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MCDONNELL DOUGLAS

SECOND GENERATION HELIOSTAT

WITH HIGH-VOLUME MANUFACTURING FACILITY
DEFINED BY GENERAL MOTORS

VOLUME I

MCDONNELL DOUGLAS ASTRONAUTICS COMPANY-HUNTINGTON BEACH

MCDONNELL
DOUGLAS
CORPORATION

SECOND GENERATION HELIOSTAT FINAL REPORT

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APRIL 1981

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PREFACE

This report provides the results of a heliostat development program performed by the McDonnell Douglas Astronautics Company for Sandia National Laboratories, Livermore, California, under Contract 830024A. This program involved design, fabrication, and test of prototype heliostats which, when produced in high volume, support the Department of Energy goals for solar central receiver power plant economics.

Volume factory design and output costs were provided under a subcontract by the General Motors Energy Systems Group and the F. Jos Lamb Company. MDAC incorporated these costs into price analysis including factory and field installation costs, a return of investment, and profit. The price followed previous program projections and substantiated the potential for attaining DOE goals.

The heliostat design was based substantially on previous MDAC development effort. The prototype heliostat, in conjunction with MDAC-developed controls hardware and software, exceeded all performance requirements.

The next requirement is a market demand, which will determine sales volume and in turn dictate production processes and costs. MDAC and its suppliers are ready to supply this market at any volume level. The design developed under this contract is the property of the US Department of Energy for any Government applications. MDAC reserves the commercial rights to the subsystem and components through proprietary developments by MDAC and its suppliers of controls system hardware and software, drive components, and mirror module fabrication technology.

This report consists of two volumes. Volume I summarizes the subsystem design, test substantiation, and operations and provides the MDAC price analysis and detail subsystem cost analysis. Volume II provides the volume factory design, manufacturing process design, and factory costs as developed by General Motors Energy Systems and the F. Jos Lamb Company.

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ACRONYMS

BCS	beam characterization system
CBS	Cost Breakdown Structure
CPU	central processing unit
CRTF	Central Receiver Test Facility
DAS	data acquisition system
DDC	Data Distribution Center
DDR	Detail Design Report
DIP	dual in-line package
DIR	direct image radiometer
DOE	Department of Energy
DPE	drive/main beam/pedestal/electronics
EPROM	erasable, programmable read-only memory
GM	General Motors
HAC	heliostat array controller
HC	heliostat controller
HFC	heliostat field controller
IC	integrated circuit
IRR	internal rate of return
LRU	line replaceable unit
MCS	master control system
MDAC	McDonnell Douglas Astronautics Company
MTTR	mean time to repair
O&M	Operations and Maintenance
PVB	polyvinyl butyral
RAM	random-access memory
SERI	Solar Energy Research Institute
WRB	wire race bearing

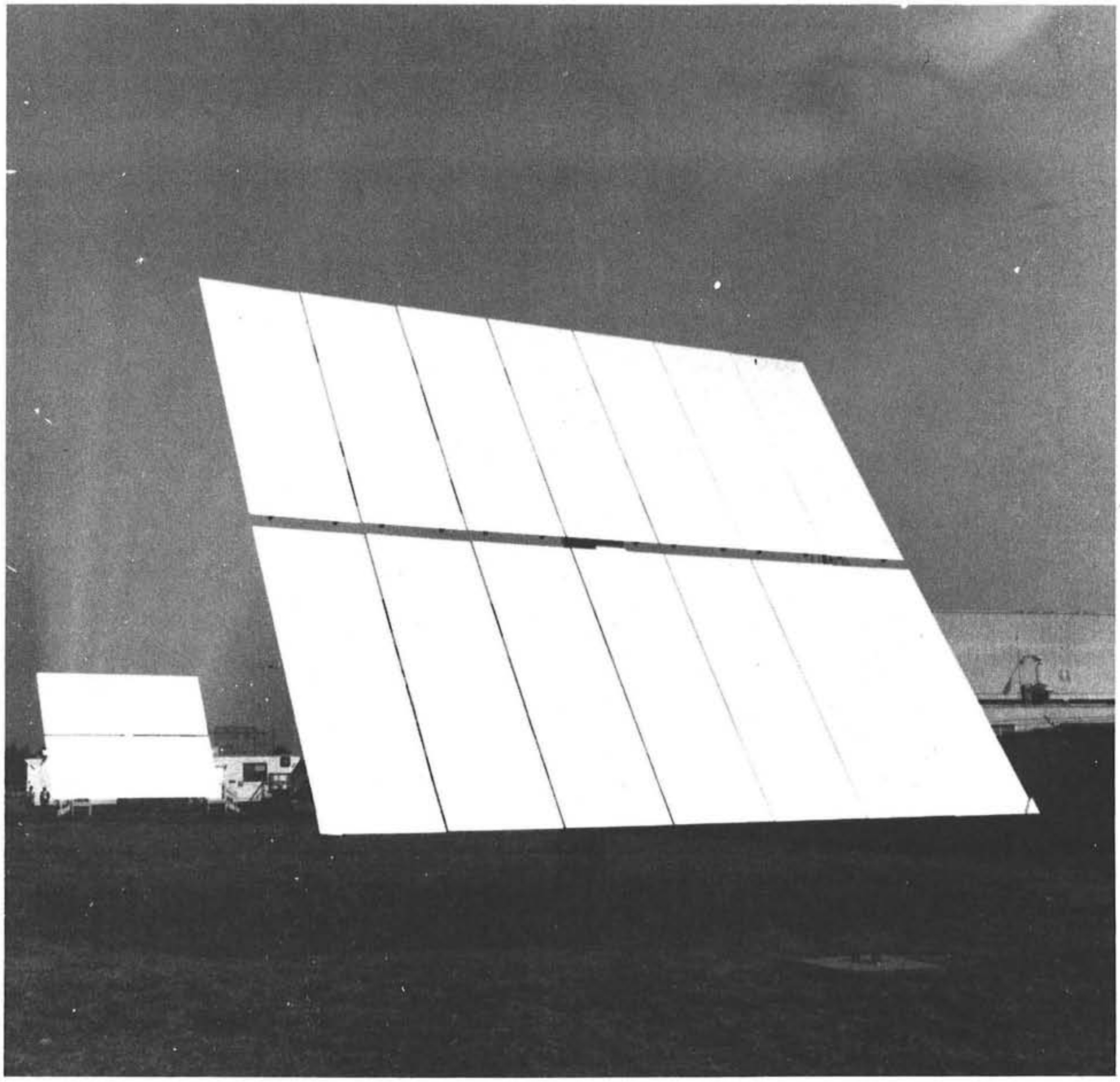

Figure 1. MDAC Second Generation Heliostat

Section 1
INTRODUCTION AND SUMMARY

In pursuit of the national goal of achieving commercially viable solar power systems, the McDonnell Douglas Astronautics Company (MDAC) has conducted a Second Generation Heliostat subsystem development program for the US Department of Energy (DOE) under the direction of the Sandia National Laboratories, Livermore, California.

The overall program goal is to develop heliostat subsystems which demonstrate the technical and economic feasibility of the generation of energy by solar central receiver power plants.

The program involved design, fabrication, and test of heliostats reflecting high-volume production designs; conceptual design of the processes and equipment for large-scale manufacturing, transportation, installation, and maintenance; and cost projections for large-scale production and deployment of the heliostat subsystem.

In demonstration of the readiness of heliostat subsystem technology to support the commercial development and deployment of solar central receiver plants, MDAC has designed, fabricated, and tested a subsystem comprised of heliostat subsystem controllers and two preproduction heliostats (see Figure 1). With support from two subcontractors, General Motors and the F. Jos Lamb Company, MDAC has performed preliminary design and costing of the manufacturing and deployment processes and equipment for 50,000 heliostats per year. The program has culminated in the delivery of the preproduction heliostat subsystem to Sandia National Laboratories on 1 December 1980 for an evaluation program and led to a volume heliostat subsystem production and deployment price projection of $87.90 per square meter.

A summary of MDAC heliostat design and testing, a description of high-volume manufacturing and deployment methods and the volume cost projections are provided in this report. A previous report, Second-Generation Heliostat Detail Design Report, MDC G8631, dated June 1980, has provided the results of the MDAC design and component testing in more detail.

1.1 PROGRAM DESCRIPTION

The MDAC approach to this program was directed toward developing a product which met cost goals, based on proven design concepts and available production processes and materials. The design and manufacturing process definition was structured as a production effort, with the next step considered to be a production implementation phase. This approach meets the technical readiness requirement of the program, with production in the early 1980's.

Although the hardware end product of this contract was two prototype units, drawing preparation and manufacturing process planning material was formatted to facilitate the initiation of volume production. Wherever practical, production processes were followed. The drawings reflected the production approach, and variation engineering orders provided the deviations necessary for the two prototype units.

The test program was structured to provide technical verification on the assembly level with performance validation of the whole subsystem. This was aided by an MDAC in-house development effort on the subsystem control hardware and software.

1.2 COLLECTOR SUBSYSTEM DESCRIPTION

The collector subsystem provided in this program consisted of multiple-heliostat control capability and the heliostat, depicted in Figure 2. The control system incorporates a unique, highly accurate pointing and tracking capability that eliminates absolute encoders and provides return to track capability following power loss to the heliostat field without heliostat realignment.

The major features of the MDAC Second Generation Heliostat configuration shown in Figure 1 are its large uninterrupted surface area with a minimum clearout area for the reflector area provided, and an aspect ratio which

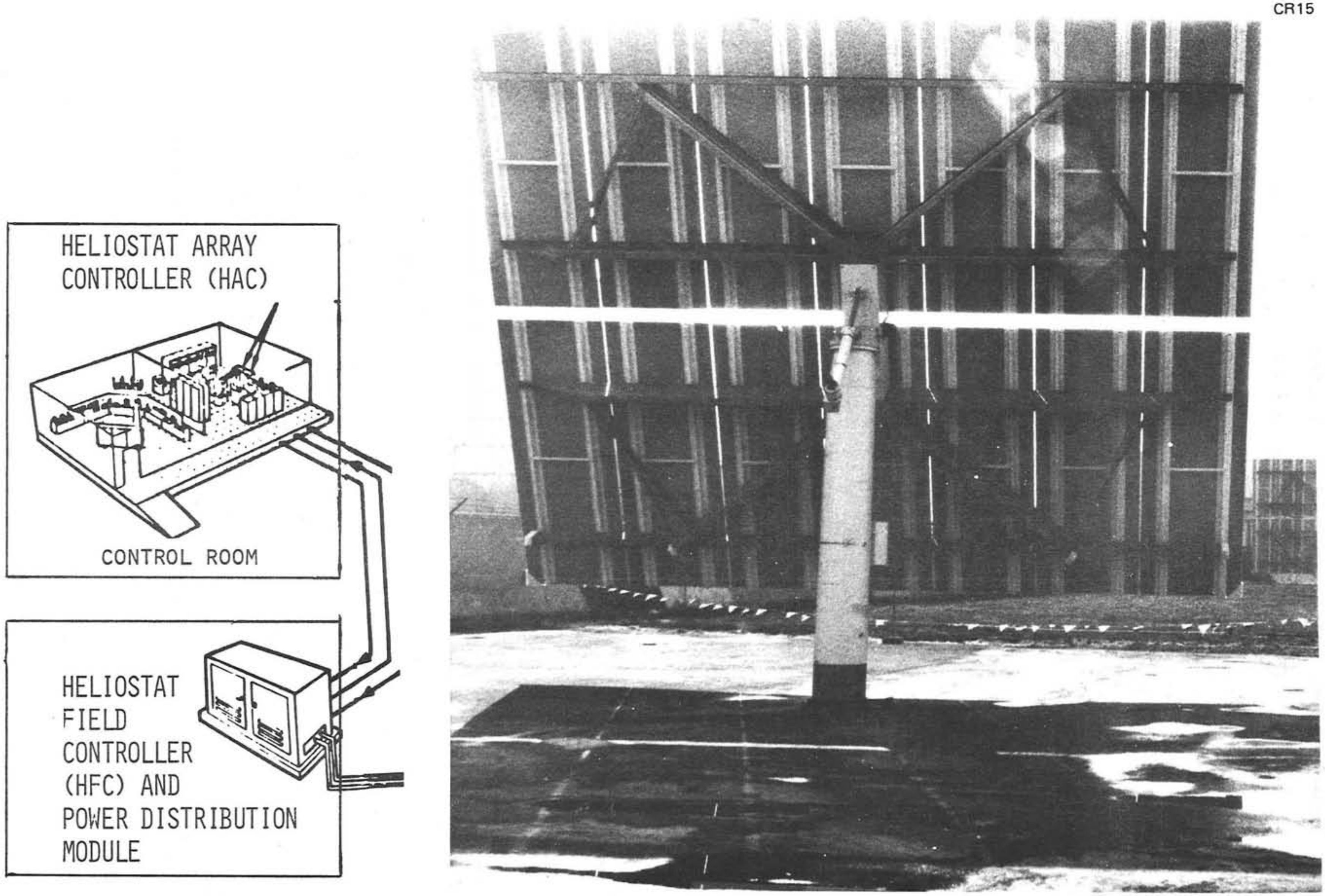

Figure 2. Second Generation Heliostat Subsystem

allows improved field utilization while achieving significant economies in fabriation and field assembly. Heliostat features are summarized in Table 1.

The heliostat is normally stowed in a vertical attitude. The heliostat operates in the tracking mode in winds up to 35 mph on command. Translation to the horizontal survival stow position occurs when winds above 35 mph are expected. In this stow position, wind load capacity exceeds 90 mph.

Table 1. Heliostat Features

Effective reflector area	57 m^2
Reflectivity	0.89 to 0.92+
Pointing accuracy	Well within 1.5 mrad rms. 0.5 mrad typical.
Beam quality	90% of redirected energy within theoretical +1.4 mrad fringe
Clearout radius	225 in.
Aspect ratio	1.27:1
Mirror focus	Common dual curvature, individual cant
Stow position	-2 deg from vertical
Survival position	Horizontal, face up
Power interface	208V, 3-phase - 4 wire
Emergency slew	Sequenced control through HFC
Field wire junction	At controller through fabrication
Operating environment	0 to 50°C
	0 to 27-mph wind
Operate to stow transition	Above 35-mph wind

All wiring is enclosed within the heliostat structure or protection shrouds, and drives are factory lubricated and sealed.

Field installation costs are minimized by factory assembly and alignment. A factory-aligned assembly, which consists of the azimuth and elevation drives, the pedestal and the main beam, and two factory-aligned reflector assemblies with precurved and canted mirrors, is provided for installation on the field assembled foundations.

The "production" configuration used in the production designs and costing tasks is the detail design provided in the prototype units. Incidental changes which adapt to the volume manufacturing process are included.

1.3 TEST PROGRAM SUMMARY

The test program included development design verification activities at component, subsystem, and assembly levels. The testing was organized to expand the existing MDAC heliostat design data base to the specific features of the Second Generation heliostat design. The total heliostat test verification includes results from the total MDAC data base. The combined data base is shown in Table 2.

1.3.1 Assembly and Subsystem Operation Experience

Heliostat assembly and installation substantially confirmed the design effort toward minimizing the time and resources required for these tasks. Pedestal drive assembly installation time associated with the production configuration was well within 5 min. Reflector assembly installation required 10 min each. Factory precanting of mirror modules was performed.

Pointing accuracy was demonstrated to be less than 0.5 mRad rms in a 5- to 10-mph wind. Power consumption for the summer solstice day at Huntington Beach, California, was measured at 775 W/hr, and signal level capability for the heliostat field controller/heliostat controller interface was demonstrated for up to 32 heliostats.

Table 2. Design Test Verification

Component	Feature	Requirement	Test schedule
Mirror	Stow	Cleanliness	CRTF, Odeillo (1)
		Safety	Noninversion Study (2) Dust Buildup Study (3)
	Laminating process	Life, materials capability	SRE Prototype Second Generation
	Hail survival	3/4-in. diameter iceball at 75 ft/sec	SRE Prototype Second Generation
Mirror module	Adhesive bond assembly	Life	SRE Second Generation
		Environment	SRE 10 MWe Second Generation
	Performance	Thermal effects curvature	Second Generation
Structure	Load determination	Wind tunnel data	SRE 10 MWe
	Load capabilities	Test verification of analysis method	SRE 10 MWe
Harmonic drive	Load capability	Maximum operating, maximum stow	SRE 10 MWe Second Generation
	Life	30 yr	SRE
	Environmental	Temperatures	SRE 10 MWe
Wire race bearing	Load capability life	Maximum operate	Second Generation
Helicon gears	Load capability	Maximum stow	Second Generation
Ballscrew jack	Load capability	Maximum operate, maximum stow	Second Generation
Sleeve bearings	Load capability	Maximum operate, maximum stow	10 MWe Second Generation
Controller	Circuit components	Operation	10 MWe Second Generation
		Life	Second Generation
		Environment	10 MWe Second Generation

(1) Heliostat Fields, Albuquerque; CNRS Plant, Odeillo, France.

