONS ARE IN INCHES		<i>K. G. LUCAS</i>	<i>5-13</i>	CHIEFER		
TOLERANCES				ENGINEER		
.XX				APPROVED		
.XX				<i>FRAME, THRUSTER</i>		
.XX						
.XX						
.XX						
SURFACE ROUGHNESS				<i>LOH-112.5</i>		
MATERIAL						
<i>2-1/4" ALUM /</i>						
<i>6-1/4" TIG</i>						
FINISH						
<i>2-1/4" ALUM /</i>						
<i>6-1/4" TIG</i>						
<i>2-1/4" ALUM /</i>						
<i>6-1/4" TIG</i>						

HELIOSTAT WIRING HARNESS

B-30

MATL HOT ROLLED STL.

* - CRITICAL ALIGNMENT REQUIRED

ENGINEERING APPROVAL				LOWER SUPPORT	G. E.	
ISSUE					E. S. P. D.	
MECH. ENG.	1	2	3	LOH-112.5	SCALE	REV.
PROG. MGR.						
DATE	10/1/73			DRAWN BY J. M. P.	LOH-112.7	5-2-73

* DESIGNATES CRITICAL DIMENSIONS

MAT'L - HOT ROLLED STL.

ENGINEERING APPROVAL				FOUNDATION PIPE		G. E.	
ISSUE				LOH-113		E. S. P. D.	
MECH. ENG.	gpl.mg	2	3	DRAWN BY		SCALE	REV.
PROG. MGR.				D. M. Cairns 4/6/78		FULL	5-2-78
DATE	11 Apr 78					LOH-112.8	

B-32

TOP VIEW

FRONT ELEVATION

ENGINEERING APPROVAL			TITLE		GENERAL ELECTRIC	
DESIGNED BY	11	2	ENCLOSURE-55M		ESP D	
DATE	7/1/78		A. CAMP SCALE: 3/12/78 1/2"=1'-0"		SOLAR PROGRAMS	
					REV. NO. LOH-12	
					REV. NO.	

B-33

$$A = 39.513 \text{ FT}^2$$

NOTE - FACTORY SEAMS ACCEPTABLE

*DESIGNATES CRITICAL DIMENSIONS

MAT'L - PLASTIC FILM
.002 LLUMAR/GLASS SCRIM/
.002 LLUMAR

REINFORCED CORNER TYP.

ENCLOSURE ENTRANCE DETAIL LOH-1211		G.E. E.S.P.D.	
DRAWN BY: J. J. [Signature] 4/13/78		SCALE 1/16 X	REV. A 5-2-78
		LOH-12.2

NOTE - FACTORY SEAMS ACCEPTABLE

* DESIGNATES CRITICAL DIMENSIONS

MAT'L - PLASTIC FILM
 .002 LLUMAR/GLASS SCRIM/
 .002 LLUMAR

PORTED VERTICAL PANEL DETAIL LOH-1212		G.E. E.S.P.D.	
DRAWN BY: J. J. [Signature] 4/12/78		SCALE $\frac{1}{4"} = 1'$	REV. A
		LOH-12.3	5

NOTE - FACTORY SEAMS ACCEPTABLE

* DESIGNATES CRITICAL DIMENSIONS

MAT L - PLASTIC FILM
.002 LLUMAR/GLASS SCRIM/
.002 LLUMAR

VERTICAL PANEL DETAIL		G.E. E.S.P.D.	
LOH-1213			
DRAWN BY:	SCALE:	LOH-12.4	REV.
<i>[Signature]</i> 4/12/78	$\frac{1}{4}'' = 1'$		A
			5-2-78

B-36

NOTE - FACTORY SEAMS
ACCEPTABLE

* INDICATES CRITICAL DIMENSIONS

MAT'L - PLASTIC FILM
.002 LLUMAR/GLASS SCRIM/
.002 LLUMAR

ENGINEERING APPROVAL

	ISSUE	
	2	3
MECH. ENG.	#	
PROG. MGR.		
DATE	4/25/78	

TOP PANEL
DETAIL
LOH-1214

DRAWN BY:
J. J. [Signature] 4/2/78

G.E.
E.S.P.D

SCALE
1/4" = 1'

LOH-12.5

REV.
A
3-2-78

* NOTE - FACTORY SEAMS ACCEPTABLE

$A = 1229.93 \text{ FT.}^2$

MAT'L HYPALON COVERED NYLON
@ 10 OZ./SQ.YD.

ENGINEERING APPROVAL				ENCLOSURE FOUNDATION DETAIL LOH-124	G.E. E.S.P.D.	
ISSUE						
	1	2	3			
MECH. ENG.	JS					
PROG. MGR.						
DATE	4/25/78			DRAWN BY: I.J. Hakeboun 4/13/78	SCALE 1/4" = 1'	REV. A 5-2-78
					LOH-12.6	

B-38

A = 302.6 FT²/PIECE
((2) PCS. REQ'D.)

MAT'L - OPAQUE PVC 5 MIL. (.005") THK.

GROUND CLOTH DETAIL LOH-1210		G.E. E.S.P.D.	
DRAWN BY: L.P. Hatcher (awd) 4/13/78		SCALE 1/4" = 1'	REV. A 5-2-78

APPENDIX C

SPECULAR SOLAR TRANSMITTANCE AND REFLECTANCE MEASUREMENTS

OPTICAL PROPERTIES/MEASUREMENTS OF REFLECTING AND TRANSMITTING MATERIALS

The optical property characterization of reflection and transmission materials consisted of two tests: 1) Total Hemispherical Reflectance or Transmittance and 2) Specular Reflectance or Transmittance.

Total Hemispherical Measurements

The measurement was obtained with a Beckmen DK-1L spectrophotometer. The measurement consisted of determining the reflectance characteristics of each reflector material, based on a Ba_2SO_4 reference standard, as a function of wavelength from 350 to 1740 NM weighted against the solar spectrum and summed.

Specular Reflectance/Transmittance

In order to complete the characterization of a reflecting or transmitting surface, the reflected or transmitted beam profile of the specular component over the wavelength range 350-1740 NM had to be determined. As a first approximation to this measurement and as a tool to obtain characterization measurements, this measurement was obtained at one wavelength (.6328 μ). This was accomplished with the aid of a laser specular reflectometer. A diagram of the device is shown in Figure 1. The instrument consisted of source optics and detector optics. The source optics consisted of a helium-neon laser, a beam expander and a beam-defining aperture. The detector optics consisted of a variable collecting aperture and a silicon detector mounted inside an integrating chamber. The laser beam can be fully characterized by a normal distribution. The data for the laser beam are given in Figure 2.

RESULTS OF SPECULARITY MEASUREMENTS ON CANDIDATE MATERIALS

Specularity measurements were performed on three candidate transmitting materials and four reflecting materials. Originally, it was assumed that a two-normal intensity distribution would be sufficient to describe the scattered light profile after reflection or transmission from the candidate materials. Although this proved

Figure 1. Diagram of Specularity Measurement Device

<u>Collecting Aperture Diameter</u>	<u>N(measured)</u>	<u>N(calculated)*</u>
.04"	.148	.139
.055"	.203	.247
.081"	.404	.460
.120"	.792	.741
.157"	.931	.901
.185"	.963	.960
.272"	.986	.999

*
$$N = 1 - \exp\left(\frac{-r^2}{2\sigma^2}\right) = 1 - \exp\left(\frac{-D^2}{8\sigma^2}\right) \quad \sigma = .0365".$$

Figure 2. Characterization of the Laser Beam

adequate for the majority of the candidate materials, a three-sigma model was required to accurately characterize the profiles of Martin 4 mil laminated and 200 Dunchrome DL-50 reflecting samples. Using these models, calculated values agreed closely with actual data. The standard deviation of the differences between actual and calculated results was about 1.0 percent in all cases.

Actual measurements were made with a number of circular collecting apertures of different diameters. N, the fraction of the total reflected energy passing through an aperture of diameter, D, was related to D by one of the two formulas:

$$(1) \quad N = 1 - A \exp\left(\frac{-D^2}{8\sigma_1^2}\right) - (1-A) \exp\left(\frac{-D^2}{8\sigma_2^2}\right)$$

for a two-sigma model where A and 1-A are the respective weighting factors for the first and second normal distributions.

$$(2) \quad N = 1 - A \exp\left(\frac{-D^2}{8\sigma_1^2}\right) - B \exp\left(\frac{-D^2}{8\sigma_2^2}\right) - (1-A-B) \exp\left(\frac{-D^2}{8\sigma_3^2}\right)$$

for a three-sigma model where A, B, and (1-A-B) are the respective weighting factors for the distributions described by σ_1 , σ_2 , and σ_3 .

The sigmas that would be calculated from the preceding equations contain contributions due to the net negligible width of the laser light source, but these effects are factored out in the following data:

SPECULARITY PERFORMANCE ANALYSIS PROCEDURE

As described in the previous section, two measurements were used to characterize a reflecting or transmitting surface: Total Hemispherical and Specular. It is relatively easy to rank a mirror or window performance on the basis of its solar average hemispherical reflectance or transmittance value alone, but it is not that obvious whether a mirror or window with high specularity for a given receiving aperture is better than one with a lower value of specularity, but a higher hemispherical reflectance or transmittance. Therefore, to ascertain the impact measured specularity has on the overall performance of a system, a mathematical data analysis procedure was developed. The procedure was based on the assumption that the reflected or transmitted beam profile from a reflector or window sample could be characterized by the sum of three normal distributions. The data analysis derived three standard deviations, σ_1 , σ_2 , and σ_3 , and two weighting factors, A and B, which were directly related to $N_{(r)}$, the fraction of the total light reflected or transmitted from a surface and passing through a defining aperture with radius, r. The equation was of the form.

$$N_{(r)} = 1 - A \exp(-r^2/2\sigma_1^2) - (B) \exp(-r^2/2\sigma_2^2) - (1-A-B) \exp(-r^2/2\sigma_3^2)$$

The generated three standard deviations σ_1 , σ_2 , and σ_3 , for a given sample specular distribution in conjunction with the weighting factors for those distributions can then be used to ascertain the impact on the overall heliostat system performance model.

SEA LEVEL SOLAR HEMISPHERICAL TRANSMITTANCE

Wavelength (Micrometers)	Transmittance		
	Average LLUMAR 2 mil	MYLAR D 4 mil	LLUMAR 5 mil
0.390	.250	.793	.200
0.444	.830	.840	.830
0.431	.845	.853	.853
0.511	.845	.855	.855
0.543	.845	.855	.855
0.574	.845	.855	.855
0.606	.845	.855	.855
0.639	.850	.855	.855
0.669	.875	.885	.885
0.705	.875	.885	.885
0.745	.880	.885	.885
0.786	.880	.885	.888
0.831	.883	.885	.888
0.877	.883	.885	.888
0.959	.886	.887	.888
1.026	.886	.887	.888
1.105	.900	.886	.888
1.228	.889	.885	.888
1.497	.889	.880	.885
1.722	.870	.850	.850
Sea Level Solar Transmittance	.838	.867	.838

SEA LEVEL SOLAR HEMISPHERICAL REFLECTANCE

<u>Wavelength (Micrometers)</u>	<u>Transmittance Average Martin-4 mil</u>	<u>200 Dunch DL-50</u>	<u>5 mil Melinex</u>	<u>2 mil Melinex-0</u>
0.390	.080	.400	.825	.885
0.444	.735	.750	.830	.887
0.431	.760	.770	.830	.885
0.511	.776	.776	.836	.885
0.543	.780	.780	.836	.885
0.574	.790	.800	.846	.894
0.606	.790	.790	.845	.890
0.639	.798	.803	.843	.890
0.669	.805	.805	.843	.883
0.705	.795	.780	.837	.881
0.745	.790	.790	.820	.870
0.786	.785	.813	.820	.860
0.831	.770	.770	.803	.853
0.827	.800	.810	.806	.870
0.959	.850	.885	.850	.913
1.026	.885	.890	.883	.930
1.105	.895	.878	.895	.945
1.228	.910	.927	.910	.950
1.497	.920	.906	.930	.969
1.722	.894	.930	.930	.960
Sea Level Solar Reflectance	.780	.803	.851	.899

SPECULAR TRANSMITTANCE OF SELECTED FILMS

Aperture Dia. (milliradians)	SOLAR TRANSMITTANCE		
	2 mil LLUMAR/ Melinex-0	5 mil LLUMAR/ Melinex-516	4 mil MYLAR
0.25	0.025	0.011	0.037
0.50	0.095	0.044	0.140
0.75	0.199	0.096	0.285
1.00	0.320	0.163	0.440
1.25	0.442	0.241	0.581
1.50	0.554	0.323	0.691
1.75	0.645	0.406	0.768
2.00	0.716	0.485	0.816
2.25	0.764	0.558	0.843
2.50	0.796	0.621	0.857
2.75	0.816	0.675	0.863
3.00	0.827	0.718	0.865
3.25	0.833	0.753	0.866
3.50	0.835	0.779	0.867
3.75	0.837	0.798	0.867
4.00	0.838	0.812	0.867
4.25	0.838	0.821	0.867
4.50	0.838	0.828	0.867
4.75	0.838	0.831	0.867
5.00	0.838	0.834	0.867
5.25	0.838	0.835	0.867
5.50	0.838	0.837	0.867
5.75	0.838	0.837	0.867
6.00	0.838	0.838	0.867
8.00	0.838	0.838	0.867
10.00	0.838	0.838	0.867
Total Hemispherical	0.838	0.838	0.867

SPECULAR REFLECTANCE OF
SELECTED METALLIZED FILMS

Aperture Dia. (milliradians)	Solar Reflectance			
	200 Dunchrome DL-50 (sl. trans.)	5 mil Melinex 516 Metal. one Side (Semitrans.)	2 mil Melinex-0 Metal. one Side (Gen. Opaque)	Martin 4 mil Lam. UV Stabilized (Opaque)
0.10				0.022
0.20				0.084
0.30				0.176
0.40				0.283
0.50	0.046	0.021	0.009	0.389
0.75				0.594
1.00	0.166	0.082	0.037	0.685
1.50	0.323	0.174	0.081	0.718
2.00	0.473	0.284	0.138	0.719
2.50	0.590	0.400	0.205	0.720
3.00	0.666	0.509	0.277	0.722
3.50	0.709	0.604	0.352	0.723
4.00	0.730	0.681	0.425	0.724
5.00	0.743	0.779	0.557	0.727
6.00	0.747	0.822	0.660	0.730
8.00	0.752	0.842	0.781	0.739
10.00	0.758	0.844	0.832	0.746
14.00	0.770	0.846	0.874	0.760
18.00	0.781	0.847	0.891	0.768
25.00	0.791	0.849	0.898	0.772
Total Hemispherical	0.803	0.851	0.899	0.780

REFLECTING MATERIAL	Specular Properties					
	R_1^*	σ_1^{**}	R_2	σ_2	R_3	σ_3
2 mil Melinex-0	.83	1.6	.17	3.7		
5 mil Melinex - 516	.99	1.1	.01	7.5		
Martin 4 mil Laminated UV stabilized	.92	0.2	.07	4.1	.01	50.0
200 Dundrome DL-50	.92	0.7	.07	5.5	.01	53.0
TRANSMITTING MATERIAL						
2 mil LLUMAR	1	0.51				
2 mil Melinex-0						
5 mil LLUMAR	1	0.76				
5 mil Melinex - 516						
4 mil Mylar	1	0.42				

*weighting factor

**value in milliradians

The equations describing the reflected or transmitted beam distribution are as follows:

Reflected

$$2 \text{ mil Melinex-0} \quad N = 1 - 0.83 \exp(-0.0488 d^2) - 0.17 \exp(-0.00913 d^2)$$

$$4 \text{ mil Melinex - 516} \quad N = 1 - 0.99 \exp(-0.1031 d^2) - 0.01 \exp(-0.00222 d^2)$$

$$\begin{aligned} \text{Martin 4 mil} \\ \text{Laminated} \quad N = 1 - 0.92 \exp(-3.13 d^2) - 0.07 \exp(-0.00744 d^2) \\ \quad - 0.01 \exp(0.00005 d^2) \end{aligned}$$

$$\begin{aligned} 200 \text{ Dundrome DL-50} \quad N = 1 - 0.92 \exp(-0.255 d^2) - 0.07 \exp(-0.00413 d^2) \\ \quad - 0.01 \exp(-0.0000445 d^2) \end{aligned}$$

(d = aperture diameter in milliradians)

Transmitted

$$2 \text{ mil LLUMAR} \quad N = 1 - \exp(-0.481 d^2)$$

$$5 \text{ mil LLUMAR} \quad N = 1 - \exp(-0.216 d^2)$$

$$4 \text{ mil Mylar} \quad N = 1 - \exp(-0.709 d^2)$$

APPENDIX D

Preliminary Draft Design Specification for Conceptual Design of Automatic Foundation Machine (AFM)

SECTION 1. SCOPE

- 1.1 This specification establishes the performance and design requirements for the Automatic Foundation Machine (AFM).

SECTION 2. APPLICABLE DOCUMENTS

The documents listed herein form a requirement of this specification.

2.1 Non Government Documents

Standards of the American Institute of Steel Construction
Standards of the National Electrical Manufacturing Association
Metric Practice Guide, ASME Designation E380-74
Regulations of Occupational Safety and Health Administration (OSHA)
Applicable construction machinery specifications

SECTION 3. REQUIREMENTS

3.1 Item Definition

The Automatic Foundation Machine (AFM) shall be a self-contained, self-powered, automatic positioning, special installation tool developed to install General Electric enclosure and heliostat foundations, survey their implanted position and bury the power and grounding cable(s) on a highly automated basis.

The enclosure foundation is a 'U' shaped plastic fabric filled with excavated earth to provide the required hold-down of the circular air-supported enclosure.

The heliostat foundation is a specially designed pipe that is vertically inserted into the ground which supports the heliostat pedestal.

3.1.1 Functional Operational Requirements

The AFM shall be designed to meet the following functional operational requirements:

- A. Locate heliostat installation centerlines
- B. Implant enclosure foundation
- C. Implant heliostat foundation
- D. Survey heliostat foundation position
- E. Bury power and grounding cables

3.1.1.1 Locate Heliostat Installation Centerlines

The AFM shall self position and level over the designated heliostat position.

3.1.1.2 Implant Enclosure Foundation

The enclosure foundation requires the excavation of a circular trench, placing a plastic foundation bag in the trench and backfilling the excavated soil in the foundation bag.

3.1.1.3 Implant Heliostat Foundation

The heliostat foundation pipe shall be inserted into the soil at the center of the heliostat installation. The verticality of the heliostat foundation pipe is critical.

3.1.1.4 Survey Heliostat Foundation Position

Upon completion of the heliostat foundation pipe installation the precise position shall be automatically surveyed.

3.1.1.5 Bury Power and Signal Cables

The heliostat power and grounding cable shall be continuously buried external to the enclosure foundation bag during the movement of the AFM to the next position.

3.1.2 Interfaces

3.1.2.1 Geotechnical

Soil Conditions: The AFM shall operate in a multiplicity of soil conditions. Generally the soil is considered to contain scattered stones and gravel (≤ 100 mm (4 in.)). Small rocks, ≤ 200 mm (8 in.) may be encountered. The AFM is not expected to operate in shelf or shale rock outcroppings.

Surface Conditions: The ground over which the AFM is to operate shall be considered cleared of trees, scrub and other obstructions. Major surface irregularities will be corrected.

3.1.2.2 Survey

The AFM automatic positioning and survey unit shall operate from one or more survey bench marks positioned as required throughout the area. These bench marks are not considered part of the AFM.

3.1.2.3 Power Cable

The AFM shall accept a power and signal cable drum with a size of 1M (3.3 ft.) diameter and .75M (2.4 ft.) long. The cable will be approximately 1/2 inch diameter polyethylene jacketed with heliostat breakouts on variable 10M (33 ft.) to 20M (65.6 ft.) spacings as required. Estimated weight of the cable drum is 907 Kg (2000 lbs.). Refer to Figure 1 for illustration of cable configuration and cable drum.

3.1.2.4 Enclosure Foundation Bag

The enclosure foundation bag will be shipped folded in a basic box shape approximately 1.5M (5 ft.) high, .7M (2.4 ft.) wide, and 1.8M (6 ft.) long. The ring fabric will be a reinforced plastic. The enclosure foundation bag shipping size is illustrated in Figure 2. Trench cross section into which the foundation bag is to be installed in is illustrated in Figure 3.