(2) King, D. L. and J. E. Meyers, Environmental Reflectance Degradation of CRTF Heliostats. Proceedings of SPIE Symposium, Optics in Adverse Environments, Los Angeles, California, 4 February 1980.

(3) Blackmon, J. B., et al, Non-Inverting Heliostat Study, McDonnell Douglas Astronautics Company, MDC G7876, July 1979.

All control system modes were demonstrated prior to shipment. Approximately 2300 cycles, consisting of vertical stow to track to vertical stow, were achieved on each of the heliostats during this activity at Huntington Beach, California.

Maintenance task experience was obtained in installation and removal of motors, elevation actuator, and mirror modules.

1.3.2 Shipment and Installation at Central Receiver Test Facility (CRTF)

This activity again demonstrated the minimum effort required to install, check out, and align the heliostat. The two reflector assemblies and the drive main beam pedestal assembly were shipped aligned. Factory canting of mirror modules was not affected by shipping, and installation with a new crew was accomplished in minimum time.

Hardware anomalies which appeared during this period allowed correction of deficiencies not previously identified. These included mirror attach bolts out of specification and a mirror defect resulting from factory handling procedures.

1.4 VOLUME MANUFACTURING INSTALLATION AND OPERATIONS SUMMARY

The volume manufacturing concept was structured specifically to the Second Generation Heliostat design. This activity was aided by the four previous hardware-based manufacturing designs conducted by MDAC. Significant gains were achieved with the production definition in materials, manpower, and other production resource requirements.

The installation, operation, and maintenance definitions also have substantial validation from the experience with these tasks on the prototype units.

1.4.1 Volume Manufacturing

The volume manufacturing design performed by General Motors is found in Volume II of this report, with processes defined in Section 5 of this volume. The make-or-buy decisions resulted in procurement of the components for the reflector assembly, with laminating and support structure welding in the factory. The drive, pedestal, and main beam assembly components are all fabricated in the factory from raw stock and commercially available parts. The controls components are purchased.

A 260,000-ft^2 factory was defined for 50,000 heliostats per year. It was located in the southwest. Tucson was used as the location in the cost model.

Factory equipment and manpower requirements were produced from detailed labor and tool routing analysis based on process flows and specifications and detail drawings provided by MDAC.

Direct labor per heliostat is approximately 10.5 hr per heliostat. Total direct manpower for the plant is approximately 300, in two shifts.

1.4.2 Installation

The installation scenario consists of site assembly of the three heliostat components with special handling equipment. The installation projections are substantiated by preproduction unit experience and task analysis using a data base developed in the prototype heliostat study.

1.4.3 Maintenance

Except for periodic washing of the heliostats, no scheduled maintenance is required. Both reliability and maintainability features have been stressed in the selection of components and configuration of assemblies. Analyses of spares requirements and maintenance tasks have been provided to define the O&M costs.

Repairs in the field are minimized by use of line replaceable units. The replaced units are repaired at a site repair center or at suppliers. In some cases the item is considered a throwaway based on evaluation of handling and repair costs compared to volume factory supply costs.

1.5 SUBSYSTEM COSTS

The costs determined for the Second Generation Heliostat reconfirm that heliostats may be manufactured, installed, and operated at prices which will make solar energy competitive with alternative energy sources.

Pricing results for the studied production rates are summarized below in terms of first-half 1980 dollars per square meter:

Second Generation Heliostat
Subsystem Prices

Price element	Average $/m^2 (1980$) 25K/yr	50K/yr	67.5K/yr
Installed heliostat price	$99.60	$87.90	$84.20
50-MWe plant auxiliary price			
Heliostat array controller (plant control)	0.40	0.40	0.40
Maintenance equipment	1.14	1.14	1.14
Initial spares	0.14	0.14	0.14
O&M - First year	1.32	1.32	1.32
- Follow-on	1.02	1.02	1.02

Heliostat investment prices represent those that may be charged during the tenth full year of production facility operation under a strategy of pricing at a fixed percentage markup over each year's cash expenditures. These results are associated with both the design discussed in the following sections and a specific production scenario conceived and costed by General Motors and the F. Jos Lamb Company in order to produce 50,000 heliostats per year. The transportation and installation scenario is based on the analysis accomplished on the Prototype Heliostat contract. The alternate prices shown represent what may be charged where the baseline production facility, costing $88 million, is operated at 50% and 135% of designed capacity.

Figure 3 shows how these prices relate to production volume based on a curve originally presented in the final report for the Prototype Heliostat contract. The curve has been adjusted for inflation and normalized to study ground rules. The triangle plots the baseline price shown above, and the visible price range indicates the range of potential cost reductions that have been specifically identified. The results are reassuring considering that they are based on a prototype test article that has been built and tested and is operational.

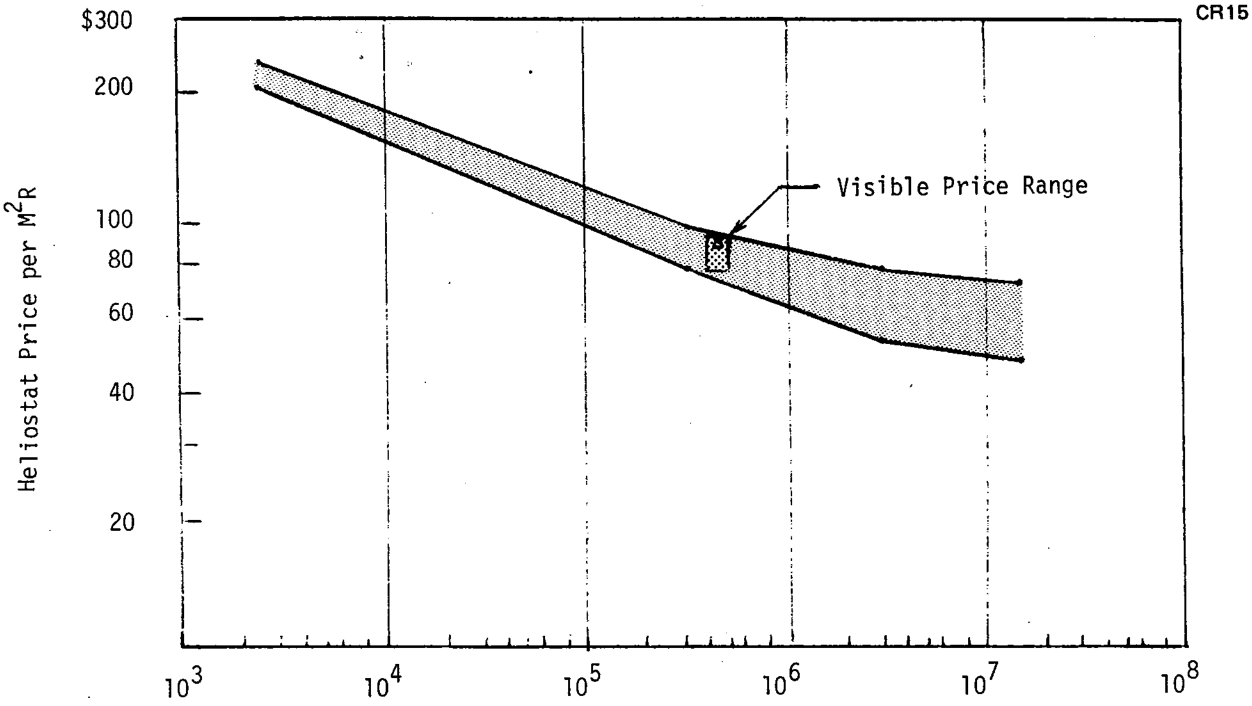

Figure 3. Installed Heliostat Price by Production Volume (1980 Dollars)

1.6 FUTURE DEVELOPMENTS

Further cost reductions are possible, resulting from developments identified in the Second Generation program. Sources of these developments are the manufacturing process design and the test results.

The manufacturing design has illuminated opportunities for decreased process time and equipment if faster curing adhesives and adhesive laminating replacing the conventional PVB-autoclave process can be developed.

Parts and material reductions will result from a directed design effort in the drive and structure areas.

Performance test results have indicated the opportunity to reallocate the error budget for parts and material reductions.

Installation operation with the preproduction foundations and heliostats indicates a potential for material saving for the foundations as well as installation labor savings through the detail design of special installation equipment.

Section 2
HELIOSTAT DESIGN

The initial task of this program was to design the prototype heliostat subsystem. The MDAC approach to this task was a straightforward implementation of design improvements resulting from contracted and in-house effort performed since 1973 aimed at heliostats designed to cost targets, as illustrated in Figure 4. Since the potential for meeting the DOE cost goals for heliostats was well established by the Sandia Prototype Heliostat Program and the Solar Energy Research Institute (SERI) Repowering Strategy Analysis, a demonstration of the capability to provide heliostats for the initial demonstration programs which could meet the cost targets when produced in high volume was required. To add further credibility to the potential of achieving the cost targets, materials and processes currently in a high-volume state were emphasized, where actual costs could be readily obtained rather than identified by extrapolation. This is also consistent with the technical readiness requirement of the program, with production in the early 1980s. Design and process improvements providing further cost reduction are defined in Section 7, Recommendations for Further Development. Finally, the innovation and experience of suppliers and the subcontractors, identified in Table 3, provided insight into high-volume cost avoidance and economies for heliostat production.

The design was produced by layout, trade studies, analyses, and test. The end product--consisting of detail drawings, procurement specifications, and parts lists as well as analyses, trade study, and components test results--is documented in the Detail Design Report (DDR). This section provides a summary description of the resulting subsystem design.

Some changes have been made in the detail design subsequent to the DDR document. These changes, resulting from test results not available at the DDR, are identified in the component descriptions. The test providing the results

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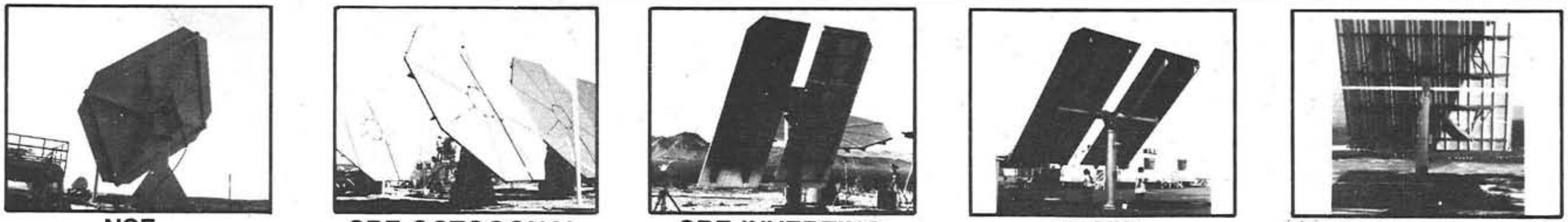

NSF	SRE OCTOGONAL	SRE INVERTING	10 MWe	SECOND GENERATION
Elevation over azimuth drive	—	—	—	—
harmonic drive	—		—	—
jack actuator	—		—	—
Bonded structure	—	—	—	—
Noninverting	—			—
	Area increase	—	—	—
	Laminated mirror	—	—	—
	Distributed structure	—	—	—
	Urethane adhesive	—	—	—
	AC motors	—	—	—
		Tube pedestal	—	—
		Standard mirror sizes	—	—
		Wind tunnel loads	—	—
		Intel micro processor	—	—
			Roll formed structure	—
			Mirror edge seal	—
			Mirror curvature	—
			Open loop control	—
			Mirror cant	—
				Tapered fit pedestal
				Wire race bearing
				Ball screw jack
				Helical gears
				Factory assembly
				Vertical mirrors
				Double curvature

Figure 4. Heliostat Configuration Development

Table 3. Supplier Participants

Linear actuator	- Duff-Norton
Harmonic drive	- USM
Helicon gear sets	- Illinois Tool Works
Roll form beams	- Van Huffel/Binkley
Mirrors	- Binswanger
Motors	- Emerson Electric
Glass	- PPG/Corning
Pedestal	- Pacific Union Metal
Bearings	- McGill
Volume factory design	- General Motors/F. Jos Lamb/ Dollar Electric/Corning
Sealed bushings	- Sargent Industries

is described in Section 3 of this report. A summary of the Second-Generation Heliostat Specification is provided in Appendix A. A summary of the critical design parameters and capabilities is provided with each component description.

2.1 HARDWARE DESCRIPTION

The collector subsystem hardware consists of the heliostats, foundations, and array control system as described below.

2.1.1 Heliostat Assembly

The heliostat assembly consists of two reflector assemblies, with seven mirror modules each, and related supporting structure; a drive, pedestal, main beam assembly; a heliostat controller; and a foundation. The overall configuration is shown in Figure 5 and the overall dimensions are summarized in Table 4. As previously described, the normal stow position is -2 deg from vertical to ensure that the reflected beam is on the ground in the near vicinity, even for low sun angles. The reflector assemblies are sized to allow shipment of a unit that is assembled and aligned in the factory. Mirror modules are sized individually for deflection under operational conditions with minimum material for panel stiffening. A maximum-size glass panel provides acceptable operational wind load and temperature deflections. Overall reflector area is selected for drive, pedestal, and foundation load/cost

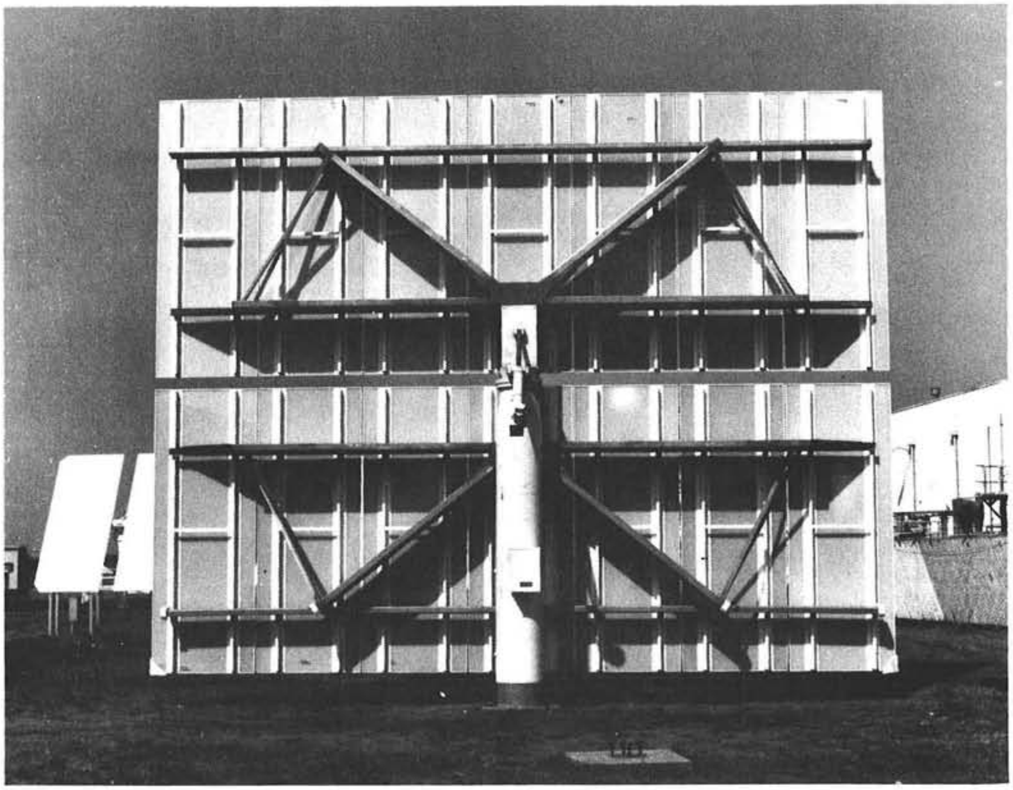

Figure 5. Assembled Second Generation Heliostat

Table 4. Heliostat Dimensions

Heliostat width	341 in.
Heliostat height*	
- Stowed vertical	282 in.
- Stowed horizontal	177 in.
Reflector height	270 in.
Clearout radius	222 in.
Effective reflector area	612 ft^2 - 57 m^2
Heliostat weight	
- Mirror modules	2721 lb
- Support structure	1586 lb
- Drive units	557 lb
- Pedestal	436 lb
Total	5300 lb

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*Dimensions given are nominal. Detail weights are found in Appendix D.

compatibility. The drive, pedestal, main beam assembly provides these functions in a factory-assembled and-aligned unit. The main beam joins the two reflector assemblies to the drive components, which consist of a linear jack in elevation and a rotary harmonic drive in azimuth. The pedestal provides the interface between the drive, a tapered fit foundation, and the heliostat controller located on the outside of the pedestal at approximately 4 ft above grade. The foundation provides the heliostat base. A junction box is located at the foundation to interface the heliostat with the field power and control wiring. The overall heliostat design critical requirements and capabilities are summarized in Table 5.