3.1.2.5 Heliostat Foundation

The heliostat foundation illustrated in Figure 4 will be a steel pipe or tube approximately 5 inches in diameter and 4 to 6 feet long to meet various site foundation requirements. It is anticipated that only one length will be used at any site. Provisions shall be provided to accommodate a drilling type kellyhead and end hardening preparation for soil drilling.

3.1.3 Major Components of the AFM

The AFM shall be capable of performing as a minimum the functional operations identified in 3.1.1. The major components to perform the functions are:

- A. Self Propelled Chassis
- B. Automatic Leveling Unit
- C. Automatic Positioning and Survey Unit
- D. Cable Burial Unit
- E. Trenching Unit
- F. Foundation Bag Implantment Unit
- G. Backfill and Compaction Unit
- H. Heliostat Foundation Implantment Unit
- I. Equipment Power Supply Unit
- J. Control

3.1.3.1 Self Propelled Chassis

The self propelled chassis shall contain as a minimum:
A structural frame, wheel or track assemblies, drive power unit, fuel storage, operating lighting, auxiliary equipment mounting provisions, storage for foundation bags and heliostat foundation pipes, and a control assembly.

3.1.3.2 Automatic Leveling Unit

The automatic leveling unit shall contain as a minimum:
Leveling jack assemblies, pressure pads, ground profile sensors, and automatic/manual control.

3.1.3.3 Automatic Positioning and Survey Unit

The automatic positioning and survey unit shall contain as a minimum: A computer unit, alignment sensors, distance measurement sensors, elevation sensors, external survey control unit(s) and a control assembly.

3.1.3.4 Cable Burial Unit

The cable burial unit shall contain as a minimum:
A cable plow unit and control assembly.

3.1.3.5 Trenching Unit

The trenching unit shall contain as a minimum:
A trenching machine, optional foundation bag form (tile box), conveyor(s), soil hopper (storage) and control assembly.

3.1.3.6 Foundation Bag Implantment Unit

The foundation bag implantment unit shall contain as a minimum: A Foundation Unfolding Machine, automatic loading unit, and control assembly.

3.1.3.7 Backfill and Compaction Unit

The backfill and compaction unit shall contain as a minimum:
Feed and conveyor system, compactor assembly, and control assembly.

3.1.3.8 Heliostat Foundation Implantment Unit

The heliostat base implantment unit shall contain:
Heliostat foundation pipe feed assembly, drill stand assembly, and control assembly.

3.1.3.9 Equipment Power Supply Unit

The equipment power unit shall contain as a minimum:

3.1.3.9 Equipment Power Supply Unit (Continued)

Diesel power unit, fuel storage, electric generator unit, hydraulic power unit (if needed) and a control assembly.

3.1.3.10 Control Panel

The control panel shall contain the necessary electronics, etc. for the operation, control and monitoring of the AFM operation in both fully automatic and manual modes.

3.2 Operating Specifications

3.2.1 Performance

The AFM shall be a self contained, powered and propelled machine with maximum automatic operation throughout its functional operation. The machine shall be designed with an operational design goal of implanting two heliostat foundations per hour. The machine is to be designed for a 10 year life with a plant utilization of 24 hours a day 6 days a week.

3.2.1.1 Self Propelled Chassis

The self contained and propelled chassis shall be capable of manual and automatic (computer) control. The vehicle self transport design speed shall be 4.5 M/S (10 mph). The AFM shall be capable of backing up. The design soil bearing pressure for the wheel or track assemblies shall be 69 KP (10 psi).

The drive assemblies shall be individually controlled to each side of the AFM to permit maximum maneuverability. The AFM design turning radius shall be 15.2M (50 ft.) hence steering to all wheel or track assemblies shall be considered. The wheel or track assemblies shall not travel over the implanted enclosure foundation bag.

Storage shall be provided for sufficient fuel for 8 hours

3.2.1.1 Self Propelled Chassis (Continued)

operation, and for 16 heliostat foundation pipes and enclosure foundation bags.

The control unit shall be mounted in a weatherproof operations cab or room also containing the control units for the auxiliary equipment.

3.2.1.2 Automatic Leveling Unit

The automatic leveling unit shall be capable of automatically leveling the AFM on the specified maximum slope to an accuracy of 0.1° . The leveling unit shall also be capable of manual operation. The Heliostat Foundation Implantment Unit may require a secondary higher precision leveling capability. The control unit for the leveling unit shall be mounted in the AFM control panel.

3.2.1.3 Automatic Positioning and Survey Unit

The Automatic Positioning and Survey Unit shall be capable of providing computer generated control signals to the AFM chassis control.

The control system shall be capable of programming such that the AFM will automatically position itself along non-linear paths within .15M (.5 ft.) of a designated heliostat position located within a 600M (2000 ft.) square area. The control computer shall be capable of storing a minimum of 20,000 heliostat positions.

The survey subassembly shall be capable of measuring the installed heliostat foundation within 30 mm (0.1 ft.). The necessary external transmitters or receivers including their support stands shall be considered a part of this unit.

The control for these units shall be mounted in the AFM control room. The unit shall operate fully automatically with the capability of manual operation or monitoring.

3.2.1.4 Cable Burial Unit

The cable burial unit shall be a fully automatic operation with capability of manual control. The cable shall be buried 1M (3.3 ft.) deep, 0.3M (1 ft.) outside of the enclosure foundation on the left side facing forward. The control of this unit shall be from the control room.

3.2.1.5 Trenching Unit

The trenching unit shall be capable of fully automatic operation with capability of manual operation. The controls shall be located in the control room of the AFM.

The trenching unit shall be capable of excavating a circular trench with a cross section 0.7M (2.5 ft.) wide, 1.2M (4.0 ft.) nominal depth, 1.0M (3.3 ft.) minimum) as illustrated in Figure 3.

3.2.1.6 Foundation Bag Implantment Unit

The foundation bag implantment unit shall be capable of unfolding the shipped foundation bag into the trench provided. The foundation bag outer wall top shall be maintained in a horizontal plane within 5 cm (2 in.). The 7.0M (23 ft.) enclosure base diameter shall be maintained at the interface of this outer wall and the existing grade line.

The foundation bag implantment unit shall also include an automatic means of reloading the Foundation Unfolding Machine (FUM) with a new Foundation Bag Cartridge as shipped and stored on the AFM.

The unit shall be capable of automatic operation with manual override and monitoring. The control unit shall be located in the control room of the AFM.

3.2.1.7 Backfill and Compaction Unit

The backfill and compaction unit shall be an automatically

3.2.1.7 Backfill and Compaction Unit (Continued)

controlled operation with capability of manual control.

The control shall be located in the AFM control room.

This unit shall provide on board storage of 2 cubic meters (2⁺ cy) of soil, necessary conveyors and metering to transport from the trencher discharge, store, and backfill the soil into the foundation bag behind the Foundation Unfolding Machine. The bottom 60% of the backfilled foundation must be compacted to a TBD density.

3.2.1.8 Helio-stat Foundation Implantment Unit

The helio-stat foundation base shall be implanted in a fully automatic mode with capability of manual control. The control shall be located in the AFM control room.

The helio-stat foundation pipe shall be positioned within 2.5 cm (1 in.) of the nominal center of the enclosure foundation. The pedestal base shall be inserted into position in a manner that the pedestal base is vertical within 0.05°. That is when the upper pedestal and king post is installed on the pedestal base it will be vertical within 0.15° without adjustment or leveling. The helio-stat foundation pipe after insertion shall have its pedestal mounting pin or slot orientation read out within .25°. The top elevation of the helio-stat foundation pipe shall be 75 cm (3 in.) below the upper edge of the foundation bag outer wall (0.3M (12 in.) above nominal grade).

3.2.1.9 Equipment Power Supply Unit

The equipment power supply unit shall be capable of supplying the necessary power to operate the AFM auxiliary equipment. The size of the power unit is TBD. The power unit shall have integral as well as a remote control unit that is to be mounted in the AFM control room.

3.2.1.10 Control

A central control room shall be provided on the AFM in which all electronic power and control of the automatic operation of the AFM can be monitored or manually controlled. The design goal is for the AFM to be full automatic (Robot) in operation with manual operations held to a minimum.

3.2.2 Physical Characteristics

The AFM width shall not exceed 27 feet centered on heliostat foundation. The size and weight requirements of the AFM necessitate the requirement of site assembly.

3.2.3 Reliability

Reliability requirements TBD.

3.2.4 Maintainability

Maintainability requirements TBD.

3.2.5 Environment

3.2.5.1 Wind

The AFM shall be capable of operating in winds of 25 m/s (50 mph) and surviving maximum winds of 40 m/s (90 mph) without damage.

3.2.5.2 Temperature

Performance requirements of the AFM shall be met throughout ambient air temperature range from -30°C (-20°F) to +50°C (+120°F).

3.2.5.3 Rain

The AFM shall be capable of meeting performance requirements under a maximum rain rate of 75 mm (3 in.) per 24 hours.

3.2.5.4 Ice Environment

The AFM shall be capable of operating in freezing rain and ice deposits in a layer 50 mm (2 in.) thick.

3.2.5.5 Performance

Under maximum severe environment the performance of the AFM may be degraded to a time cycle TBD.

3.2.6 Transportability

The physical size requirements of the AFM dictate site assembly of the unit. This assembly requirement will be kept to a minimum designed for highway transport with emphasis on ease of site assembly and operational maintenance.

3.3 Design and Construction

The AFM shall be designed to meet existing construction equipment and OSHA standards.

3.3.1 Material, Processes, and Parts

The material used in the AFM shall be selected on the basis of high performance and for minimum wear of the parts.

3.3.2 Workmanship

The AFM design shall be fabricated and assembled in accordance with the best modern engineering, shop, and field practices consistent with required performance and reliability requirements.

3.3.3 Interchangeability

The AFM shall be designed for field interchangeable individual parts or major optimum replacement units (ORU).

The ORU level shall be determined to be the lowest replaceable subassembly that minimizes realignment and adjustments at assembly.

All items bearing the same manufacturers part number shall be physically and functionally interchangeable.

3.3.4 Safety

The AFM shall perform in all modes of operation and maintenance in a safe manner. Design shall be for minimum hazard with safety and warning devices per OSHA standards.