2.1.1.1 Reflector Assembly

The reflector assembly consists of seven mirror modules and a supporting structure. Figure 6 illustrates the reflector assembly, and Figure 7 shows the mirror module configuration. It consists of a laminated mirror bonded to two galvanized steel shims. A mirror support consisting of two galvanized steel hat section stringers is bonded to the shims. The laminated mirror for

Table 5. Heliostat Requirements/Capabilities

Requirement	Capability
Performance	
Pointing accuracy, 1.5 mrad	0.5 mrad both axis typical
Beam quality	
90% of redirected energy within theoretical + 1.4 mrad fringe	Design capability
Operational environment	
T = 0°C to 50°C	Design capability
Wind 0 to 12 m/s operating	Design capability
16 to 22 m/s maximum stow operation	Design capability
Survival environment	
Wind 40 m/s	Design capability
Temperature -30°C to +50°C	Design capability
Slew travel speed, full travel 15 min	Full travel 13 min
Cost-effective stow	
Beam safety, dust buildup	-2° normal stow position
Transportability, highway	2 assemblies packaged in shipping containers

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For specification and compliance demonstration method, See Appendix A.

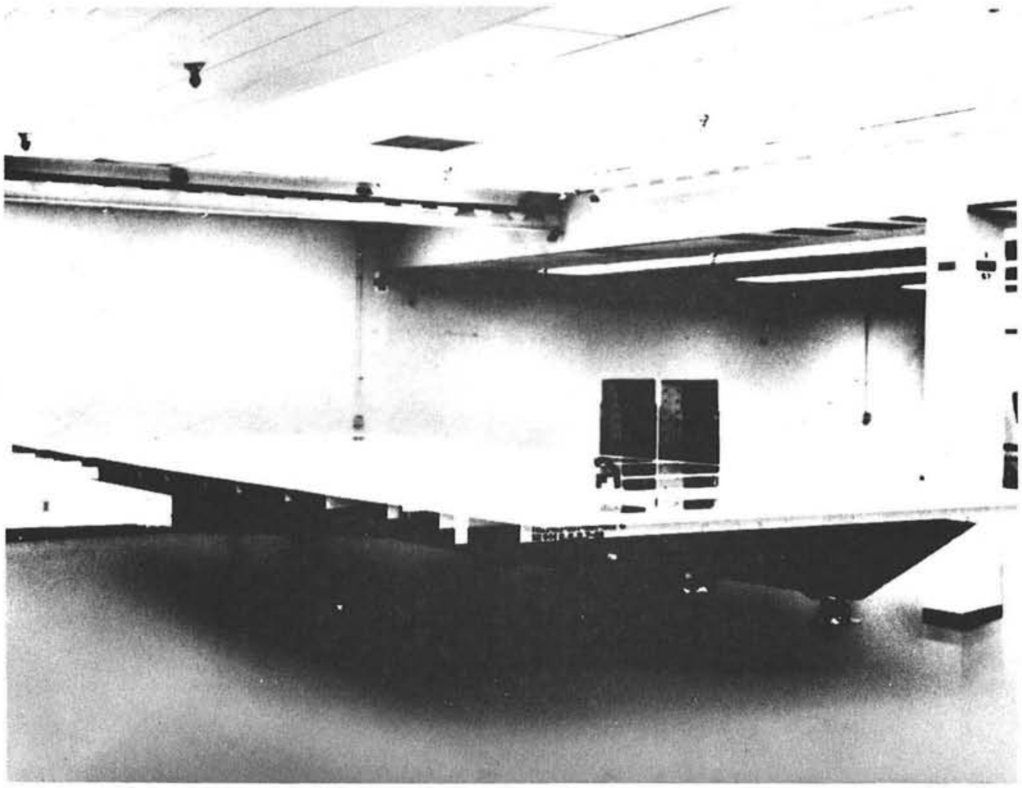

Figure 6. Reflector Assembly

the preproduction units is comprised of a 0.092-in. clear float glass (0.07% to 0.08% iron oxide content) mirror laminated to 0.188-in. float glass substrate. Production design is based on a 0.059-in. glass mirror. The mirror is capped around the edges with a metal edge member attached with a silicone seal. The overall dimensions of the panel are 48-1/4 by 132-1/4 in. Each panel has a reflective surface of 43.7 ft^2. The mirror module is curved in both directions to enhance performance.

The panel has demonstrated hail survival of 1-in.-diameter hail stones at over 100 fps for both front and back surface impacts, which is in excess of the requirements.

The mirror assembly is a conventional silver-copper-white backing paint polyvinyl butyral (PVB) laminate with autoclave cure. The shim-to-glass adhesive and the shim-to-hat section adhesive are urethanes. The two-part (shim and hat section) system was chosen based on test results and production

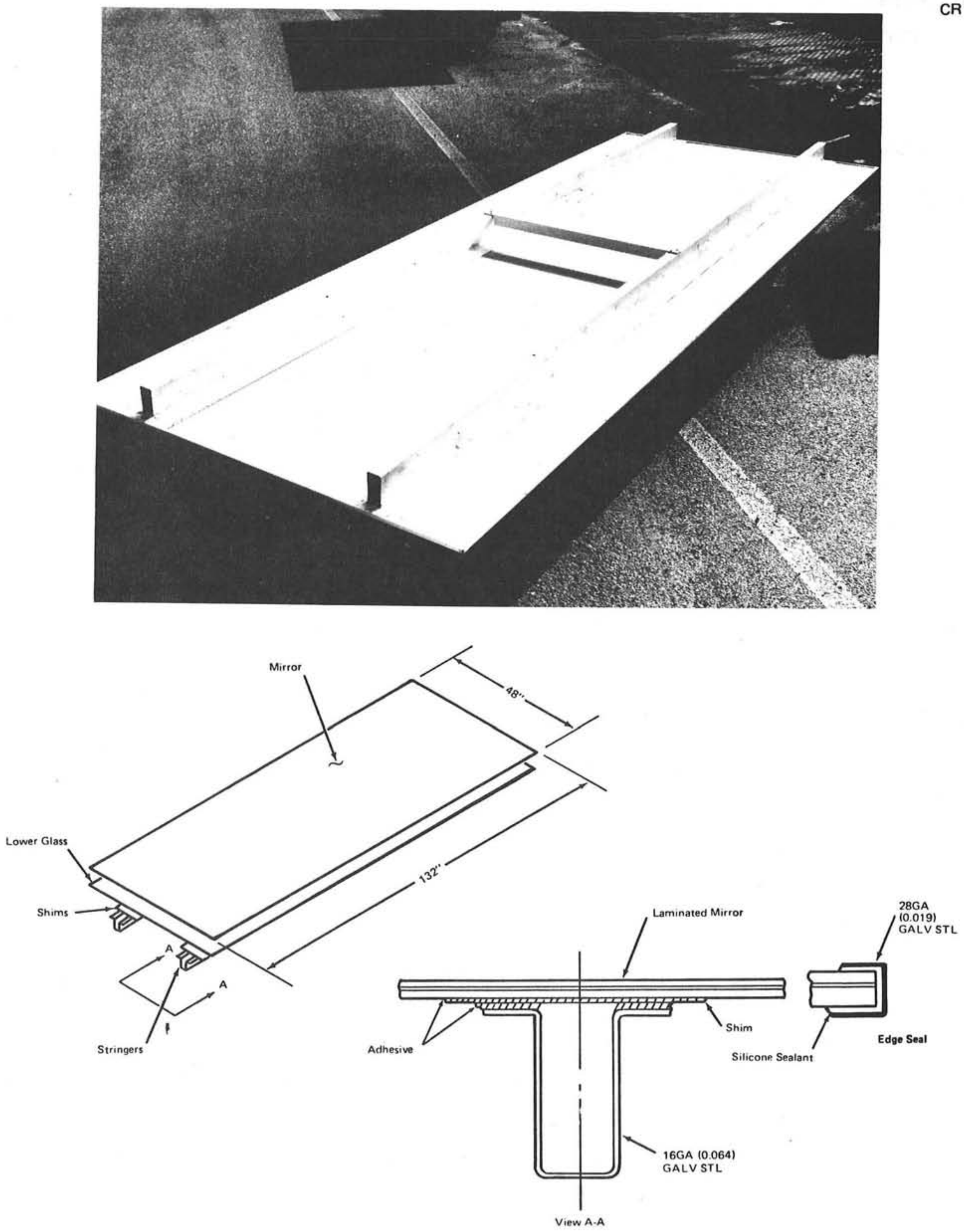

Figure 7. Second Generation Heliostat Mirror Module

process time requirements. A silicon coating is provided over the exposed urethane adhesive to prevent UV exposure.

The cross brace between the hat sections was added to the mirror module subsequent to the detail design report. It was added to increase mirror stability in the short span direction. Initial test of the mirror module assembly process indicated that sufficient stability was provided by the laminate, shim, and hat section assembly process in the long direction. In the short direction, initial results were variable but flatness appeared adequate. However, subsequent to manufacture, image quality results from a larger quantity of modules revealed that the short span required greater control. Tests conducted with one, two, and three braces equally spaced from the center of the panel at approximately 70 deg ambient indicated that a single brace provided 80 to 90% of the control provided by three. Subsequent tests at CRTF at cold temperatures (about 32°F) indicate that for positive beam quality compliance, additional braces are required. Although the preproduction heliostats were delivered with a single cross brace, more cross braces will be used on subsequent units for better control over the full temperature range.

The support structure is shown in Figure 8. It consists of an inboard cross beam, two diagonal beams, an outboard cross beam, and two sets of diagonal braces. The support structure is made from mill galvanized steel and is entirely spot welded together for low cost in high quantity production. The deep roll-formed sections provide high stiffness, low weight, and ease of fabrication.

The mirror modules are attached to the support structure by four studs, two mounted on each hat section.

2.1.1.2 Drive/Pedestal/Main Beam Assembly

This assembly with the pedestal detached to show the azimuth drive assembly is shown in Figure 9; requirements and capability are shown in Table 6. The assembly shown provides all the moving parts and control executions of the heliostat. The azimuth drive is at the bottom, connected to the main beam through the elevation support (structure) which also interfaces the elevation

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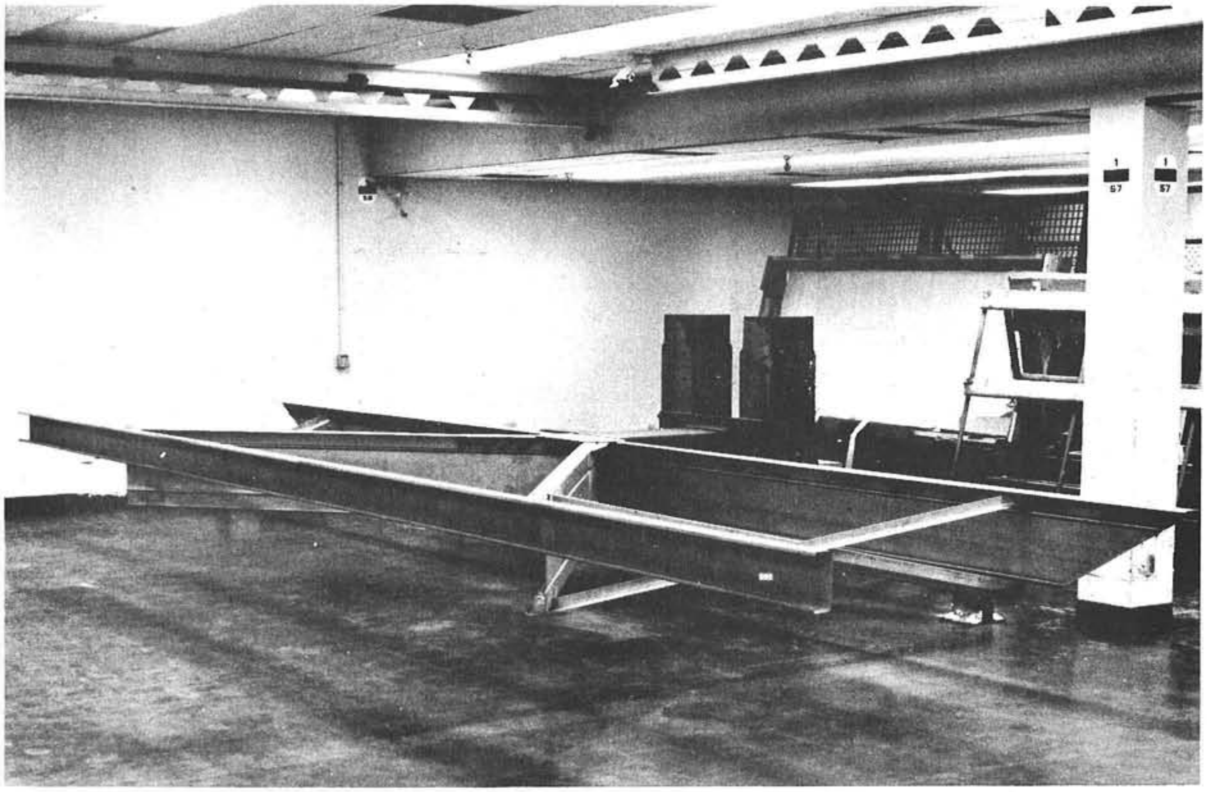

Figure 8. Reflector Support Structure Assembly

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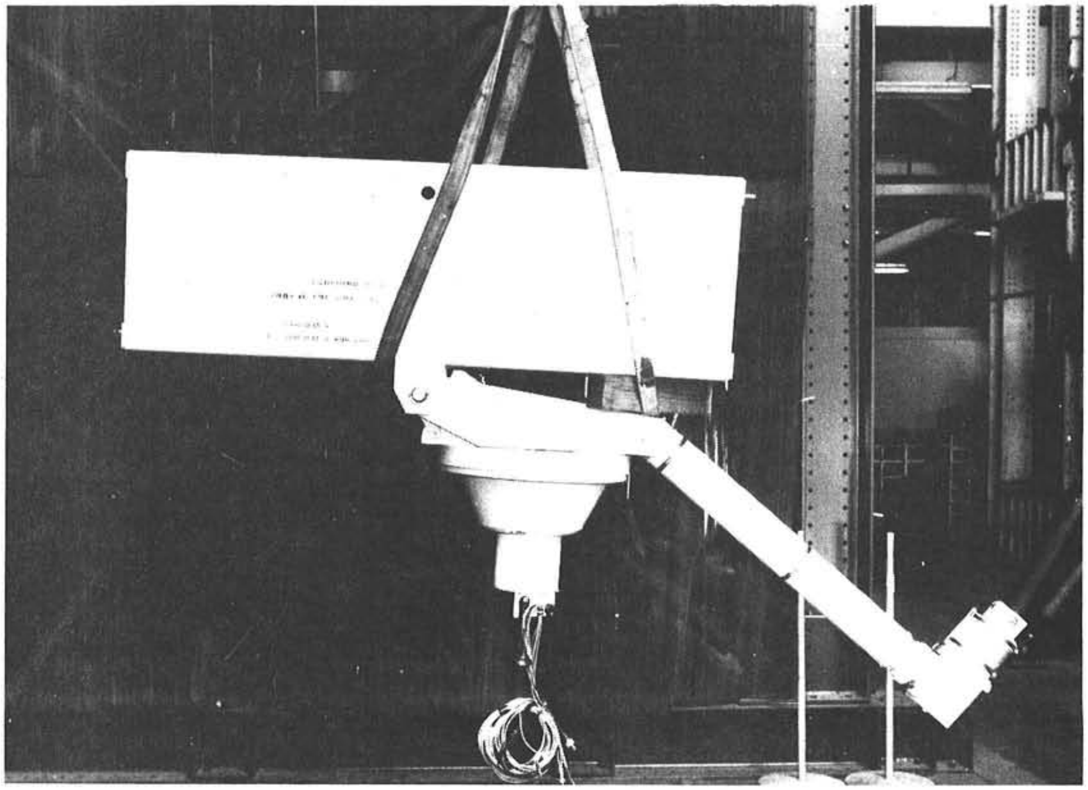

Figure 9. Drive/Main Beam Assembly

Table 6. Drive Pedestal/Main Beam Requirements/Capability

	Azimuth		Elevation	
Parameter	Requirement	Capability	Requirement	Capability
Travel time	180 deg in 15 min	180 deg in 12.5 min	90 deg in 15 min	90 deg in 6.0 min
Survival load (face up to 90 mph)	99,500 in-lb	>212,500 in-lb	27,300 lb	>44,000 lb
Max static load (any orientation at 50 mph)	144,000 in-lb	>212,500 in-lb	13,900 lb	>18,600 lb
Max operational	80,900 in-lb	*100,000 in-lb	10,816 lb	>18,600 lb
Deflection at 27 mph	2.4 mrad at 41,900 in-lb	1.7 mrad at 42,000 in-lb	1.85 mrad at 52,900 in-lb and α = 20, 40 deg	1.6 mrad at 52,900 in-lb and α = 40 deg
Overturning moment (at the azimuth drive bearing centerline)	401,000 in-lb with 9,400 lb axial and 4,500 lb radial	>512,000 in-lb		
Emergency stow condition (50 mph gust) nonoperational		**	13,800 lb	>15,000 lb

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*Prototype units, >144,000 in-lb for production

**Maximum azimuth dynamic load exposure limited by elevation only travel in 50 mph gust front stow. Azimuth static capability exceeds gust requirement. See Appendix A-3.

drive to the main beam. The power and control cables which connect this assembly to the heliostat controller are also shown. They are enclosed in the pedestal when it is installed onto the azimuth drive. The interfacing attachment of the drive elevation support and main beam are shown in Figure 10. A cover over the elevation support cavity has been removed for clarity.