3.4 Documentation

Engineering and assembly drawings shall be provided to show the equipment construction, including assembly and disassembly procedures. Engineering data, wiring diagrams and parts lists shall be provided.

Instructions shall be provided covering assembly, alignment, operation, lubrication, and maintenance.

SECTION 4. QUALITY ASSURANCE

4.1 General

The quality assurance and testing requirements of this specification shall be mutually determined during design reviews. The design reviews shall provide verification of AFM design conformance to the specification.

APPENDIX E

CRITIQUE and RECOMMENDATIONS

with reference to the

PRELIMINARY DRAFT - DESIGN SPECIFICATION

of the

AUTOMATIC FOUNDATION MACHINE CONCEPT

as proposed by

GENERAL ELECTRIC - ENERGY SYSTEMS PROGRAMS DEPT.

for the

SOLAR CENTRAL RECEIVER PROTOTYPE HELIOSTAT

STUDY PHASE I

(REF. ERDA RFP #EG-77-R-03-1468)

Date: *May 30, 1978*
Automatic Production Systems Division
Ingersoll-Rand Company
23400 Halstead Road
Farmington Hills, Michigan 48024

Edward L. Rogers -

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TABLE OF CONTENTS (With Cross References to the
Preliminary Draft, Design Specification)

I.	Introduction	
II.	Conclusions - Overall Concept	(Ref. 2.1.3)
III.	Critique and Recommendations Referred to the preliminary specifications.	
	1. Helio-stat Pedestal Foundation	(Ref. 3.2.1.8)
	2. Helio-stat Enclosure Foundation	(Ref. 3.1.3.5 and 3.1.3.7)
	3. Helio-stat Control Cable Implantation	(Ref. 3.1.1.5)
	4. Drive and Power Unit Recommendation	(Ref. 3.1.3.1 and 3.2.1.1)
	5. Logic Control and Guidance System	(Ref. 3.1.1.1 and 3.1.1.4)
	6. Operator Requirements	(Ref. 3.2.1.10)
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	9. Vendors Catalogs and Miscellaneous Relevant Data	(Ref. 3.4)

CONSULTING INFORMATION REQUESTED

FROM INGERSOLL RAND ON
GENERAL ELECTRIC AFM CONCEPT

Ingersoll-Rand
Response
Cross Reference

1. Critique of the AFM Specification.	II.	1.
2. Critique of overall machine concept and configuration.		1.
3. Complete detailed treatise of heliostat foundation insertion machine design and operation.	III.	1.
4. Recommendation and design detail for vehicle wheel or track system with steering and powering provisions.		6.
5. Recommendation for leveling and anchoring or stabilizing of the machine platform.		7.
6. Critique the proposed trenching and bag insertion unit.		2.
7. Recommendations for cable laying and critique of concept.		3.
8. Recommended power unit and design details.		4.
9. Recommendation of features and/or limitations for the automatic control system including the guidance system.		5.
10. Are there special construction machinery industry specifications that should apply -- what are they -- copies, etc.		9.
11. With each area of critique or recommendation, in addition to the written report, supply drawings, catalog information, general pricing information and specification whenever possible.		10.
12. Evaluation of operator requirements.		8.

Date of Meeting: January 25, 1978

Written response requested by: February 27, 1978

R. H. Horton, Manager
Solar Central Power Systems

I. INTRODUCTION

1. Scope

1.1 The specification presented to Ingersoll-Rand covers a preliminary design and performance specification for an Automatic Foundation Machine (AFM) which will:

- a. Automatically locate and level to a specific x-y-z position as directed by a computer and associated laser or other guidance means.
- b. Automatically implant a foundation "pipe" to which the heliostat pedestal will be attached by others.
- c. Automatically implant a circular foundation enclosed in suitable container.
- d. Automatically bury a control cable with attaching plugs.
- e. Be economically justifiable when examined from an operational and maintenance aspect, based on a ten year life, including cost of site to site set up and transporting equipment (other than standard and not including site to site time and mileage).

1.2 Ingersoll-Rand is released to present a critique of the specification, overall machine concept and configuration, and to present recommendations and design details to further the feasibility of the concept.

1.3 We have included as part of each section, where applicable, catalog excerpts of material or designs, part or all of which could be modified or combined with other equipment in the final design.

The use of established techniques or equipment wherever possible will eliminate the risks inherent in new designs.

II. CONCLUSIONS

1 Critique

- 1.1 The basic concept as presented and modified as recommended in several areas, can be feasible to implement. The machine concept is not entirely automatic, cycle to cycle, as originally presented or with recommended modifications.

The most troublesome areas due to lack of previous design experience seems to be:

- a. Steering and locating the unit to the prescribed foundation location. A combination of several existing laser techniques should be able to accomplish this. The techniques have not been selected at this time.
- b. Feeding and backfilling the foundation liner (enclosure, bag). The design of the mechanisms must be closely coordinated with the design of the liner. We have proposed one such system in a concept that should be evaluated full scale. A small scale ($3/4" = 1'$) concept of operation has proven the feasibility of much of the concept.
- c. Compacting the backfill. The apparent necessity of utilizing three (3) earth rammers (tamperers) is troublesome in the design. Considerable length will be required to provide space for three back-fillers plus three tamperers and clearances.

- 1.2 The recommendations set forth will cover the most difficult specified terrain. Units that will be designated for the best possible soil conditions can be retrofitted with the simpler mechanisms to reduce maintenance and improve cycle time and effective utilization. These options will be more clearly defined in the final design.

2. Alternate Approach

2.1 In assembling data to determine the state of the art, it appears that much has been developed in individual units in the three basic areas, specifically:

1. Implanting drill casings in various overburdens.
2. Trenching and backfilling (without liner) in circular configuration, which would use pedestal foundation (drill casing) as a point of reference.
3. Trenching, cable laying, and backfilling, using laser techniques as guide for grade (level) and alignment (straight line).
4. Transporting these items from site to site would offer no problems as the overall width could be held to 8 - 10 ft. or the design is already highway mobile.
5. Manpower would be increased to four or five.
 1. Pedestal foundation implant (1)
 2. Enclosure foundation implant (2)
 3. Enclosure backfill and tamp (1)
 4. Control cable implant (1)
 5. Supervisor or inspector (technical) (1)

III. CRITIQUE AND RECOMMENDATIONS

1 Heliostat Pedestal Foundation

- 1.1 Several different methods are available for implanting pedestal foundations but each, except one, depends on a particular soil composition, which might not be consistent over the entire site, and very likely will vary site to site. One system will cover all types and mixtures of overburden, although the rate of penetration will vary. This is the ODEX system of Atlas Copco, and they have developed a mechanized method of joining cases to facilitate multi-casing length depths. This appears capable of moderate modification to enable the use of shorter casings, one at each location, rather than several at one location.**

Ingersoll-Rand Company also makes a similar type mechanism. Either of these can be modified to suit the unique requirements of implanting pedestal foundations.

Pipe rack designed for safety and high productivity

Rotamec 1300 is equipped with two drill pipe racks: a horizontal storage rack on the right side of the drill, plus a pipe rack of the "Lazy Susan" type mounted inside the mast.

The Lazy Susan pipe rack is a part of Rotamec 1300's pipe handling system which saves times and eliminates heavy physical work. When the drill pipes are not in use, they are safely stored in the pipe rack.

The rack holds four 114 mm (4 1/2") drill pipes, 6250 mm (20 1/2 ft) in length. With one pipe in the spindle and a full pipe rack, a 31 m (102.5 ft) hole can then be drilled with no need for manual pipe handling. With optional pipe rack, two 140 mm (5 1/2") or two 168 mm (6 5/8") pipes can be placed in the mast.

An early unit with 600-cfm air capability was called *The Turtle*. It was traded a few years ago for the company's second machine, a T-4W with 750-cfm air and good over-the-road characteristics; its name, *The Hare*. *Windy* seemed a logical name for the new big-air rig.

Windy is assigned the tougher jobs—deeper wells, very tough rock, thicker overburden requiring deeper casing, or where high heads of water are anticipated. The high velocity and volume of air exiting the hole acts as a kind of venturi, opening veins of water-bearing material along the well wall at shallower depths that might normally be sealed off in the course of drilling. This adds to well production, a kind of customer insurance.

Fig. 3. Sand deposit with admixture of boulders between Toluca and Mexico City

Fig. 4. Material from an auger-drilled hole in glacial deposits near Montreal, Canada. The hole collapsed as soon as the auger rods were taken up.

- A. 1.5 m — Large stones
- B. 2.0 m — Boulders
- C. 5.0 m — Moraine with admixture of large stones
- D. 1.5 m — Boulders
- E. 3.0 m — Sandy moraine
- F. 1.0 m — Boulders
- G. 5.0 m — Coarse sand with passage to clay
- H. 10.0 m — Very hard stone-free clay
- I. 1.0 m — Rock
- K. Rock
- L. Casing tube 140 mm (5 1/2")

Fig. 5. Composition of the soil layer at a water well drilling site in Norway

DEVELOPMENT OF THE ODEX METHOD

With experience gained from the development work and drilling with the Atlas Copco — Sandvik OD (=Overburden Drilling) equipment and eccentric drilling equipment of the Tiltex type, new advances were made. By drawing up a "requirements profile", the outlines of a practicable new eccentric drilling equipment gradually became clear. This new drilling procedure — overburden drilling with the eccentric method — has been given the name ODEX.

This Atlas Copco — Sandvik equipment meets the demands made for a methodologically correct, economical soil drilling equipment. It permits drilling through all types of soil, even those with a high occurrence of boulders. The casing tubes require no rotation when being driven down, which is effected by the impact energy of the rock drill.

Extensive drilling operations at a great number of work-sites have all given very good results. All field tests were initially made in Scandinavian moraines, in most cases through earth-boulder strata, normally difficult to drill.

In the drilling completed to this date, the greatest hole depth which has been reached is 72 m (236'). This operation was carried out in the Gothenburg area, Sweden, with a casing tube size of 140 mm (5.5"). This was a water well drilling operation with 127 mm (5") ODEX equipment, which has been developed for just this type of drilling work, among others. The method makes it possible to drill with inexpensive standard casing tubes, readily available on the market, which are welded together as drilling continues.