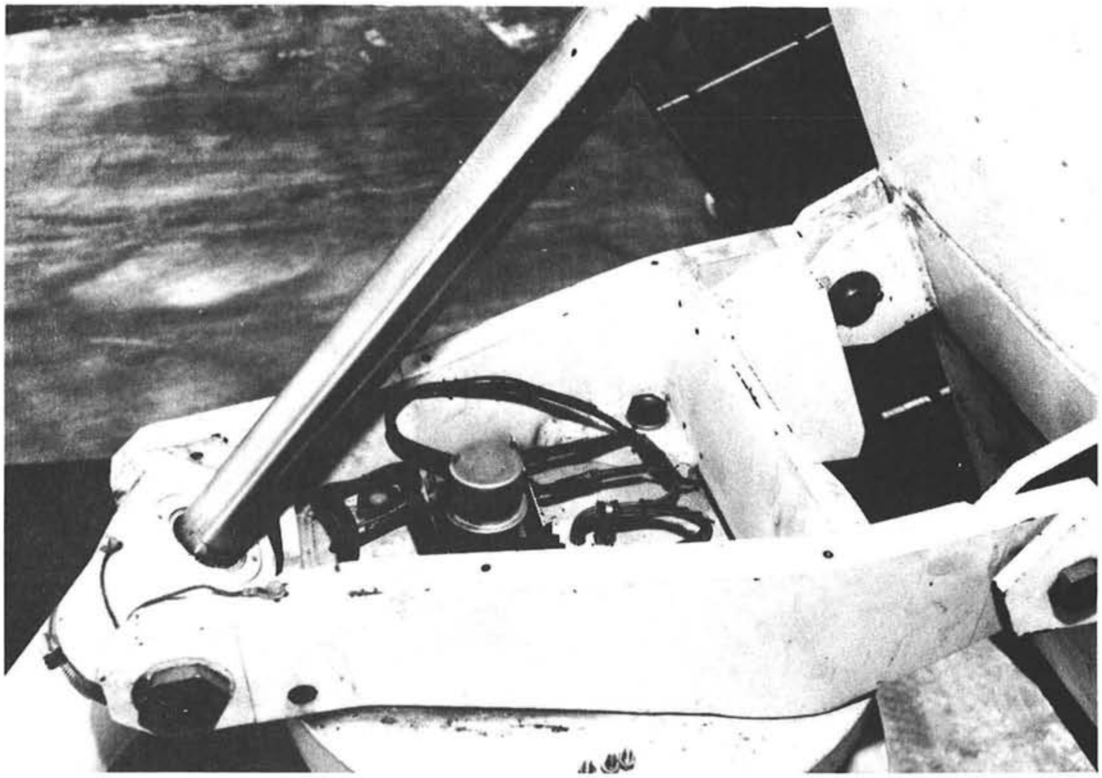

Figure 10. Elevation/Azimuth Drive Interface

Four bolts attach the elevation support to the azimuth drive. Two pins join the main beam to the elevation support. One contains a spherical bearing to transfer side load from the main beam to the elevation support. Screw-in trunion pins join the elevation jack actuator to the structure, and a clevis pin (not shown) attaches the jack rod to the main beam. All the joints contain sealed, self-lubricating bearings. The elevation support is a welded steel part for the preproduction units but will be a casting in production.

Azimuth Drive

The azimuth drive is a separable sealed unit that is recessed into the top of the pedestal. Two expansion chambers are used to compensate for internal pressure fluctuations. One is shown in Figure 9 in the elevation support interior. The other is located on the side of the housing. The major components inside the drive are shown in Figure 11.

The circular spline portion of the harmonic drive provides the azimuth output rotation. It is supported by a wire race bearing (not shown) which

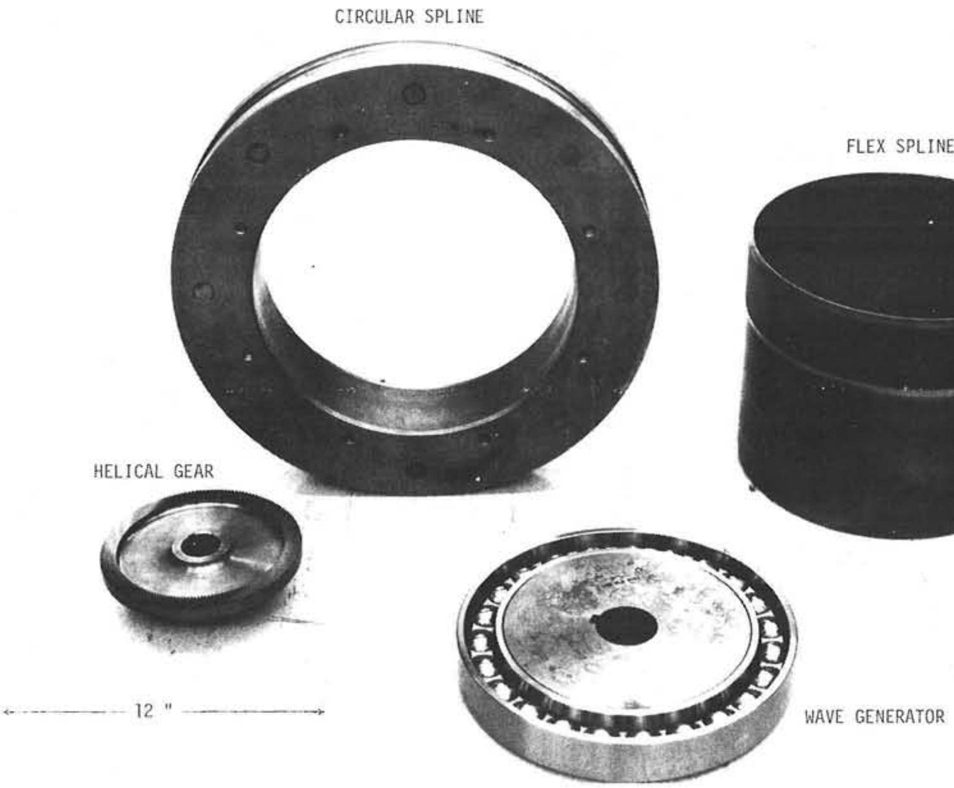

Figure 11. Azimuth Drive Components

utilizes the circular spline as seats for the two inner wire races. The lower outer race is in a flange in the drive housing that mates with the top of the pedestal. The upper race is contained in a clamping flange that bolts to the drive housing.

The elevation support is bolted to the circular spline which provides the drive output rotation. The flex spline portion of the harmonic drive is stationary and attached to the outer housing. Flexing is accomplished by a rotating three-lobe wave generator resulting in a reduction of 226:1. The wire race bearing and harmonic drive are oil lubricated. Filler blocks are used in the housing to reduce the quantity of oil to reduce cost and minimize effects of thermal expansion. The unit is factory sealed and oiled, and no scheduled maintenance is required.

A hollow shaft driven by helicon* gearing provides the input rotation to the wave generator. The helicon gear is keyed to the shaft and the pinion is

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*A trademark of Illinois Tool Works, Inc.

an integral part of the drive motor shaft. The helicon reduction is 162:1. A grease port is provided in the housing at the gear level. The hollow shaft is used to route the electrical harness for the elevation motor, limit switches, and sensor through the center of the drive. An electrical proximity sensor and magnet are used to indicate revolutions of the helicon gear. Another sensor mounted on the pedestal is used with a magnet on the azimuth cover to provide azimuth output rotation count. A motor-mounted incremental encoder provides motor rotation count. The sensors are used in a position reference update scheme described in Section 2.2.2.7.

The azimuth drive requires no field adjustments, even with motor replacement. The drive motor is accessible, by removing a cover, through an opening in the side of the pedestal as shown in Figure 12, and is retained by four bolts. It can be driven manually or with a portable drill motor by removing the incremental encoder cover and rotating the extended motor shaft, as shown in Figure 13. The torque required is approximately 20 in-oz. This procedure can also be performed on the elevation drive.

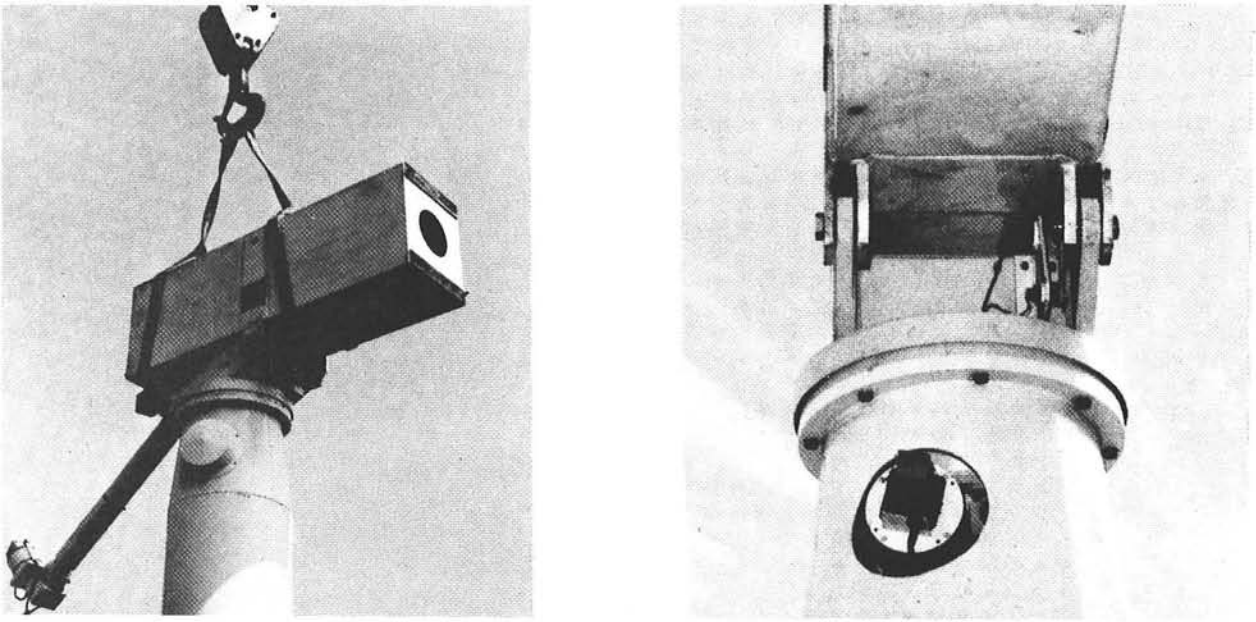

Figure 12. Motor Access

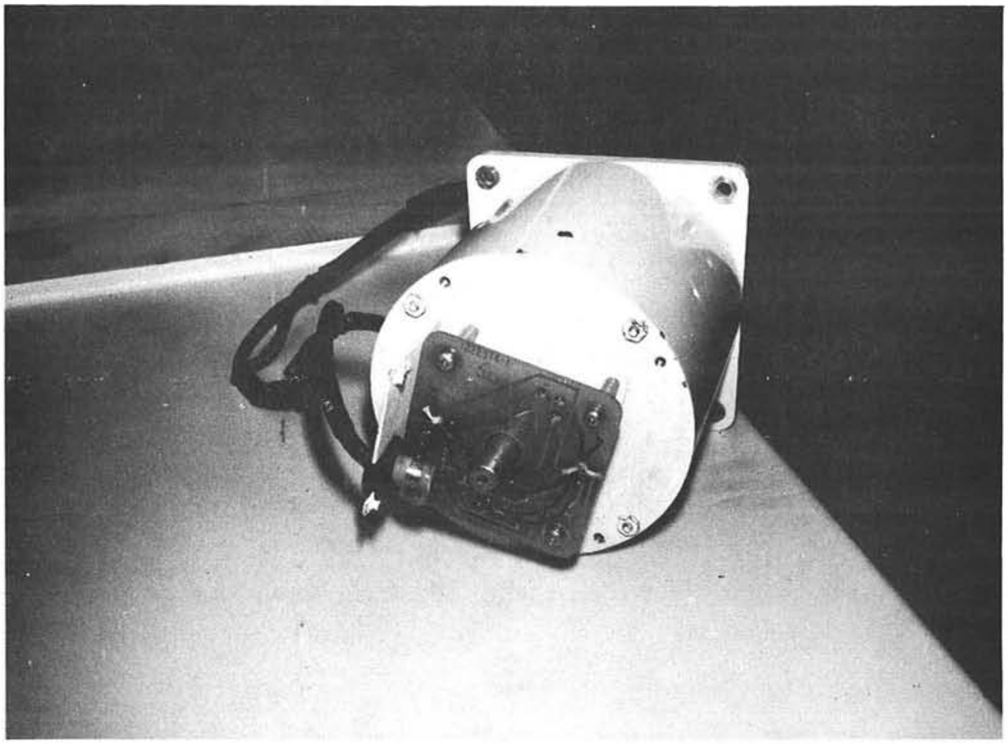

Figure 13. Motor Shaft Access

Azimuth drive dynamic capability of greater than 144,000 in-lb is achievable with minor Harmonic Drive Kit modification. This capability is currently under test and will be provided in future heliostats.

Elevation Drive

The elevation drive, as shown in Figures 9 and 14, is also a sealed module and has an integral expansion chamber to compensate for pressure fluctuations. The output rod is chrome plated to resist corrosion and to provide a smooth interface for dual self-lubricating support bushings. The same type of bushings is used at the trunnion block for interfacing with attaching trunnion pins. This type of bushing is widely used in actuation cylinders and at pinned joints on earth moving equipment.

The ball screw and traveling nut have a 1/4-in. lead (four turns per in. of stroke). The base of the ball screw rod is supported by a set of preloaded tapered roller bearings and driven by the helicon gear set. The output gear is keyed to the rod and the pinion is integral with the motor shaft. The helicon reduction ratio is 106:1. The bearings and gearing are oil lubricated

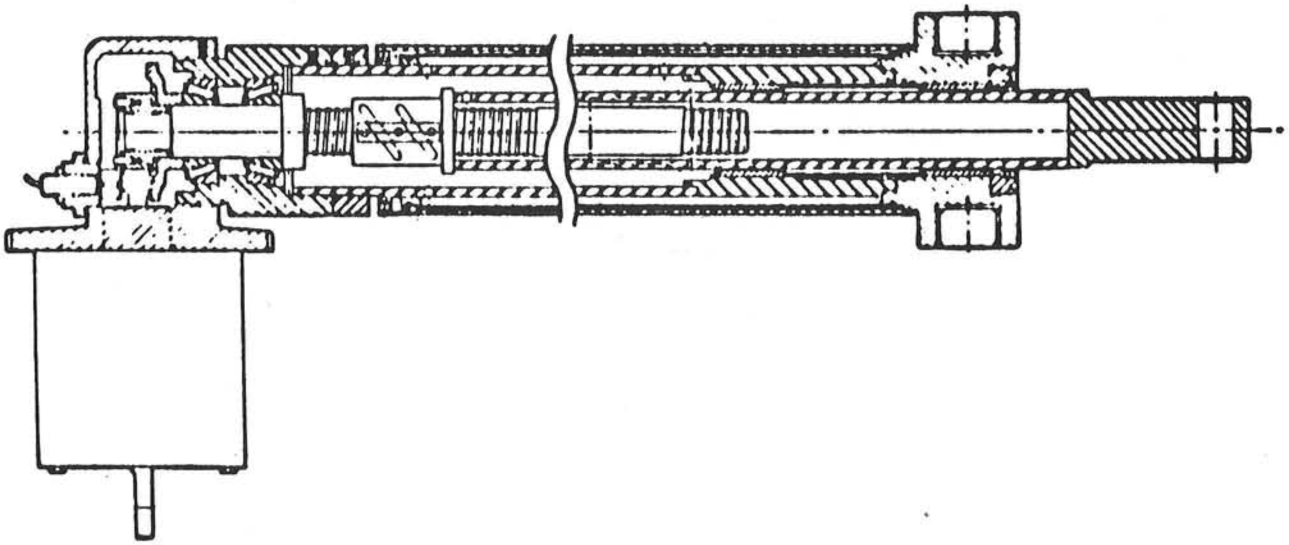

Figure 14. Elevation Drive Assembly

at the factory. The ball screw is installed with an oil film and then supplemented with grease which is picked up each time the jack is retracted. No field maintenance or lubrication is required.

Subsequent to the DDR, tests on the drive (as discussed in Section 3) resulted in a modification which increased the helicon gear diameter from 3.75 to 4.5 in., instituted oil lubrication, and changed the gear material from powdered iron to aluminum bronze. This change produced an increase in jack efficiency and breakout load capability. The result is increased capability to operate in high winds, which is discussed in Appendix A-3. Motor replacement requires no adjustments. Helicon gear rotation sensing is provided by a proximity switch and magnet.

Reference Limit Switch Sensors

Position-sensing proximity switches provide azimuth and elevation reference point detection on the drive axis and the drive helicon gears. The sensors are purchased parts and, in conjunction with control software, replace the previously used absolute encoders. The sensor is a magnetically actuated mercury-wetted sealed switch. This device has a significant cost advantage over the absolute encoder approach while providing high reliability with mean cycles between failure exceeding 2×10^9 operations. The device operates with the control logic 5-VDC system and is field replaceable.

The reference update control scheme using these sensors provides a nonvolatile capability to maintain heliostat alignment. It is discussed in more detail in Section 2.2.2.7.

Motors

The azimuth and elevation motors, as shown in Figure 13, are AC motors manufactured by Emerson Electric, operating at 208 V~, 60 cycle, 3-phase, wye connected. The azimuth motor is 1/4-HP and the elevation motor is 1/3-HP. Both have a NEMA Type C torque/speed relationship. An MDC-developed incremental encoder is installed on each motor. The helicon pinion is integral to the motor shaft as shown in Figure 15.

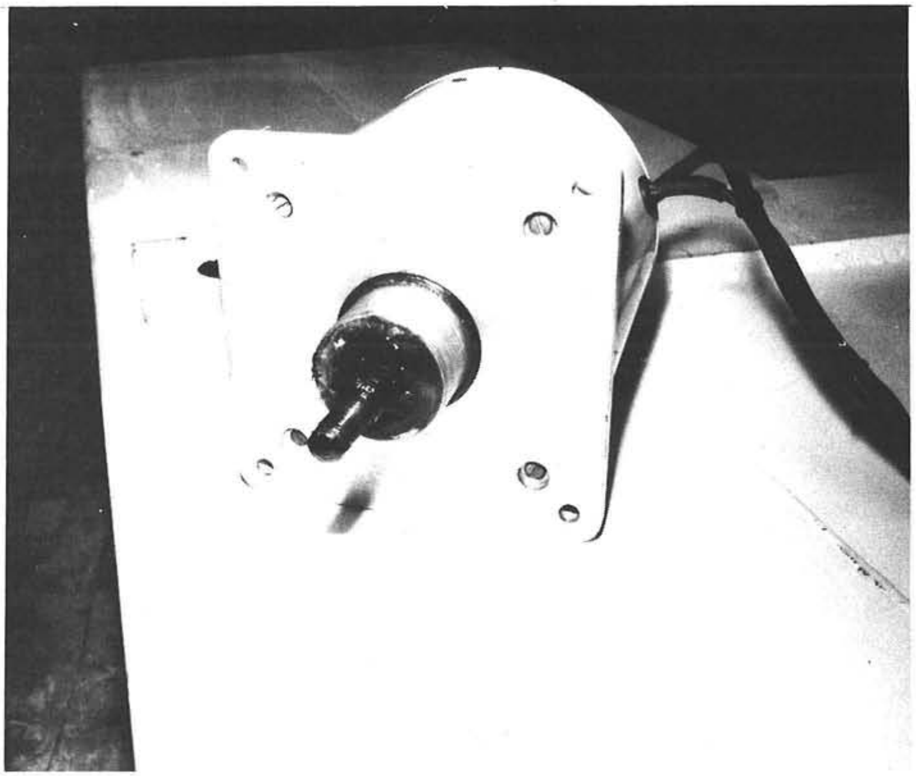

Figure 15. Motor Pinion Shaft

The incremental encoder uses two magnetic sensors and a ferrous metal vane on the motor shaft to generate a pulse at each motor turn. The HC processor counts these pulses in order to determine heliostat position.

A proven, "vented" environment design of the encoder cover has been retained. The incremental encoder and motor will be handled and field serviced as a unit; no field repair of the encoder itself is anticipated.

Wiring

There is essentially no exposed wiring on this heliostat. Wiring from the controller assembly to the azimuth reference sensor, azimuth helicon sensor, azimuth motor, and azimuth incremental encoder is enclosed within the pedestal where it is protected from the environment, particularly ultraviolet radiation and other sources of damage. Connector terminations are used where appropriate for assembly and maintenance. Wiring for the elevation drive and elevation sensors passes through the azimuth drive in a tube within a tube. All wires are clamped to the inner tube which turns with the azimuth drive, eliminating any possibility of twisting wires within the tube. Connectors are provided for production and field-replaceable joints.

Main Beam

The main beam connects the reflector assemblies to the drive components. It consists of a 16-in.-wide by 18-in.-deep rectangular tube fabricated from carbon steel with welded end plates and lugs for the reflector assembly mounting, and drive component interfaces. Figure 16 shows the reflector interface consisting of two tapered pins and eight threaded holes for mounting bolts.

Pedestal

The pedestal is shown in Figure 17. The design was selected for ease of installation in conjunction with a low-cost foundation adaptable to a wide variety of site conditions. It consists of a twin tapered low carbon steel circular tube approximately 139 in. long. A flange is welded to the top to provide for bolted attachment to the drive unit. The pedestal contains an azimuth drive motor access hole near the top and an access hole provision for heliostat controller attachment at a height of 5 ft from the ground. A cover

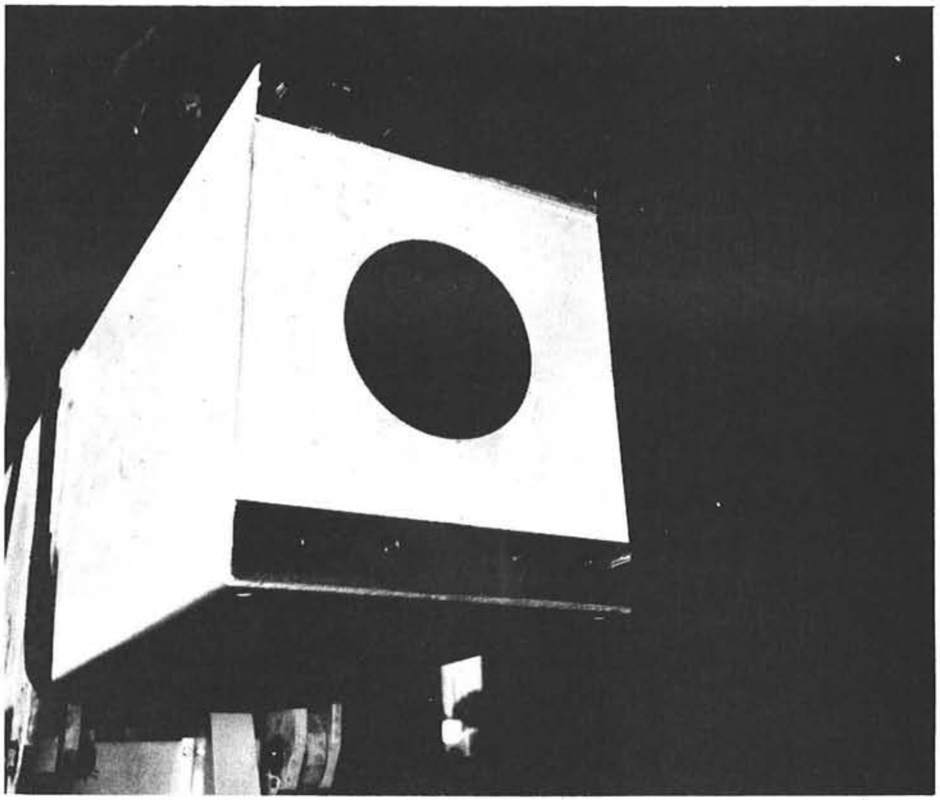

Figure 16. Reflector Interface

is provided over the azimuth motor. The prototype units have two nuts spaced longitudinally on each side near the base to attach an installation fixture to apply load during mating between pedestal and foundation (20,000 lb). In production, the nuts on the pedestal are replaced by a collar which interfaces with an installation tool mounted on a tractor.

Heliostat Controller

The heliostat controller is part of the drive, main beam, pedestal assembly. For this report, it has been included with the array control hardware.

2.1.1.3 Foundation

The foundation, as shown in Figure 18, consists of a 46-in.-high metal tapered cone integral with a drilled, poured, reinforced pier. Although the pier dimensions may change as a function of soil conditions, the prototype units installed at CRTF used a 24-in.-diameter pier extending 15 ft below grade with reinforcing rods. The cone is welded to the reinforcing rods to

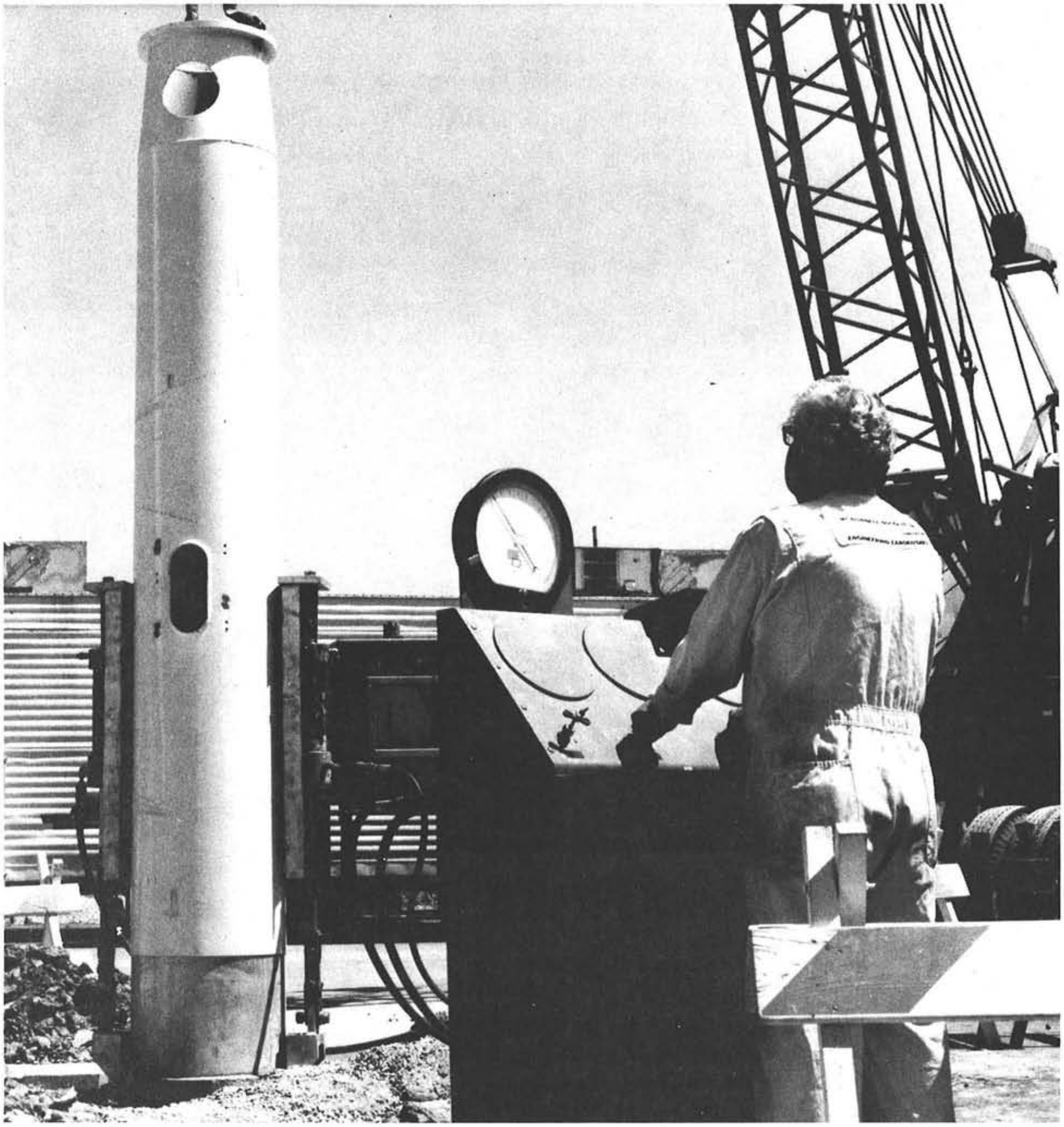

Figure 17. Pedestal (In Test)

- **Vertical plumbness of tapered cone within ± 1.0°**
- **Azimuth orientation of tapered cone within ± 3°**
- **Satisfy performance deflection requirements for operating loads (at ground level)**

    V = 1200 lb

    M = 200,000 in lb
- **Satisfy plastic deflection and survival requirement for maximum loads (at ground level)**

    V = 4100 lb

    M = 825,000 in lb

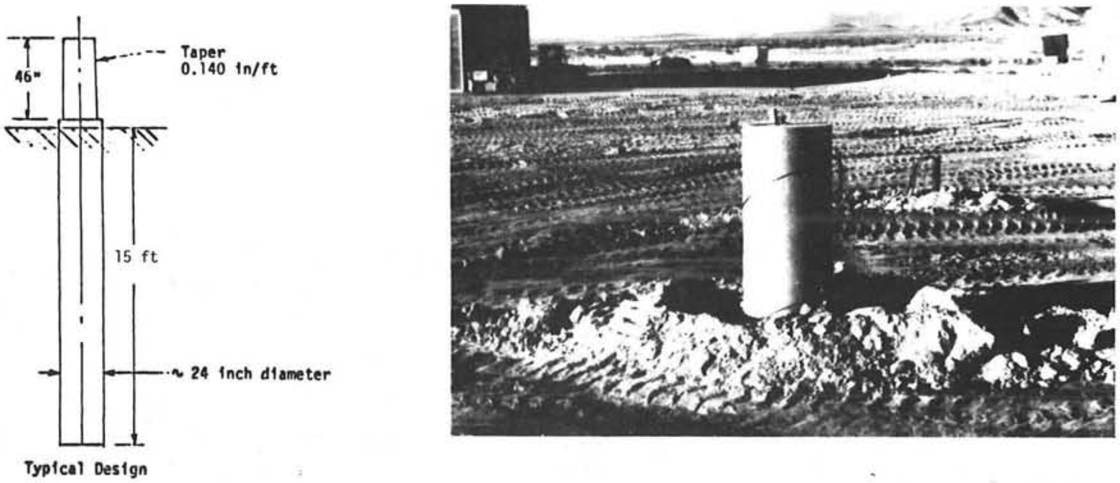

Figure 18. Foundation Requirements

provide stability during the pour, and grounding of the heliostat. The cone is filled with concrete, and a wiring conduit and separate drain passage are provided from the top of the cone to the base. For the prototype units, nuts were welded to the cone to aid in leveling and for pedestal pull down during installation. The cone requires vertical alignment to within 1 deg. The foundation provides the vertical alignment of the pedestal on installation with an overlap between the two parts of approximately 35 in.