Extensive production drilling has also been carried out with 76 mm (3") ODEX equipment, which is adapted to extensible, threaded casing tubes. This drilling has for the most part been investigation drilling combined with conventional soil- and core-sampling and anchoring drilling to soil depths between 10 and 35 m (33–115'). The horizontal drilling of 50 m (165') long holes has been carried out with 76 mm (3") ODEX equipment. Fill consisting exclusively of blasted rock has also been drilled through with good results. Wooden piles in old foundations or excavated materials pose no problems, but are easily passed through.

In anchoring drilling and water well drilling the 115 mm (4 1/2") ODEX equipment may also be used, and holes to a depth of 51 m (167') in the soil layer have been completed. Fig. 5 illustrates the composition of the soil layer in a water well drilling operation in Norway.

2 Helio-stat Enclosure Foundation

- 2.1 Standard trenching equipment has a maximum width of 24" on dualchain. Depending on slope of drag (60 degrees is usual maximum) a slope will be formed on the outer edge. Since this depends on trencher frame, and trencher angle along the radial plane, it can be adjusted so that there is some slope on inner wall, or can be almost equal. By this means the average trench width can be nearly equal to 2.5 feet over 4 feet depth with 2 foot chain width.
- 2.2 The trench liner for the backfill appears the most troublesome part of the entire concept (whether as part of unitized rig or individual unit). The concept of a properly folded liner (according to our model) can easily be "plowed" into the excavated trench and backfilled, at the same time being held by upper edge. The use of an encased rope has been successfully used on late design sailboats. This should be practical here. It would necessitate being "threaded" in to start, once per roll, manually.
- 2.3 The trench liner needs to be held securely at the start because of necessity to "overlap". This can be accomplished by an in flatable "stop" with "pins" to hold liner in place. Liner would be hand loaded onto this item.
- 2.4 Liner cutoff - if continuous roll is utilized for up to 50 foundations. A problem not fully resolved. As the Liner Plow overlaps the beginning end, means must be provided to cut "rope binding" and material.
- 2.5 If the temporary retaining walls are retracted at this point, we can maintain the "threaded in" portion.
- 2.6 Backfill storage (approximately 250 cubic feet - 25,000 pounds) on conveyors or hoppers proved to be an unworkable concept. current construction practice utilizes onground storage.

2.6 (continued)

We recommend modifying the concept accordingly. The method of backfilling utilizing a screw is also current practice, and location of screws can divide the stored soil into the proper proportions for tamping and can also lift the final load up and over the liner bead.

2.7 Feedback from tampers can be utilized to set scoop-up level if this degree of sophistication is desired.

2.8 Backfill Compaction. Current usage is either air driven, or most generally by self-contained combustion engine. Adaptation to electric drive should be no problem.

**THE DIGGIN'
DUTCHMAN**

VERMEER TRENCHER-PLOW DIVISION

VERMEER

T - 800

DAVIS®

**All-Season
Rock and
Frost Chain**

**For Davis Trenchers
30 hp and larger**

9. Factors affecting machine choice and performance

Lift height

Lift height or the depth of the soil being compacted is an important factor and affects the machine and its owner in two ways:

1. Performance of the machine
2. Cost of compaction

Vibratory and ramming type machines both compact the soil the same direction, from the bottom of the lift to the surface.

As the machine hits the soil, the impact travels to the hard surface and returns upward. This action sets the particles in motion and compaction takes place. As the soil becomes compacted, the impact has a shorter distance to travel so more force returns to the machine, making the machine lift off the ground higher.

If the lift is too deep the machine will take longer to compact the soil and a layer will be left which is not compacted.

There is no set lift-depth for soil compaction since the depth is determined by the machine used and the type of soil being compacted.

For example, a trench that is 32" wide could be compacted by several different machines, each having a different lift-height capability.

Obviously, the most economical method here would be the rammer plate because of its wide plate and deep compaction.

Since soils are usually found in mixtures of clay and granular, machine selection becomes more difficult. Generally, the machine used should be the type required for whichever solid represents the largest percentage of material.

The graph below illustrates machine application:

Backfill Tampers

Sizes GT341, GT441 and GTD341

Ingersoll-Rand
Tampers

The Ingersoll-Rand Triplex Tamper consists of three standard Backfill Tampers mounted in a yoke. A single air inlet carries the air to all three Tampers simultaneously.

Both Sizes 341 and 441 Tampers are available as Triplex Tampers and carry the symbols GT341, GT441 and GTD341. These tools are ideal on large projects requiring considerable backfilling which cannot be handled by heavier mechanical equipment. With quality uppermost in the eyes of all construction men, a backfill that assures no subsequent settlement is a must. I-R Triplex Tampers with their de-synchronized action and rapid hard hitting butts give that assurance.

Size GT341 and GT441 are standard gang tamping machines. The Size GTD341 is used for narrow ditch tamping.

FEATURES

FAST—One man operating an I-R Triplex Tamper can solidly compact, in $\frac{1}{3}$ the time, the same area as one man operating a single Tamper.

SAFE—The butts are held away from the operators feet by the wheel barrow type handles.

HIGHER LIFTS—20% higher lifts of solidly tamped ground can be had with Triplex Tampers.

EASY TO USE—One man does the work of 3 with less effort than he would use operating a single tamper.

UNIFORM WORK—The wide pattern made with the Triplex Tamper provides systematic uniform coverage of the work.

Size GT341 Triplex Tamper

Size GTD341 Triplex Tamper

Size GT441 Triplex Tamper

AIR engineering at work

Multiple Tamper + 3 Men = 8 Tampers + 8 Men !

Shown here is the construction of the Multiple Tamper.

In use, two men are able to handle the Multiple Tamper, while a third man keeps track of the hoses.

3 Heliostat Control Cable Implantation

- 3.1 The only item different than current practice is the handling of the attached branch-off connectors. Design consideration should be made to a configuration where the connector is a part of the main cable to prevent fouling in the main coil, and to a mechanism to provide a loop to surface the connector. This does not seem to be an insurmountable problem in either case.
- 3.2 The best choice is a chain trencher with cable feed and back-fill plow. This will permit the operator, or special automation, to loop the connector to the surface.
- 3.3 Depending upon the connector design, a plow type could possibly be used, and would be particularly effective in sandy soils with no hard pan or rocks.

M-485 — This heavy-duty, center-articulated, 4-wheel drive unit out-performs, out-muscles, and out-maneuvers all others in its class. As a trencher, the M-485 digs 6" to 16" wide, 72" deep. For an all inclusive direct burial operation, the M-485 can be equipped with a reel carrier and P-20 cable plow. Powered by a 70 hp. Ford 254 diesel this unit makes fast work of burying services up to 2" diameter to a cover depth of 30" with additional depth possible under ideal conditions. Engine output is coupled to a hydrostatic drive which powers a 4-speed transmission, enabling you to "fine tune" the ground speed for best production. A full line of attachments — backhoe, blade, trencher, plow, end loaders, reel carriers, boring tool, tree spade — make the M-485 the multi-purpose machine you can tailor to your needs.

Steiger/Krac—a Krac double linkage plow built into a much modified Steiger tractor. It has been developed into an efficient, high performance trenchless system.

Zor—the original double linkage plow. The small DP50 model is designed for fitting to a large four-wheel drive farm tractor. Other Zor models include the DP200 and the large DP300 for installing tubing up to 24 in diameter.

Badger—probably the original trenchless system developed in Britain and modified to suit the North American market.

Speicher—the Model 7060 has surprised many contractors with its digging performance in all types of working conditions. Wide flotation tires, a 4-71 GM diesel engine and extensive use of hydrostatics are the main features on this popular trencher

Radahl—a unique wheel-type trencher from Norway. The Radahl in action is similar to a chain-type trencher in that it saws through the soil.

ADS—Advanced Drainage Systems (ADS) pioneered plastic drainage tubing in the US and is a recent entry into the drainage machinery business. A plow is the first production machine.

Sanilac—the Gentle Giant is a hybrid that has set all kinds of installation records for its contractor/manufacturer, Russ Hall. Main features include a Michigan dozer power unit equipped with Zor plow.

Hoes—585—a chain digger mounted on rubber tires for roadability. Without the need for a low-boy, the 585 can travel easily between jobs at speeds up to 20 mph.

Hoes Gigant—the most popular Hoes trencher used by contractors throughout the US. It is one of seven different models available in North America.

Eberhardt—a West German trencher that has made inroads into the Canadian market. A V-6 Deutz power unit provides the muscle.

Barth TL-75—a self-propelled plow typical of European designed trenchless drainage systems. It offers low ground pressure and high traction.

Barth K-170—the K-170 can be seen all over Canada and the US. It is the favorite machine in a range consisting of ten different models.

Ditchwitch—a relative newcomer to the land drainage market, the Ditchwitch R100 has impressed contractors with its versatility.

Buckeye—the trencher that started it all. Buckeye designs have retained a family likeness for more than half a century.

ZBT—manufactured by three drainage contractor brothers, the ZBT 100 features rubber tires and a rugged digging chain mechanism.

Koehring/Parsons—clean lines and heavy-duty construction are characteristic of the Koehring/Parsons line of trenching equipment.

Wedge Plow—a Canadian double linkage trenchless system favoring the crawler/plow combination as opposed to the self-propelled unit.

Drainmaster—a Dutch-built trencher that has an established reputation in Holland, Britain and Canada. It is a rugged, high performance machine.

4 Drive and Power Unit

- 4.1 The necessity to transfer power to the "rotation" trencher, liner, backfill system indicates the use of electric power in this area. This can subsequently be converted to hydraulic to drive the various subsystems. A separate self-propelled unit generating as much as 500 or 1000 kilowatts is recommended.
- 4.2 The rig would be supported and driven on three or four (to be determined) pairs of tracks. In response to the laser-computer trigonometry, the rig would be powered and steered by these drive packages. The self-propelled unit would assist in locomotion over difficult terrain.
- 4.3 The rig would have its own electric to hydraulic and electric to air power units to drive the pedestal foundation implanter, and the cable trencher and backfill. The on board computer and laser generator should have an additional battery storage to prevent loss of memory, etc., if there is an interruption of electric power.

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Sundstrand, with nearly 50 years of fluid power experience, provides the most complete line of mass produced hydrostatic transmissions.

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- Field proven and reliable—More than 1.5 million units operational.
- One of the largest facilities devoted to exclusive manufacture of hydrostatic transmissions.
- World wide experienced application engineering, sales and product service.