2.1.2 Controls Hardware Design

The major elements of the controls hardware are the heliostat array controller (HAC), heliostat field controller (HFC), and heliostat controller (HC).

The HAC is located in the plant master control area. The HFC is located in the collector field in a data distribution interface assembly. For Second Generation prototype demonstration purposes, the HFC electronics are located with the HAC. The HC is located at each heliostat. Critical control system requirements and capabilities are shown in Table 7, and the controls subsystem schematic is provided in Figure 19.

Table 7. Control System Requirements and Capabilities

Requirements	Capabilities
HAC interface with MCS, BCS, DAS	Available
Beam pointing error less than 1.5 mrad	Less than 0.5 mrad typical
Resolve singularity control in 15 min	13 min
Position heliostat to an orientation within 15 min	13 min
Control a field of heliostats as a group or individual basis	Available
Defocus from receiver within 120 sec	<30 sec
Local override of HC	Provided
Electrical transients of 1.7 overshoot for 5 cycles and dropout for 3 cycles	Provided
Temperature requirements	
Performance, 0° to 50°C	Exceeded
Function, -9° to 50°C	Exceeded
Survival, -30° to 50°C	Exceeded
HFC initiate safe stowage upon loss of communication with HAC	Provided
Lightning protection from a strike to an adjacent heliostat	Provided
Minimize susceptability to electromagnetic interference	Provided

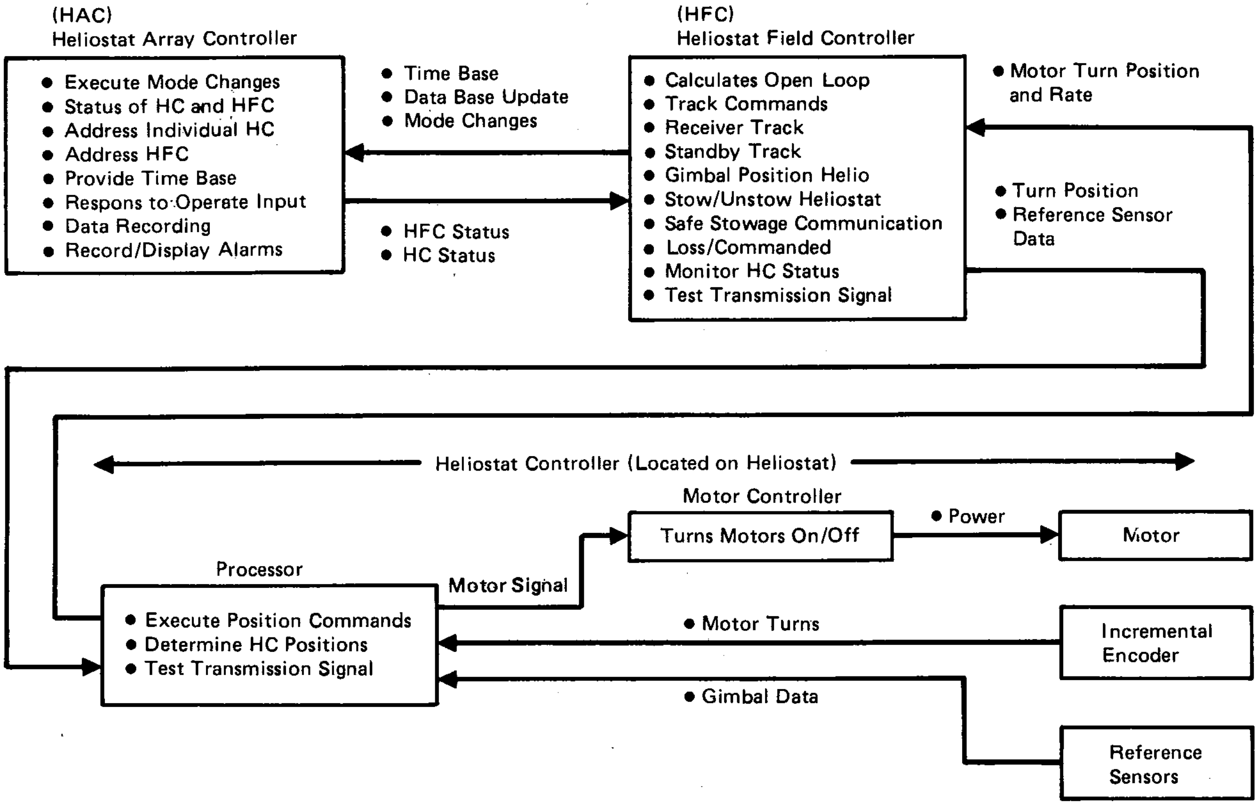

Figure 19. Controls Subsystem Schematic

MDAC has had heliostat control systems under development for several years. Since the Second Generation Heliostat program scope did not include a prototype control system simulating the high-volume approach, the current MDC-developed system was used to demonstrate the preproduction capability. This system incorporates all the features and much of the hardware required for the large field application.

2.1.2.1 Heliostat Array Controller

The HAC is a PDP 11/34 with 128K bytes of memory, floating point operation, a four-line EIA RS232 serial interface, and an RSX-11S operating system. Peripherals include a fixed disk, a 150 CPS printer and a color CRT. All of this hardware is currently commercially available.

2.1.2.2 Heliostat Field Controller

The HFCs for Second Generation are located in the data distribution centers (DDC) which are strategically distributed in the collector field.

Each DDC will contain up to eight HFCs providing control of up to 256 heliostats. The DDC is a weatherproof enclosure mounted on a concrete slab. In addition to HFC circuit cards, it will contain 5-VDC and 12-VDC power supplies. DDC field locations will be optimized for minimum field wiring costs.

The HFC circuit design is based on the 8085 central processing unit (CPU). It operates at 3.072 MHz. Memory consists of 2K bytes of erasable programmable read-only memory (EPROM) and 16K bytes random-access memory (RAM). Features include a direct memory access, an arithmetic processing unit, an interrupt controller and a real-time counter. Communication with the HACs and HCs is handled by three universal synchronous/asynchronous receiver/transmitters which are linked to the communication lines by transceivers. A field programmable logic array is used for certain decoding. The rest of the integrated circuits (ICs) consist of various gates, buffers, decoders, flip-flops and counters.

2.1.2.3 Heliostat Controller Assembly

The heliostat controller assembly is shown in Figure 20. The enclosure is an 18 x 12 x 8-in. welded steel NEMA 3 box. It is hinge mounted on the

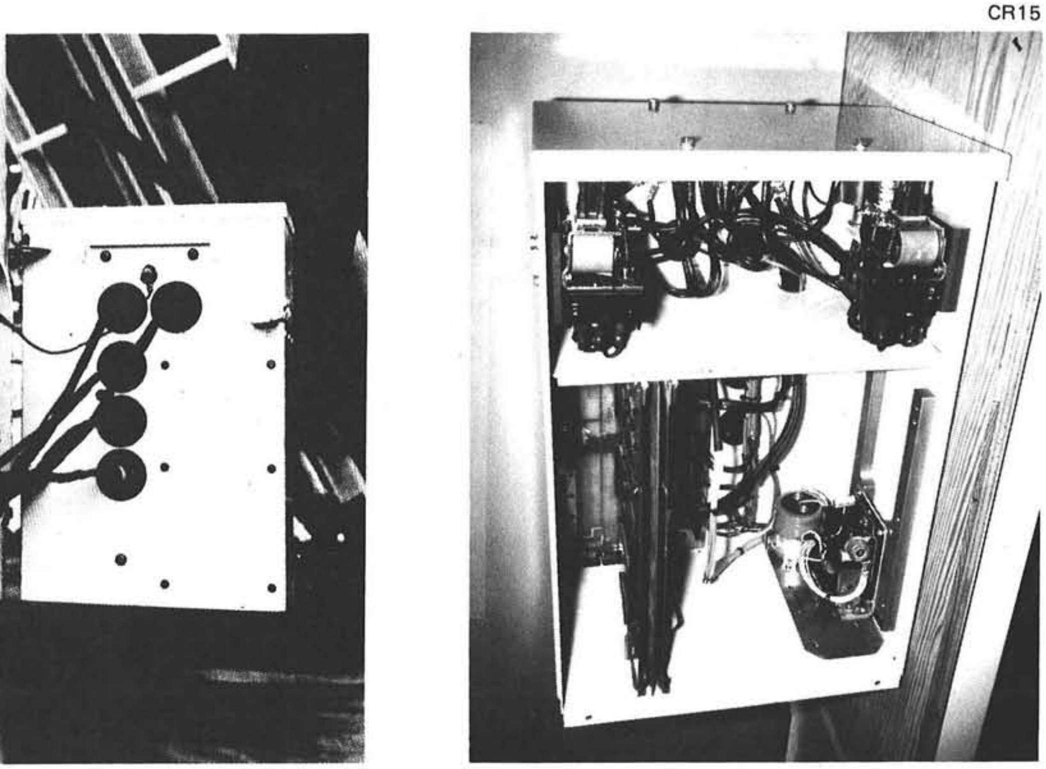

Figure 20. Controller Assembly

south side of the pedestal and contains the following: HC processor circuit card, motor controller circuit card, motherboard, 5-VDC power supply, contactors, and lightning surge arrestors. Connectors for the controller assembly interface with the balance of the heliostat electronics, and field wiring was selected for ease of maintenance and service considerations. The connectors also serve to segregate the box between the DC (lower section) and AC (upper section) functions.

The HC processor circuit card is a 7 x 11-1/2-in., two-sided board. The layout of the board was based on automatic insertion equipment with wide circuit traces, trace spacing, and pads to minimize production cost by maximizing yield. The processor is developed around the INTEL 8748, one-chip microcomputer which contains 1K EPROM and 64 bytes of RAM. An 8755A EPROM is used during development for an additional 1K of EPROM. In production, the 8748A/8755 will be replaced with an Intel 8049.

In order to provide an automatic test capability, the circuit card for Second Generation includes a test connector and IC sockets for selected components, e.g., the microprocessor, consistent with standard methods for achieving high reliability with economy. Industrial grade IC components (or better) with an extended temperature capability to 85°C, are baseline for the HC processor. In addition, all ICs are screened to MIL 883B and all passive components have an established reliability. This is the industry standard method of obtaining environmental reliability at low cost.

The motor controller circuit card is also a 7 x 11-1/2-in., two-sided board. Motor control is achieved by TRIAC switching of three-phase 208V 60-cycle AC. TRIAC switching commands initiate at the HC processor with pulse transformer coupling on the motor controller circuit card. The motor controller has also been designed for automatic test equipment.

The motherboard is a 2 x 11-in., two-sided circuit board which provides the interface between the HC processor, motor controller, and the balance of the controls hardware. Three phenolic alignment guides, one at each end and one in the middle of the board, have been used to ensure proper mating of the daughter/motherboard connectors before pin engagement.

The 5-VDC power supply used by the controller is a commercially purchased part. Analysis and test have determined that the power supply, as purchased, can tolerate the AC voltage overshoot requirements of the specification without modification. However, approximately 30,000 μf has been added to the power supply to accommodate the three-cycle dropout requirements.

Contactors and lightning surge arrestors are also purchased parts located in the controller.

In the high-volume design the controller components will be reduced to a single board. Solid-state switching and use of fiber optics for communication between the HC and HFC could be employed for large fields. The physical controller assembly and mounting would be changed to take advantage of the single board design.

2.2 SOFTWARE DESCRIPTION

The control system software has been developed with the capability of providing the required functions associated with small or large field operations. Implementation has been made for the two prototype units based on test requirements for CRTF. The software capabilities are discussed below.

2.2.1 Heliostat Array Control Interfaces

Total heliostat array control is provided through the interface at the HAC. In a large field, interfacing will occur with a master plant control, a beam characterization system, a data acquisition system, a backup HAC, and operators. For the prototype units, the only interface required was the operator.

2.2.2 Array Control Models

The following control modes are provided by the software.

2.2.2.1 Stow Position

In the operational systems two stow modes are provided: normal stow and survival stow. Normal stow places all the heliostats in a vertical position with the mirror normal at -2 deg to horizontal and azimuth due south. The survival stow command drives the reflecting surface to a horizontal position, mirror normal vertical, with the last azimuth position retained. In the preproduction software, the normal stow is provided. The survival stow is achieved with an input gimbal position command. In production a survival stow command will execute proper commands to individual heliostats based on field condition at time of command.

2.2.2.2 Beam Safety

The software has the capability to accept instructions inherent to maintaining beam safety. An alarm will be printed out if a mode change request is made that could be unsafe. Depending on site specific beam safety requirements, the transition will be inhibited or allowed but alarm noted.

Facilities for operation intervention and override will also be provided. The normal software command, stow/unstow trajectory, inherently maintains beam safety.

2.2.2.3 Receiver Defocus

On command, the heliostats are moved from the receiver position to the standby position. This may be accomplished in a 50 MWe field in approximately 30 sec. At CRTF the two preproduction heliostats are individually commanded in this mode and can be removed from the target in 15 sec.

2.2.2.4 Communication Loss

If communication between the HAC and HFC should go down, the HFC will move the heliostats to standby and then move them to the stow position. The HFC time spaces individual heliostat beams under its control to preclude beams crossing on the way to the stow position. This will occur for all heliostats that were in a track mode. Heliostats that were in a static position will maintain that position.

If communication between the HFC and HC should go down, the heliostat will continue moving at the present rate for the next 64 sec. Then the heliostat will stop moving until communication between HFC and HC has been reestablished.

2.2.2.5 Operator Mode Commands

The basic operator commands for moving the heliostat are:

- Receiver Beam Aimpointing Track. The control system will keep the beam at a point that has been defined as the receiver aimpoint.
- Standby Beam Aimpointing. The control system will keep the beam at a point that has been defined as the standby aimpoint.
- Gimbal Position (individual heliostats). The control system will move the heliostat to the commanded gimbal angles.
- Stow. The control system will move the heliostat from the standby aimpoint to a vertical stow position. The beam will be maintained on a defined trajectory.
- Unstow. The control system will move the heliostat from the stow position to the standby aimpoint. The beam will be maintained on a defined trajectory.
- Survival Stow. The control system will sequence command all heliostats to the horizontal position. Operator command at CRTF.
- Heliostat Alignment. When this command is used, an individual heliostat image is moved to the beam characterization system target and the track alignment parameters are updated. This command does not exist for the CRTF demonstration.

2.2.2.6 Special Test Commands

The following special test modes were provided for CRTF.

- Life Cycle. For CRTF testing a life-cycle program is provided. The program takes the heliostat from stow to standby to a commanded receiver position, to standby, to stow. Specific days and time of day may be used. The program operates in fast time, in that one day of track is done in a few hours.
- Data Record (for Test Evaluation). Upon request, the heliostat position (turns and gimbal angle), sun position, and calculated beam error versus intended aim point are printed. Alarms are printed out when they occur.

2.2.2.7 Reference Update

To achieve the beam pointing accuracy, the control system maintains heliostat position with respect to the inertial reference system in which the control equations are developed. In the event the power to the heliostat goes down, the HC will lose the referenced position. The Second Generation control system incorporates an MDAC-developed update scheme that makes use of magnetic position sensors to reestablish the track reference.

Except for the elevation pivot point sensors, these sensors do not play a role in the basic day-to-day control function of the heliostat. The reference update feature is used only after a power loss or by operator request. The purpose of the sensors is to provide a one-bit resolution reference.