100 hp, 5500 psi

Sundstrand transmissions are available as split systems and in many instances as self contained packages.

A wide range of controls that optimize performance and save energy are available. These include standard proportional speed controls, output torque and torque limiting controls, horsepower limiting controls, anti-stall, remote hydraulic, electric or pneumatic and many others that can be customized to your application.

You can count on Sundstrand. Request bulletin for further information.

20 hp, 4000 rpm

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110 hp, 6000 psi

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Hydro-Transmission **SUNDSTRAND**

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Circle 131

5 Logic Control and Guidance System

- 5.1 The logic control is relatively simple and can be accomplished with 1 or 2 small program controllers. One on trencher system and one on the rig for pedestal foundation and cable trench.
- 5.2 The guidance system to locate accurately at preselected pedestal positions needs some further study. It is desirable to set up as few survey markers at a site as possible. For a 50 by 50 rectangular array, one laser marker can be set up per row, and rangefinding laser system can locate linearly. The expected accuracy of this system has not been determined. Otherwise, a second station can be set up perpendicular to the base line and positions determined by triangulation. If it is not desirable to move the "row" marker 50 times, that can also be triangulated. ("Circular" arrays would be more complicated.)
- 5.3 A small computer should be ample for holding and issuing guidance information. A minimum program for 50 foundations would appear reasonable.
- 5.4 Comments on guidance and control are as follows:
 - a. "Laserplane" has complete 'laser to hydraulic' for controlling grades.
 - b. K&E has digital linear distance and angular outputs.
 - c. The Tellurometer U.S.A. Division of Plessey, Inc. has equipment of systems similar to K&E.

A SUGGESTED GUIDANCE SYSTEM

5-25-78
E.L.R.

- (a) Heliostat field divided into quadrants
- (b) Two rotating receivers at approximately 180° , with radio relay telemetry
- (c) Laser #1 strikes receiver #1, signal relayed to computer, angle of rotating laser recorded.
- (d) Laser #1 strikes receiver #2, signal relayed to computer
- (e) Computer calculates position of #1 and of A.F.M.
- (f) Steps b, c, d, e repeated for #2 and #2 laser
- (g) Computer sends corrective signals to drive/steer train.

COMMENTS: This arrangement keeps most electronics on board A.F.M.

If desired, 3rd laser on pedestal drill mast can be used to record or adjust, using markers 1 & 2 a triangulation in computer.

If necessary, x-y mechanism can relocate drill mast ± 6.0 inches

NOTE: At 500 fph traverse speed (cable laying), 31 ft will be traversed in 3.72 min or 1.67 in/sec. Overall response of system should give us vehicle position error of $< \pm 6$ inches

LASERPLANE

the pioneer

The Laserplane System was designed specifically to control land drainage machines and in the past decade has revolutionized a very traditional industry with a speed, accuracy and efficiency that was impossible to achieve before.

First used commercially to control grade on wheel-type ditchers, the System was soon adapted to chain-type trenchers and trenchless machines. This same basic Laserplane System has been refined and is used on bulldozers, graders, scrapers, land levelers and even rice contouring equipment.

Laserplane Corporation has more experience in the land drainage industry than any other manufacturer of automatic grade control systems. The Laserplane System has been fitted to most makes of wheel ditchers, chain type trenchers and trenchless machines available in the US, Canada and Europe and is operating successfully throughout the world. The System is available on many makes of trenchers as original equipment and can be retrofitted to all existing machines. Here are some of the drainage machines available with the Laserplane System as original equipment —

The installation kit includes mast mount, mounting brackets and plates as needed for each machine.

The Laserplane Sentry.

The Laser Rod is an automatic survey rod.

Slope Control

The slope control indicates the digging frame attitude, or controls the machine grade hydraulics when surface elevations vary enough to be out of the total range of the automatic laser system and grade breaker.

When set in the 'indicate mode', the panel lights warn the operator of changes in the tile shoe attitude caused by over crowding or soft bottom conditions. This mode is used when setting in at an intersection to establish proper shoe attitude.

In the 'control mode', the slope control will take over from the Laserplane System on steep slopes at the beginning or end of a drainage line to maintain proper grade. The slope control system has two main components; a sensor which is mounted on the machine's grading mechanism and a control panel at the operator's station.

Survey Equipment

Laserplane offers contractors two surveying systems, the Sentry and the Laser Rod.® The Sentry has a laser sensing detector and a Lenker tape rod which extends to 15 ft. The detector is powered by four C cell batteries and is moved up or down with an extension handle to indicate the laser light plane position audibly, and visually with Hi, Lo, and On-grade lights.

Laser Rod Sensor.

Mark II Detector.

The Sentry can be used to survey from a level light plane to determine elevations directly and from a sloped light plane to find minimum or maximum cuts. It can also be used to determine necessary grade break points and gauge heights required to make proper lateral intersections with the main.

The automatic Laser Rod is the ultimate in speedy, efficient elevation surveying equipment. A laser sensor built into the Laser Rod automatically tracks up and down until it locates the laser beam. It then stops and the number directly across from the pointer on the detector is the elevation reading. The increased speed and accuracy provided by the Laser Rod has revolutionized the field of construction site measurements.

Both the Laser Rod and Sentry provide measurement information at the point where it is needed—not at the instrument hundreds of feet away. Savings and labor costs alone amount to more than 50 percent over conventional surveying methods.

Electronic Distance Measuring Equipment

From its very beginning in 1807, Keuffel & Esser Company has been among the pioneers in the science of measurement. As problems in measuring lengths and angles arose, we researched and found solutions—through combinations of mechanical, optical and electronic means.

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G.E. - A.F.M.

- 6 Drive and Support System (Wheel/Track)
- 6.1 Track system is more stable at rest and has considerably more load carrying capacity per assembly.
- 6.2 Track system is more difficult to steer and would be slower, if not inappropriate for highway transfer.
- 6.3 Wheel system is less stable at rest, but would appear to be sufficient for the application. While the load carrying capacity on certain soils per assembly is less than track type, this soil condition might be inappropriate for foundation work.
- 6.4 Wheel system is less difficult to steer and would present few, if any, problems when free wheeling on highway between sites.
- 6.5 It is recommended that the design be considered that will permit interchangeability between track or wheel bogies.

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**"Since we've had Travelift.,
we have never damaged a unit,"**

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CARRIER AIR CONDITIONING DISTRIBUTION CENTER
NASHVILLE, TENN.**

In moving dozens of air conditioning units a day, a DROTT 250 AI Travelift has maintained a damage-free record in this Carrier yard despite working at a high rate of speed. An operator and two riggers load and store the units in 15 to 20 minutes.

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This kind of material handling efficiency is typical of Travelift performance. Your DROTT dealer has information on four sizes with capacities up to 120,000 lbs., or write to DROTT Manufacturing, Dept. DT-7425, P.O. Box 1087, Wausau, Wis. 54401.

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7 Leveling and Support

- 7.1 Auxiliary leveling and support pads, hydraulically operated, are necessary to anchor the unit and to resist moving thrust forces imposed by the trencher.
- 7.2 Standard leveling cylinder assemblies are available, and special modifications are no problem.

8 Operator Requirements

- 8.1.1 Operator No. 1 provides initial guidance of rig to a position and direction where laser finder can take over.
- 8.1.2 Operator No. 1 initiates cycle start for pedestal foundation upon signal from automatic guidance positioning control.
- 8.1.3 Operator No. 1 readies equipment and material for trencher, liner and backfill.
 - a. Threads liner unto guides.
 - b. Fastens liner to stop and locates
 - c. Initiates start cycle for trencher.
 - d. Observes trencher cycle for first 60 degrees or so.
 - e. Observes trencher during overlap.
 - 1. Initiates stop and manual takeover if necessary.
- 8.1.4 Operator No. 2 (ground level) observes connection loop of cable, adjusts if necessary and puts automatic cycle in "ready" mode for next move to foundation location.

- 9 Standard and Special Construction and
 Industrial Machinery Specifications
- 9.1 AASHO American Association of State Highway Officials
 (T-99 "Proctor Method of Compaction Test Procedures")
- 9.2 ICED Industrial and Construction Equipment Division of
 Fair and Industrial Equipment Institute
- 9.3 SAE Society of Automotive Engineers
 Industrial and Construction Equipment Recommendations
 (Off Highway Vehicles - Section 41 - 1978 Handbook - Part II)
- 9.4 OSHA Occupational Safety and Health Administration
 OSHA No. 29 CFR 1926.1001 Minimum Performance
 Criteria for Roll Over Protective Structures for
 Designated Scrapers, Loaders, Dozers, Graders
 and Crawler Tractors
 (SAE-J 10406)

		Engineering
		Design
10	<u>Preliminary Cost Estimates</u>	<u>Hours</u>
10.1	Structure	
	Center Section (Wgt)	\$100,000 500
	RH- LH Side "	\$200,000 500
	Cab "	\$200,000 500
10.2	Pedestal Foundation - Drill Tower and Fittings	
	Ready to mount	\$150,000 150
10.3	Pedestal Foundation - Casing Holder and Manipulator	\$100,000 500
10.5	Foundation Liner Holder and Mechanism	\$150,000 1000
10.6	Foundation Retainer and Liner Plow and Mechanism and Drive	\$200,000 2500
10.7	Soil Backfillers (3)	\$ 30,000 500
10.8	Soil Tamper (Compaction) (3)	\$ 30,000 500
10.9	Anchoring and Leveling Pads (4)	\$ 40,000 300

10.10	Support and Drive Carriages (C.F straddle lift type)	\$245,000	750
10.11	Self-Propelled Power Unit 500 Kilowatts	\$100,000	200
10.12	Logic Control and Laser Guidance System	\$200,000	1500
10.13	Overall Project Leadership and Supervision, Travel, Etc.	<u>\$ 15,000</u>	<u>2000</u>
		\$1,760,000	11,400 Hrs.
10.14	Detail Design (Est'd.)	---	18,240 Hrs.
10.15	Assembly and Dry Run Tryout (Est'd.) Including Shop and Engineering Supervision	---	12,750

APPENDIX "F"

APPENDIX A: FLOWCHARTS OF CLOCK INTERRUPT PROGRAM AND SUBROUTINES

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APPENDIX A:
FLOWCHARTS OF CLOCK INTERRUPT
PROGRAM & SUBROUTINES

A.1 INTERRUPT PROGRAM

Function

This program controls priority activities that depend on clock cycle counts:

1. Tower message reception (PROTOCOL subroutine).
2. Feedback message transmission (FDBACK).
3. Pulse Transmissions to drive motors (PULSE(I)).
4. Locking onto synchronization pulse from tower (SYNC).

Subroutine SAVE stores the content of registers and accumulators in memory, and RESTORE restores them to their state before the interrupt.

Flowchart

See next page.

A.2 FDBACK SUBROUTINE

Function

This subroutine controls the transmission of the heliostat feedback message to the tower.

Flowchart

See next page.

FDBACK SUBROUTINE FLOWCHART

A.3 MOVCHK(I) SUBROUTINE

Function

This subroutine sets appropriate error flags if the azimuth (I=1) or elevation (I=2) drive motor fails to respond to drive pulses.

Flowchart

See next page.

MOVCHK(I) SUBROUTINE FLOWCHART

A.4 PROTOCOL SUBROUTINE

Function

This subroutine has two principal functions:

1. To receive the tower command message and to store it in the local heliostat microcomputer memory if and when appropriate.
2. To check the message code word CHECKSUM to verify agreement with the received message, and if necessary to place the heliostat in the failsafe "STOW" mode.

Flowchart

See next two pages.

PROTOCOL SUBROUTINE FLOWCHAR

(continuation)

A.5 PULSE(I) SUBROUTINE

Function

This subroutine controls the drive pulse transmission to the azimuth (I=1) and elevation (I=2) drive motors.

Flowchart

See next page.

PULSE (I) SUBROUTINE FLOWCHART

A.6 SYNC SUBROUTINE

Function

This subroutine locks the software clock onto the synchronization bit transmitted via the communication link from the control tower once each 5-second control period.

Flowchart

See next page.

SYNC SUBROUTINE FLOWCHART

APPENDIX B:

FLOWCHARTS AND ALGORITHMS OF EXECUTIVE OPERATING PROGRAM AND SUBROUTINES

B.1 OPERATING PROGRAM

Function

This program controls the computations for parameters and logic variables (flags) needed by the interrupt program in accordance with the "current" operating mode.

Flowchart

See next page.

OPERATING PROGRAM FLOWCHART

B-2

B.2 CALEND SUBROUTINE

Function

This subroutine carries out terminal computations at the completion of a calibration run. It is called by subroutine CALIB.

Algorithms

The subroutine uses standard algorithms for matrix inversion and matrix multiplication.

Flowchart

See next page.

CALEND SUBROUTINE FLOWCHART

B.3 CALIB SUBROUTINE

Function

This subroutine controls the updating of computed matrix elements in the calibration mode. The computations are delegated to subroutines CALMAT and CALEND.

Flowchart

See next page.

CALIB SUBROUTINE FLOWCHART

B.4 CALMAT SUBROUTINE

Function

This subroutine carries out periodic computations for updating the elements of the A-matrix and the B-vector during a calibration run.

Algorithms*

1. Definitions:

θ = azimuth angle, represented by DESCO(1)
 φ = elevation angle, " " DESCO(2)
 $C(1) = \cos \theta$; $C(2) = \cos \varphi$
 $S(1) = \sin \theta$; $S(2) = \sin \varphi$
 $DEL(1) \triangleq$ desired angle - actual angle

Therefore

$DEL(I) = \Delta * [DESCO(I) - ACO(I)]$ I=1 azimuth
I=2 elevation

where Δ = nominal angle per step.

$CC = C(1) * C(2)$
 $SS = S(1) * S(2)$
 $CS = C(1) * S(2)$
 $DC = DEL(1) * C(2)$
 $S2 = S(2) * S(2)$
 $THS = \Delta * DESCO(1) * S(2)$
 $PHI = \Delta * DESCO(2)$

2. H - Matrix

$$H = \begin{bmatrix} \cos \theta \sin \varphi & \sin \theta \cos \varphi & -\sin \varphi & \theta \sin \varphi & 0 & 0 \\ -\sin \theta & \cos \theta & 0 & 0 & -\varphi & 1 \end{bmatrix}$$

* These algorithms are essentially those devised by Drs. R.S. Baheti and P.F. Scott. (Ref. Internal memo of 26 April 1978 by Dr. Baheti.)

Using this definition of H in the algorithms to follow, columns 1, 2, 3 refer to the x, y, and z axis rotations respectively.

$$3. \quad B = \sum H^T q$$

$$H^T q = \begin{bmatrix} -C(1) C(2) S(2) DEL(1) & -S(1) DEL(2) \\ -S(1) C(2) S(2) DEL(1) & +C(1) DEL(2) \\ S(2)*S(2) DEL(1) \\ -\theta * S(2) DEL(1) \\ -\varphi * DEL(2) \\ DEL(2) \end{bmatrix}$$

$\theta = DESCO(1)$
 $\varphi = DESCO(2)$

(Ref: Baheti memo of 4/26/78, p.8, with first three columns of H-matrix rotated to match new definition of a_1, a_2, a_3 .)

Hence

$$\begin{aligned} B(1) &= B(1) - CS*DC - S(1)*DEL(2) \\ B(2) &= B(2) - SS*DC + C(1)*DEL(2) \\ B(3) &= B(3) + S2*DEL(1) \\ B(4) &= B(4) - \Delta *DESCO(1)*S(2)*DEL(1) \\ B(5) &= B(5) - \Delta *DESCO(2)*DEL(2) \\ B(6) &= B(6) + DEL(2) \end{aligned}$$

$$4. \quad \sum H^T H$$

$$H^T H = \begin{bmatrix} CC & -S(1) \\ SC & C(1) \\ -S(2) & 0 \\ THS & 0 \\ 0 & -PHI \\ 0 & 1 \end{bmatrix} \begin{bmatrix} CC & SC - S(2) & THS & 0 & 0 \\ -S(1) & C(1) & 0 & 0 & -PHI & 1 \end{bmatrix}$$

$$= \begin{bmatrix} A(1) & A(2) & A(4) & A(7) & A(11) & A(16) \\ A(2) & A(3) & A(5) & A(8) & A(12) & A(17) \\ A(4) & A(5) & A(6) & A(9) & A(13) & A(18) \\ A(7) & A(8) & A(9) & A(10) & A(14) & A(19) \\ A(11) & A(12) & A(13) & A(14) & A(15) & A(20) \\ A(16) & A(17) & A(18) & A(19) & A(20) & A(21) \end{bmatrix}$$

The algorithms for $A = \sum H^T H$ are:

```

A(1)  = CC**2 + S(1) ** 2  + A(1)
A(2)  = CC*SC - C(1) * S(1)+ A(2)
A(3)  = SC**2 + C(1) **2   + A(3)
A(4)  = -CC*S(2)           + A(4)
A(5)  = -SC*S(2)           + A(5)
A(6)  = S2                  + A(6)
A(7)  = CC*THS              + A(7)
A(8)  = SC*THS              + A(8)
A(9)  = -S(2)*THS           + A(9)
A(10) = THS**2              + A(10)
A(11) = S(1)*PHI            + A(11)
A(12) = -C(1)*PHI           + A(12)
A(13) = 0
A(14) = 0
A(15) = PHI**2              + A(15)
A(16) = -S(1)               + A(16)
A(17) = C(1)                + A(17)
A(18) = 0
A(19) = 0
A(20) = -PHI                + A(20)
A(21) = 1                   + A(21)

```

Flowcharts

See next page.

CALMAT SUBROUTINE FLOWCHART

.5 DIAGNOS SUBROUTINE

Function

This subroutine checks the operational readiness of important hardware systems.

Algorithms

Each potential failure condition is checked by examining an appropriate logic "flag." They are identified as follows:

<u>Flag</u>	<u>Associated Component</u>
FLAG (1)	Microcomputer memory
FLAG (2)	Microcomputer processor
FLAG (3)	Heliostat enclosure air compressor
FLAG (4)	Serial input line (for message reception)
FLAG (5)= CHECK	Checksum codeword in tower message
FLAG (6)= NERROR (1)	Negative movement of azimuth wheel
FLAG (8)= PERROR (1)	Positive movement of azimuth wheel
FLAG (7), FLAG (9)	Similar checks for elevation wheel

In each case of an indicated fault, the fault must persist for 4 successive control periods or 4 successive checks, to minimize the likelihood of shutdown from false alarms.

After a fault has been confirmed in this manner, the heliostat mode is switched to the "STOW" mode. It remains in that mode indefinitely (i.e., until the fault has been corrected and correct operation confirmed through local checks).

Flowchart

See next page.

DIAGNOS SUBROUTINE FLOWCHART

B.6 INIT SUBROUTINE

Function

This subroutine controls the search for the reference marks of the azimuth and elevation wheels, and sets the angle counters to zero when the reference marks have been found during initialization.

Algorithm

The search algorithm is called via the SEARCH(I) subroutine.

Flowchart

See next page.

INIT SUBROUTINE FLOWCHART

B.7 LOCAL SUBROUTINE

Function

This subroutine implements instructions inserted locally and manually at the heliostat. Two modes of special interest are

- JOG (1 step at a time in a given
 direction for a given drive motor)
- SLEW (constant rate to desired angular
 position)

Algorithm

The following manual entries are required:

Set JOG or SLEW flag
Set DRIVE(I) flag*
Set (or clear) DIRECT (I) flag*
Enter values for DESCO(I), KA(I), etc.

*I=1 for azimuth, I=2 for elevation.

B.8 PANG SUBROUTINE

Function

This subroutine computes the desired next mirror pointing angles (I=1 for azimuth, I=2 for elevation), and the pulse rates required to attain those angles in the "current" control period.

Algorithms

1. Corrected Mirror Direction Cosines

Given: Nominal desired pointing vector (x_o, y_o, z_o) .

$$1.1 \quad x = x_o + a_2 y_o - a_2 z_o$$

$$1.2 \quad y = y_o + a_1 z_o - a_2 x_o$$

$$1.3 \quad z = z_o + a_2 x_o - a_1 y_o$$

where a_i ($i=1,2,3$) as defined in 11 May 78 memo on Terminology.