There are two types of reference updates that can be commanded. The first method performs an update by moving the heliostat to the next helicon gear crossing. This method requires some knowledge of heliostat position at the time of power failure. In the second method for situations where both the HC and HFC have an unscheduled power failure or the heliostat is moved by other than a command from the HFC, such as by maintenance personnel, the heliostat is rotated until the gimbal sensors are encountered. Then the heliostat is moved to the reference helicon gear crossing.

The majority of the time the first update can be used. It will take somewhere between 45 to 120 sec to complete. The second method will take from 1 to 8 min to complete.

2.2.2.8 Heliostat Track Alignment

The baseline track alignment scheme uses a beam centroid measurement device such as a beam characterization system (BCS) to determine the orientation of the heliostat in inertial space. Because alignment methods which require field operations are very costly, this system has been developed so that there are no field operations. In order to accomplish this, there are three basic operations:

A. Heliostat installation
B. Coarse track alignment
C. Fine track alignment

In the first step when the heliostat is installed on the foundation, it is turned in azimuth such that the azimuth gimbal reference sensor is north. The accuracy of this placement is ±3 deg.

In the second step, a coarse track alignment is performed in order that the control system can direct the heliostat such that the reflected beam will be on a target. This is accomplished by first commanding the heliostat to move to the gimbal reference sensors. At this point, an initial estimate is made of the elevation and azimuth reference position. The heliostat is then commanded to a standby aimpoint that is a long distance from the target aimpoint. A search mode is used to find the target. When the beam is on the target, the operator then moves the heliostat until the beam is at the target center. At this point, a second estimate is made of the azimuth and elevation reference position. This estimate will be adequate to allow the control system to keep the beam on the target or find the target the next time it is unstowed.

In the final step the beam is put on the target and the BCS is used to take measurements and calculate the beam centroid. Data are taken four times at approximate 1-hr intervals. Multiple heliostats can be undergoing this process. Using these measurements, the errors in the heliostat orientation can be calculated. These error terms are then used by the HFC to determine the gimbal position which should be commanded in order to move the beam to the desired aimpoint. The errors which will be determined and resolved are tilt of the foundation in two directions, pedestal, azimuth alignment, vertical alignment, orthogonality of elevation axis, vertical position, and horizontal position.

2.3 SITE FACILITY INTERFACE REQUIREMENTS

This section is provided to allow system designers to identify the heliostat subsystem integration requirements. Although not specifically developed in the Second Generation Heliostat program, inclusion here allows summary of all subsystem interfaces. Costs associated with these provisions are included in Section 6.

2.3.1 Civil Engineering

The civil requirements for subsystem installation are a field survey of heliostat locations and field perimeter fencing for safety and equipment security.

Heliostat survey locations are required for heliostat alignment and track software with a tolerance of ±3 in. from a known benchmark and ±10 in. in grade elevation. The heliostat clearout envelope for field layout purposes is a 234-in. radius circle.

A perimeter fence for the heliostat field should be placed at least 100 ft from the outer boundary heliostats to limit casual public access and vandalizing. A screen or covered fence surface is desirable.

2.3.2 Electrical Interface

A typical facility interface with the Second Generation Heliostat is shown in Figure 21. Three-phase, 208-V, 60-Hz power with a neutral and safety ground is required. For data communications, a twisted shield pair is required, No. 18 AWG with less than 50 pf/ft nominal capacitance and limited to 2000 ft. Similar power is also required at each data distribution field controller location. These locations might also be used for step-down transformers for a higher voltage field power distribution scheme.

2.3.3 Power Requirements

Power requirements have been estimated for the Second Generation Heliostat for the tracking, slew and stow modes based on test data (for measured values see Section 3.2.1.1). During unstow to track, 520 W per heliostat is required. During track, approximately 75 W per heliostat is required

POWER REQUIREMENTS
- 3 PHASE, 208V AC, 60 HZ, ± 10%
- NEUTRAL
- 15 AMP SERVICE

COMMUNICATIONS REQUIREMENTS
- TWISTED SHIELDED PAIR
- #20 AWG

PULL BOX REQUIREMENTS
- 208V UTILITY OUTLET (5 WIRE)
- 110V UTILITY OUTLET (3 WIRE)
- ONE 3/4 INCH KNOCKOUT
- TERMINAL BOARD INTERFACE

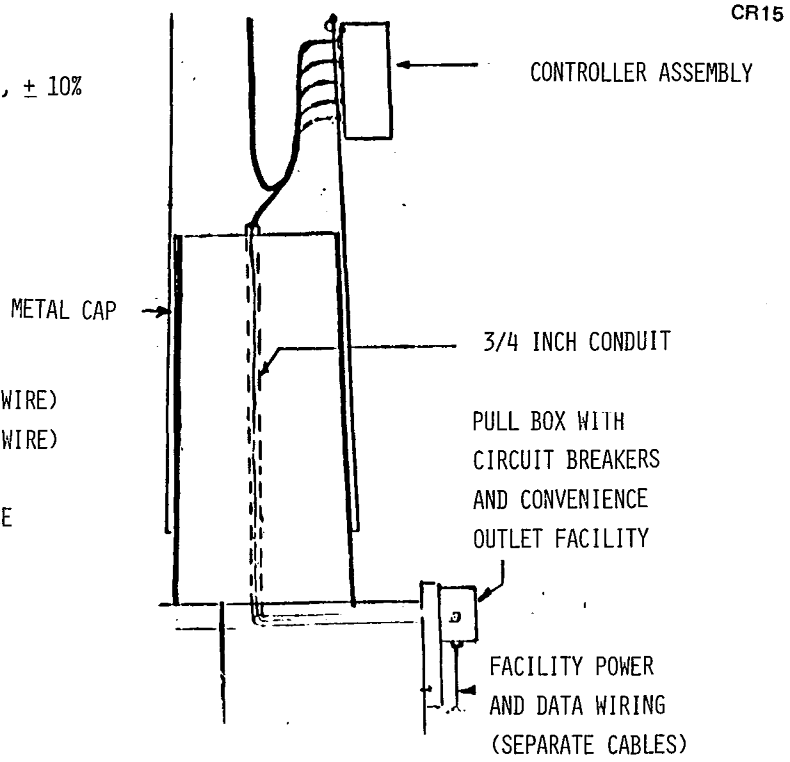

Figure 21. Electrical Interface Requirements

(this estimate and all others include motors and electronics). For normal stow, 290 W is consumed. In a 1-yr period, a heliostat may use 175 kW-hr of power assuming one unstow and one stow operation per day, and a 10-hr tracking day.

The power requirements for defocus and emergency stow for a 50 MWe field are more system dependent than collector dependent. Although exact power requirements are a function of field layout, defocus and stow power requirements are estimated as shown.

2.3.3.1 Emergency Defocus

The maximum field power required for the Sandia sized 50 MWe field (5412 heliostats) is 790 kW as developed below. Approximately 335 W/heliostat is required to move a heliostat from target track to standby aimpoint track. Heliostats are commanded to the standby point in groups of three, separated by 1 sec.

After 11 sec, the HFC will have communicated with all 32 heliostats in the group. The power requirements, therefore, for a typical group will grow from 335 W to a maximum of 32 x 335 W or 10,720 W.

However, the total power required by a 50 MWe field is not the number of heliostats per 50 MWe field x 335 W. The modifying consideration is the variable time required by individual heliostats to get off target. For instance, a heliostat 1000 m away from a 20-m^2 target 200 m above grade, will take approximately 2.5 sec to get off target. Under these conditions, some heliostats will achieve the standby aimpoint before others have even been addressed by the HFC. In fact, only 9 heliostats in this group of 32 will be in the slew mode at any one time. The power demand for this group is reduced by approximately 72% from 10,720 W to a maximum of 3,015 W. For heliostats closer into the receiver tower, e.g., 250 m, the time to move any one heliostat off target exceeds the time to communicate with all 32 heliostats.

The total power required by a 50 MWe field depends on the field layout (north field only or surround field), the allowable number of seconds to get the whole field or a percentage of the field off target, and the location of the standby aimpoints (one, two, or three ... receiver diameters away from receiver).

A rough estimate for a surround field of 5400 heliostats, 20-m^2 target 200 m high, and a standby aimpoint one receiver diameter away from the target would be 790 kW, where 75% of the heliostats would be off-target in 20 sec and all heliostats off in 30 sec. If heliostats were further sequenced such that all heliostats were off target in 60 sec, the power demand could be reduced to 300 kW.

2.3.3.2 Survival Stow

An estimate of 380 W maximum per heliostat for stow (face up) is based on continuous operation of elevation motors. This stow operation takes from 2 to 6 min depending on initial heliostat orientation. To stow an entire field in less than 6 min would require 380 W x number of heliostats per field.

2.3.3.3 Transient Response

The above data are based upon motor running currents. Each heliostat does, in addition, have a starting transient of approximately 6 amps which decays to running load in about 5 AC cycles (80 msec). It is doubtful that this would be seen by the bus.

2.4 PERFORMANCE

The MDAC Second Generation Heliostat subsystem is in compliance with the A10772D, Collector Subsystem Requirements, specification from the standpoint of performance as well as design features. Performance features are summarized in Section 1. A specification summary and the methods used to verify compliance are provided in Appendix A-1.

MDAC has followed the specification. There are two specification sections with respect to operation and survival stow which MDAC has analyzed and which require amplification in this report. The relationship of individual heliostat performance to overall field performance is discussed in Appendix A-2. Operation to survival stow transition requirements is discussed in Appendix A-3.

Section 3
TEST PROGRAM

The Second Generation test program includes component testing, subsystem operation at MDAC-Huntington Beach, and the shipment and installation at CRTF. The subsequent demonstration and testing by Sandia will be reported on by Sandia under separate cover. Table 8 provides a list of the tests to be conducted by Sandia. Part of the component testing has been reported in the Detail Design Report (DDR). These tests will be summarized below, along with tests accomplished subsequent to the DDR.

3.1 COMPONENT TESTING

The component test program was directed toward obtaining design data as well as substantiation of completed designs. Table 9 identifies the component-level tests and where they are reported. Summaries of each of the tests and results are provided in this section. A more complete description of some of the tests not provided in the DDR is found in Appendix B.

3.1.1 Drive Testing

The drive testing was directed toward capability assessment of new hardware and previously applied hardware under new conditions.

3.1.1.1 Drive Motor Capability

This test was performed by the motor manufacturer, Emerson Electric, and provided motor speed torque curves and stall torques for the design effort. The performance conformed closely to predicted computer model performance for both the 1/4- and 1/3-HP motors used in azimuth and elevation, respectively.

3.1.1.2 Azimuth Harmonic Drive Capability

This test was performed on the 10-in.-diameter harmonic drive from the MDAC Pilot Plant heliostat to determine static and dynamic load capabilities.

Table 8. Sandia Test Program

Heliostat testing at CRTF

General observations
Test 1 - Control system operational modes
Test 2 - Beam quality
Test 3 - Beam pointing
Test 4 - Heliostat surface accuracy
Test 5 - Life-cycle tests
Test 6 - Pointing accuracy with operational wind loads
Test 7 - Wind load deflections
Test 8 - Survival wind loads - heliostat stowed
Test 9 - Water spray, disassembly and inspection
Test 10 - Long-term operation

Mirror module tests

General observations
Test 1 - Contour measurement
Test 2 - Wind load glass stress
Test 3 - Thermal stress and contour change
Test 4 - Residual glass stress
Test 5 - Gravity sag
Test 6 - Thermal cycling
Test 7 - Environmental cycling
Test 8 - Hail test
Test 9 - Cold water shock
Test 10 - Reflectivity
Test 11 - Laser ray trace

Confirming analyses

Helio performance for a single heliostat
DELSOL for field performance
Finite element structural analysis for
  Facet alignment gravity errors
  Wind loads deflection
  Survival maximum stress
  Natural dynamic frequencies and mode shapes
Accelerated aging
  Sealants and adhesives

Table 9. MDAC Component Test Program

	Reported
Drive tests	
Drive motor capability	DDR*
Azimuth harmonic drive capability	DDR
Wire race bearing load and life	Appendix B
Linear actuator acceptance	Text
Drive design evaluation	Appendix B
Mirror module	
Adhesive laminate development	DDR
Mirror hail survival	DDR
Adhesive bond durability	DDR
Mirror module environmental exposure	Appendix B
Mirror module thermal distortion	Appendix B
Mirror design and process development	DDR
Mirror module maximum temperature predicted	Appendix B
Mirror module supporting data	Text
Vandalism effects on mirror modules	Appendix B
Controller	
Controller power transient effects	Text
Controller noise response	Text
Reference update development	Text
Motor control algorithm	Text
Controller extreme temperature operation	Text
Controller component life	Text

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*Second-Generation Heliostat Detail Design Report, MDC G8631, Aug 1980.

The tests identified static load capability exceeding 212,000 in-lb and dynamic capability up to 103,000 in-lb without drive ratcheting. Repeated ratcheting occurred at 125,000 in-lb.

3.1.1.3 Wire Race Bearing Load/Life

The wire race bearing has not been used on previous heliostats. It consists of four drawn and heat-treated wires providing the races for standard-size ball bearings. It is installed between the drive housing, circular spline and a clamping ring which is shimmed to provide a preload on the assembly. Figure 22 provides a cross section of the azimuth drive, showing the bearing location. The test program objectives were to:

- Establish the assembly process.
- Determine the proper bolting torque and shim sizing for acceptable deflection and hysteresis in the bearing up to the overturning moments corresponding to survival loads.
- Perform life-cycle loading and determine the effects.

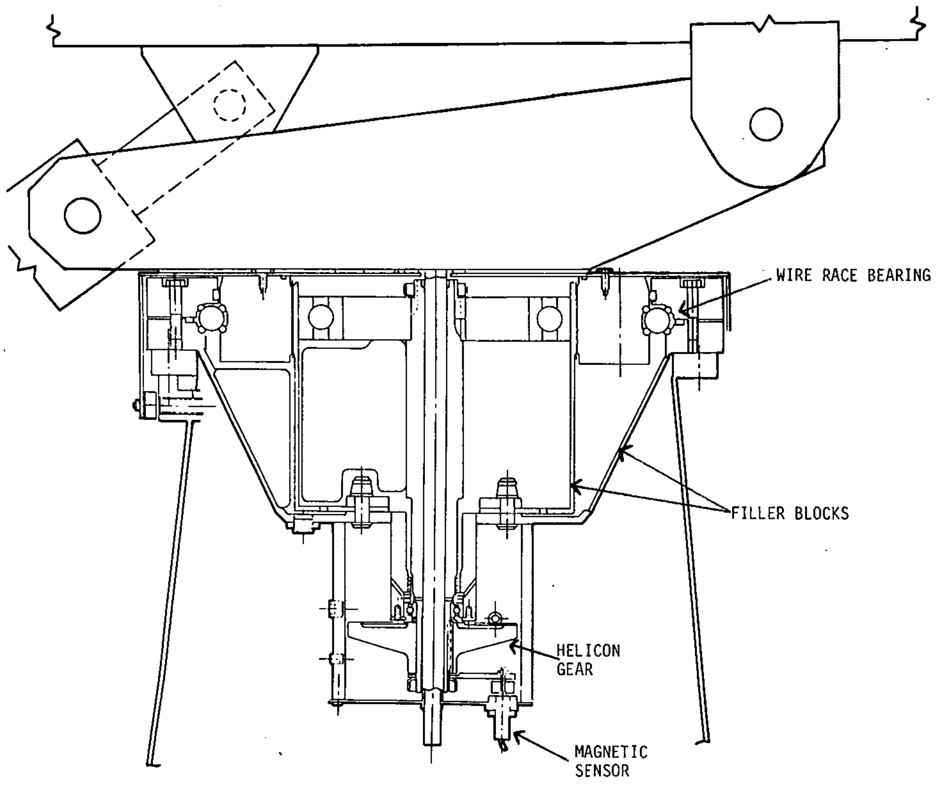


Figure 22. Azimuth Drive Cross Section

The test results showed that assembly was a simple process of inserting the races into the proper slots, loading in the balls, emplacing the shims, and installing the clamping ring. The most important requirement is determination of the proper shim thickness.

The proper combination of bolting torque and shim spacing was defined and later verified on the two preproduction units. With the proper preload, bearing breakout torque is about 2.6% of the available drive capacity. Compliance of the bearing was greater than anticipated by the design but still well within the available budget. The life testing demonstrated adequate performance over a simulated 30-yr life. This was substantiated by an inspection of parts after the test by McGill Manufacturing Company, the bearing supplier.