2. Desired Azimuth Wheel Count

Given: x, y .

$$2.1 \quad \text{DESCO}(1) \equiv m = (r_o/\Delta) (1 + a_4) \theta$$

where $\theta = \arctan (y/x)$, $-\pi \leq \theta \leq \pi$.

3. Desired Elevation Wheel Count

Given: x, y, z .

$$3.1 \quad \text{DESCO}(2) \equiv n = (r_o/\Delta) (1 + a_5) (\varphi - a_6)$$

where $\varphi = \arctan \left[(x^2 + y^2)^{1/2} / z \right]$, $-\frac{\pi}{2} \leq \varphi \leq \frac{\pi}{2}$.

4. Rate Algorithm

The rate algorithm is called via the RATE(I) subroutine.

Flowchart

See next page.

PANG SUBROUTINE FLOWCHART

B.9 RATE(I) SUBROUTINE

Function

This subroutine computes the cycle count per pulse period to attain a desired angular rate of movement of the heliostat drives. (I=1 for azimuth, I=2 for elevation.)

Algorithms

1. Azimuth Drive Count/Pulse, NA(1)

Given: "Current" count $m_o = ACO(1)$
 Desired count $m = DESCO(1)$
 Nominal clock count/period = KPER

Then: $NA(1) = 2 * KPER$, if $m = m_o$
 $NA(1) = KPER / (m - m_o)$, otherwise.

2. Elevation Drive Count/Pulse, NA(2)

Given: "Current" count $n_o = ACO(2)$
 Desired count $n = DESCO(2)$

Then: $NA(2) = 2 * KPER$, if $n = n_o$
 $NA(2) = KPER / (n - n_o)$, otherwise.

Flowchart

See next page.

RATE(I) SUBROUTINE FLOWCHART

B.10 SANG SUBROUTINE

Function

This subroutine computes the desired mirror pointing angles for sun reflection to the target, both in the "steering" and the "standby" mode.

Algorithms

1. Target Direction Cosines

Given:

Target coordinates = (X, Y, Z)

Heliostat coordinates = (X_H, Y_H, Z_H)

$$1.1 \quad x_T = X - X_H$$

$$1.2 \quad y_T = Y - Y_H$$

$$1.3 \quad z_T = Z - Z_H$$

$$1.4 \quad R = (x_T^2 + y_T^2 + z_T^2)^{1/2}$$

$$1.5 \quad x_T = x_T / R$$

$$1.6 \quad y_T = y_T / R$$

$$1.7 \quad z_T = z_T / R$$

2. Nominal Desired Mirror Direction Cosines

Given:

Target direction cosines = (x_T, y_T, z_T) ≡ U_T

Sun direction cosines = (X_S, y_S, z_S) ≡ U_S

Desired pointing vector

$$U_d = \begin{bmatrix} x_o \\ y_o \\ z_o \end{bmatrix} = k [U_S + U_T] \quad \text{where } k = \frac{1}{\sqrt{2}} (1 + U_S \cdot U_T)^{-\frac{1}{2}}$$

$$2.1 \quad x_o = x_s + x_T$$

$$2.2 \quad y_o = y_s + y_T$$

$$2.3 \quad z_o = z_s + z_T$$

$$2.4 \quad k = \frac{1}{\sqrt{2}} (1 + x_s x_t + y_s y_t + z_s z_t)^{-\frac{1}{2}}$$

$$2.5 \quad x_o = k x_o$$

$$2.6 \quad y_o = k y_o$$

$$2.7 \quad z_o = k z_o$$

Note: The factor k must be computed in this revised algorithm, in order that the error model can correctly compensate for the error parameters. (See algorithms for subroutine PANG.)

Flowchart

See next page.

SANG SUBROUTINE FLOWCHART

B.11 SEARCH (I) SUBROUTINE

Function

This subroutine controls drive wheel movement during the search for the zero reference mark (I=1 for azimuth, I=2 for elevation). The subroutine is called by the INIT subroutine during initialization.

Flowchart

See next page.

SEARCH(I) SUBROUTINE FLOWCHART

B.12 STEER(I) SUBROUTINE

Function

This subroutine stops mirror movement (I=1 in azimuth, I=2 in elevation) when the desired pointing angle has been reached. The subroutine is called by the operating program as well as by the STOW and SUNPOINT subroutines.

Flowchart

See next page.

STEER(I) SUBROUTINE FLOWCHART

B.13 STOW SUBROUTINE

Function

This subroutine drives the mirror to the stowed position.*

Flowchart

See next page.

*The stowed position is the same as the initial position, with both angle counters reading zero and the mirror pointing straight up.

STOW SUBROUTINE FLOWCHART

B.14 SUNOUT(I) SUBROUTINE

Function

This subroutine is called (by the SUNPOINT subroutine) to interpret the sun sensor output signals during a calibration run. (I=1 refers to azimuth, I=2 to elevation error signals.) The interrupt signal is disabled during processing of this subroutine.

Flowchart

See next page.

SUNOUT(I) SUBROUTINE FLOWCHART

B.15 SUNPOINT SUBROUTINE

Function

This subroutine controls the mirror drives to follow the sun according to the sun sensor signals (closed-loop control) or according to sun position data transmitted from the tower (open-loop control).

Flowchart

See next page.

SUNPOINT SUBROUTINE FLOWCHART

APPENDIX C

MEMORY REQUIREMENTS

C.1 FLAGS

Table 1 on the next page lists the 21 flags cited in the program flowcharts. Eight of the flags are subscripted; i.e., they have multiplicities greater than unity. The total flag count, including multiplicities, is 36.

TABLE 1 FLAGS CITED IN THE FLOWCHARTS

<u>Name</u>	<u>Function</u>	<u>Multiplicity</u>
CAL	Calibration angle determination	1
CHECK	Check sum is incorrect	1
CALCUL	Recalculate desired wheel positions	1
DIRECT(I)	Move I th drive wheel in positive direction	2
DRIVE(I)	Let pulses go to drive wheel I	2
FIRST	First pass during initialization	1
FLAG(K)	Diagnostic flags	9
FOUND(I)	Stop search for reference mark of drive wheel I	2
LOCAL	Local vs. tower control flag	1
MODE	Bypass reading of new mode	1
NCHECK(I)	Confirms neg. movement of I th wheel	2
NERROR(I)	No movement detected in neg. direction (drive wheel I)	2
STOW	Drive mirror to stow position	1
PCHECK(I)	Confirms pos. movement of I th wheel	2
PERROR(I)	No movement detected in pos. direction (drive wheel I)	2
SECTOR	New mode applies to whole sector of heliostats	1
SUNAC	Sun acquired by sensor	1
SUNTOL	Sun pointing error is within tolerance (during calibration)	1
TARGET	Read new target coordinates	1
TOWER	Confirms syne bit reception	1
TRANSMIT	Transmit feedback message during current 5-sec cycle	1

36

C.2 PARAMETERS AND VARIABLES

Tables 2 and 3, respectively, list many of the more significant parameters and variables cited in the program flowsharts.*

The tables show 10 parameters and 62 variables (including the multiplicities of subscripted variables).

* An example of variables that are omitted are DO-LOOP indices.

Table 2 PARAMETERS

<u>Name</u>	<u>Meaning</u>
IBIT	Initial value of KBIT
IKAL	" " KAL
IKLOK	" " KLOK (after sgne bit)
ISUM	" " KSUM
IWORD	" " KWORD
KMAZ	max.clock count for syne window
KMIN	min. " " " "
KPER	nominal clock count per period
MAXSYN	max.number of no-sgne events before switching to stowing mode.
Δ	constant (nominal angle per pulse)

TABLE 3 VARIABLES

<u>Multiplicity</u>	<u>Name</u>	<u>Use</u>
1	KLOK	clock count from sync bit
1	NOSYN	count of "no syne" in clock window
1	KAL	period count for calibration readings
2	MACO (I)	max. value of ACO (I) (used during initialization search)
1	KMAT	count of matrix updates (in calibration)
1	IKMAT	initial count of KMAT (negative)
1	KSUM	count of bad CHECKSUM's (PROTOCOL)
1	KBIT	count of bits in message from tower (PROTOCOL)
1	KWORD	count of words " " " " (PROTOCOL)
2	KA(I)	clock count for pulse period
2	KP(I)	pulse count for movement check
2	MKP(I)	max. pulse count KP(I)
2	NA(I)	pulse period, in clock cycles/pulse
2	ACO(I)	actual angle count I=1 for azimuth () =2 for elevation ()
2	DESCO(I)	desired angle count
2	DEL(I)	difference angle
21	A(K)	K=1, 2, . . . , 21 Matrix A
6	B(L)	L=1, 2, . . . , 6 Vector B
2	C(I)	I=1, 2 cosine function for I th wheel
2	S(I)	sine function " " "
7	CC, CS, DC, SS, S2, THS, PHI	variables used in calibration

62 = count of variables with their multiplicities.

C.3 ALGORITHMIC STATEMENTS

Tables 4 and 5 show in separate columns the approximate number of

- conditional branches
- subroutine calls
- other statements

for each of the two main programs and their associated subroutines.

TABLE 4 COUNT OF ALGORITHMIC STATEMENTS:
INTERRUPT PROGRAM AND SUBROUTINES

<u>Program Name</u>	<u>Conditional Branches</u>	<u>Subroutine Calls</u>	<u>Other Statements</u>
CLOCK	5	7	4
FDBACK	1	0	7
MOVCHK(I)	4	0	13
PROTOCOL	6	0	22
PULSE(I)	2	1	7
SYNC	4	0	13
	<hr/>	<hr/>	<hr/>
Totals	22	8	66
	<hr/> <hr/>	<hr/> <hr/>	<hr/> <hr/>

TABLE 5 COUNT OF ALGORITHMIC STATEMENTS:
OPERATING PROGRAM AND SUBROUTINES

<u>Program Name</u>	<u>Conditional Branches</u>	<u>Subroutine Calls</u>	<u>Other Statements</u>
Operating Program	8	11	11
CALEND	1	2	11
CALIB	3	2	6
CALMAT	0	0	36
DIAGNOS	4	0	11
INIT	3	2	13
PANG	0	2	6
RATE (I)	5	0	13
SANG	0	0	15
SEARCH (I)	3	0	9
STEER (I)	2	0	4
STOW	0	4	3
SUNOUT (I)	2	0	7
SUNPOINT	3	4	7
Totals	<u>34</u>	<u>27</u>	<u>152</u>