3.1.1.4 Linear Actuator Load Capability

Load capability tests were performed by Duff Norton on the ball screw jack actuator. These tests consisted of static load and dynamic cycling under load. During the dynamic load tests, the first unit tested bound up. On disassembly, the powdered metal helicon gear was found to be chipped and worn. Subsequent investigation revealed that the failure was caused by an overheating of the gear and pinion. The high gear ratios in conjunction with the gear diameter, and the powdered metal part produced a combination of fit and material problems. Although several solutions were independently possible, a number of changes were made to avoid an extensive development effort. These changes were an increase in helicon gear diameter to 4.5 in. from 3.75 in. and oil lubrication to replace the grease lubrication. The redesigned jack was subjected to the load tests at Duff Norton without incident. They have been subsequently tested in the drive assembly evaluation, also without incident. The net impact of the changes was an approximately $10 increase in the gear cost at high volume. The cost increase is associated with the material substitution as well as the manufacturing process change.

This change also increased the efficiency of the jack and, therefore, increased the breakout load capability.

3.1.1.5 Drive Design Evaluation

This test was conducted on a complete drive assembly as shown in Figure 9.

The test consisted of load deflection measurements of loads simulating operation and survival. The drive assembly test unit was subsequently assembled into a heliostat without refurbishment. The testing consisted of a repeat of the wire race load deflection evaluation, and elevation and azimuth drive tests of starting torques, efficiency, maximum operating hysteresis, and maximum static hysteresis.

The test verified the load deflection characteristics of the drive to be well within the requirements. The test also provided additional insight into the shimming and preload requirements of the wire race bearing in order to provide low deflections in conjunction with low drive friction.

3.1.2 Mirror Module Tests

Mirror module tests included manufacturing process development and environmental performance.

3.1.2.1 Adhesive Laminate Development

This program was directed toward identifying a mirror-to-glass laminating material and process which could be performed in line with the mirroring process. A number of adhesives and application processes were investigated. The program did not result in identifying a satisfactory substitute for the conventional laminating process using polyvinyl butyral cured in an autoclave.

Subsequent to the completion of the MDAC testing, suppliers have demonstrated promising bonded laminates which may be pursued in the future to reduce mirror laminate costs.

3.1.2.2 Mirror Hail Survival

Mirror panels representing the preproduction heliostats (0.090 front lite) and the production heliostat (0.060 fusion glass front lite) were subjected to hail testing conditions per the specification. Ice balls up to 1 in. in diameter at 75 ft/sec were successfully withstood.

3.1.2.3 Mirror Module Exposure Tests

A series of tests was conducted on full-size mirror modules to assess mirror survival in desert and marine environments, the effects of thermal distortion and cold water shock, and the effects of repeated thermal cycling.

For the outdoor exposure tests, one mirror module was placed in an exposure rack in Huntington Beach, California, and another at Fort Irwin, California. These specimens were produced in the normal process flow for the preproduction heliostats. Mirror curvature was measured before transfer to the exposure locations. These units will remain at these sites for an extended period. Periodic inspection will be made to assess panel conditions.

The Huntington Beach specimen was emplaced on July 17, 1980. It was updated with another unit containing the cross-brace on November 5. The desert specimen was emplaced on August 29, 1980. Experience to date shows good accommodation of the environments.

3.1.2.4 Thermal Distortion and Cold Water Shock

Each of two specimens was stabilized at 32°F, 77°F, and 118°F where slope and deflection measurements were taken. The results followed theoretical curvature versus temperature predictions. After measurements were taken at 118°F, the specimens were stabilized at 122°F, and 5 gal. of tap water at 65°F were poured over each specimen. No visible damage occurred.

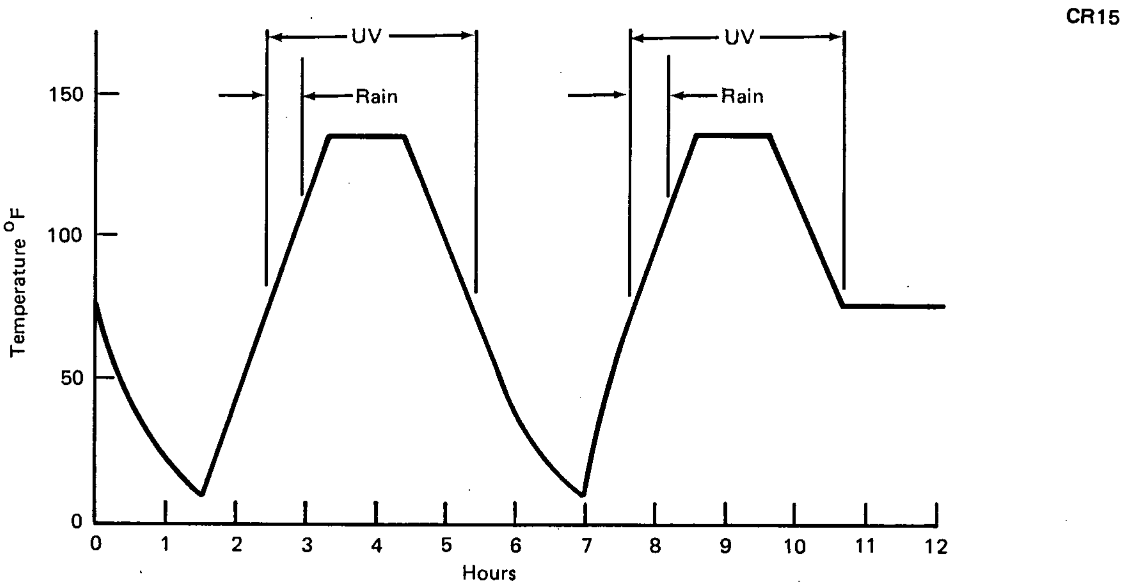
Two mirror modules were used for the thermal cycle test. The thermal cycle imposed is as follows:

Temperature	Time (Min.)
Ambient to -22°F	45
-22°F	30
-22°F to +122°F	90
+122°F	30
+122°F to Ambient	45

Temperature cycles (82) were performed with inspection and curvature measurements before and after the test. Following this test another series of 45 cycles was performed with the high temperature raised to 140°F. No visual damage or deterioration could be found during or after exposure.

3.1.2.5 Mirror Module Stiffener Bond Stress Durability

This test program was used to select and verify the material and process used to bond the hat section stiffener to the mirror laminate. The test consists of continuous exposure of bonded specimens under load in a weatherometer chamber. The test shown in Figure 23 was initiated in March 1980 and resulted in the selection of Stabond X 1894M for the glass-to-metal bond. However, since the cure time for this adhesive is 18 hr, a design using a sheet metal shim bonded to the glass out of the production flow is used.



- Temperature Range
  - 10°F to 135°F
- UV Radiation
  - 500 μW/cM^{-2}
  - Duration 12 H/Day
  - Maximum Intensity At
  - Wavelength of 365 MM
- Relative Humidity
  - Greater Than 85%
- Water Spray
  - 1.12 Gal./Min Over 16 Ft^2
  - Duration 2 H/Day

Figure 23. Weatherometer Testing

A shorter cure time adhesive, EC3532 urethane, is used to bond the hat sections to the shim on the curved bonding pallet. This process was also based on the weatherometer tests, as reported in the Detail Design Report. The weatherometer tests continued through November 1980. At this time, the maximum chamber temperature was increased to 150°F through December 1980, at which time testing under the Second Generation program was completed. In addition to the weatherometer tests, shear creep tests at 70°F, 140°F, and 160°F were performed with satisfactory results.

3.1.2.6 Supporting Mirror Modules Test

In addition to the development tests performed by MDAC in the second generation program, two other sources of tests data have been used to substantiate the design: laminated mirror testing by the supplier and long-term desert exposure tests.

The laminated mirror supplier performed tests on the laminated and unlaminated mirror prior to producing the prototype modules. These tests included mirror defects analysis, silver, copper, and painting thickness determination, paint cure time investigation, salt spray, boiling water, humidity, and compressive shear. These tests were responsive to the MDAC mirror laminate procurement specification. They were used to qualify the process, and the supplier.

In selecting the adhesive for stiffener-to-glass bonding, laminated mirror and edge seal samples exposed in a desert and marine environment in 1975 and 1976 were examined. These samples consisted of double-lap shear specimens of Stabond, and full-size mirror modules laminated with PVB and bonded to metal stiffeners with Stabond. These samples provided two results. Whenever the Stabond was protected from UV and standing water, it retained the original adhesive strength. This substantiated the application to Second Generation Heliostats, with a silicone covering for UV and standing water protection.

Mirror laminates in the Huntington Beach environment were found to have edge degradation of the reflecting surface, up to approximately 1 in. from the edge. The edge seal was implemented based upon these results, plus a desire to protect the glass edge from damage during the manufacturing and installation process.

3.1.2.7 Mirror Image Quality

During the mirror stiffener bonding development, it was observed that the mirror modules exhibited consistent curvature in the long direction but had variable curvature in the short direction.

Testing conducted on all modules, fabricated for all purposes, revealed that 40% were acceptable and the remainder were marginal or not satisfactory. Although quality was improved by a 4-point suspension of the module, additional stiffness was required. A test program was initiated to develop a short-span direction stabilizing approach. The approach was to add stabilizing bars between the hat section stringers. Tests were conducted with two configurations: one bar (in the center), and three bars, one at each end and one in the center. These tests, conducted with an ambient temperature above 75°F, showed that a single bar in the center of the panel provided adequate mirror image quality. This change was implemented on the prototype units.

Subsequent beam quality testing at CRTF at temperatures below 37°F indicate that the short-span stability may still not be adequate. The solution is the addition of more short-span stiffeners. This is a simple change which will be investigated and implemented, if required, on future heliostat production.

3.1.2.8 Heliostat Mirror Module Maximum Temperature Prediction

Tests were conducted to determine the maximum temperatures which might be experienced by the mirror modules in the desert environment. The tests were conducted at the MDAC Grey Butte desert test site. Two Second Generation mirror modules were instrumented and placed in racks with mirror face up, mirror face down, and vertical with the mirror facing the sun. One module was a prototype configuration with a glass back surface over the white mirror backing paint. On the other module, the back glass surface was painted white. Temperatures, wind speed, and insolation were recorded. Based on this data, the maximum temperatures were extrapolated for a 122°F ambient case. The maximum temperature under normal operation was 131°F. The maximum temperature of a backlighted module was 158°F on the backlighted area.

3.1.2.9 Vandalism Effects on Mirror Modules

Vandalism in the heliostat field could increase the predicted operation and maintenance costs for a central receiver application. Shattered mirror panels might also pose a hazard to maintenance personnel.

Although the field will be protected by a perimeter security fence, outer edge heliostats may be subject to vandals taking "pot shots" at the mirror panels. This is particularly possible in remote desert sites. This test characterized the damage to a mirror panel caused by gunfire. The goal was to demonstrate whether damage will be localized, thus allowing continued use of the mirror panel, or whether damage will be severe enough to necessitate replacement of the mirror panel.

Three laminated mirror panel samples measuring 16 in. x 16 in. and identical to Second Generation Heliostat mirror panels were tested as follows:

1. First sample	Angle of incidence	30 deg from normal, mirror surface facing front
	Range	100 ft
	Projectile	0.22 cal bullet fired from a standard 0.22 cal rifle
2. Second sample	Angle of incidence	30 deg from normal, mirror surface facing front
	Range	100 ft
	Projectile	0.38 cal pistol, soft lead bullet fired from 6-in. barrel
	This shot was placed near a supported edge to evaluate edge and support effects.	
3. Third sample	Angle of incidence	60 deg from normal, mirror surface facing back
	Range	100 ft
	Projectile	0.38 cal pistol, soft lead bullet fired from 6-in. barrel

The following conclusions were made:

1. For angles of incidence from 0 to 30 deg off normal, damage from small caliber gunfire is localized.
2. For an angle of incidence of 30 deg and a range of 100 ft, there is no significant increase in damage between a 0.22 cal bullet and a 0.38 cal bullet.
3. When struck near a supported edge, panel damage is similar to that of a nonsupported section. No shattering occurs and the sample remains intact.
4. For a large angle of incidence (60 deg) in which a panel is struck from behind, damage will be most severe.
5. Even for severe damage cases, the laminated structure of the glass panel will keep the panel intact.

In general, the laminated panels are shatterproof and retain their structural integrity, even when severely cracked. From a solar facility operations standpoint, it will not be necessary to replace a panel immediately if it is damaged by gunfire vandalism, although performance will be somewhat degraded.

After a few thermal cycles (day/night), the cracks may propagate and panel replacement will have to be made.

In conducting this test, it was noted that when a panel was tested, the person shooting could not, from a distance of 100 ft, observe the damage done. Vandals typically enjoy seeing the damage they do. Since they will not "see" or "hear" any shattering glass, they may be less likely to continue their activity and risk being caught.

3.1.3 Heliostat Controller Development Component Tests

Controller component tests were conducted to verify design requirements as imposed by the Collector Subsystem Requirements. These include the following:

A. Power transient.

B. Noise. HC response to self-generated noise.

C. Reference Update. Ability of HC to locate heliostat position after power loss.

D. Motor Control Algorithm. Determine gain requirements for the HC motor control algorithm.

E. Controller extreme temperation operation.

F. Controller component life tests.

3.1.3.1 Power Transient Tests

System requirements state that the HC or HFC shall operate for input power line dropouts of 3 AC cycles (50 msec) and for an overvoltage transient of 1.7 times for 1 cycle followed by an exponential decay back to normal in 5 cycles (Section 3.3.2). This can be accomplished by maintaining the power supply outputs within their tolerance band of ±5% over the transient period. To determine the effects of these transients on the power supply, laboratory tests were set up and measurements taken for an HA5-1.20 VP (HC supply) and an HCC512 (HFC supply).

In the overvoltage test on the +5V power supply, component ratings were high enough to withstand the overshoot and it was regulated out before it could effect the +5V output. The following results were obtained for the HA5-1.20 VP supply.

Load	Dropout protection time (msec)
1.0A	95
1.2A	50

Since a nominal load is only 0.6-0.8A, the power supply provides ample protection. The same test performed on the HCC512 supply gave values of:

Load	Dropout protection time (msec)
2.5A	65
3.3A	50

Here again, ample protection is provided since the nominal load is 1.8 to 2.0A.

Similar results were obtained for the +12V part of the HCC512.

3.1.3.2 Noise Test

The sensitivity of the heliostat controller (HC) to its operational noise environment has been investigated on the bench and heliostat. The bench setup consisted of the pedestal wire harness, two 1/2-HP motors, and the associated heliostat electronics (actual and simulated). To establish a noise margin, the bench setup environment was deliberately made more severe than the heliostat environment.

Bench tests of the unit yielded an occasional error in accumulated motor turns count. Noise spikes were determined to occur during the time when the contacts of the contactors were bouncing (after the coils were switched). The magnitude of the voltage seen during this period differed as a function of the magnitude of the back EMF of the motors (motors still coasting), the time at which the bounce occurred, and the duration of the contact bounce. A DC supply was substituted in place of the AC voltages normally switched by the TRIACs on the input side of the contacts in order to eliminate one of the variables. Switching the contactors resulted in momentarily switching the DC voltage into the inductive load (motor windings). Adjusting the voltage and switching the contactors showed the controller performance to be satisfactory. The effects of shield lengths, location of the terminations, and filter networks to improve the noise immunity of the unit were demonstrated using this method.

In order to present the maximum ("worst-case") level of noise in testing the effects of the modifications made to the box, the HC software was changed such that the motors would be switched on during the contact bounce period. (The normal software delays this turn-on until there is no contact bounce.)

The margins obtained from various modifications to the controller were demonstrated using the DC level and worst-case noise tests.

The final configuration was tested on the heliostats where they were subject to the noise environment of the heliostat. No errors were present.

3.1.3.3 Reference Update Test

To achieve pointing accuracy, the heliostat control system must know heliostat position at all times with respect to the inertial reference frame. If motor turn position (reference) is lost, a reference update scheme is used to locate the position of the heliostat.

Tests were conducted to verify the HAC, HFC and HC software logic; the hardware/software interface, hardware variations such as helicon sensor pulse width, motor coast, and software variation such as status update time do not affect the accuracy and repeatability of the update.

Testing was performed on three configurations: bench breadboard, bench breadboard with elevation jack, and heliostat brassboard (all electrical parts in their heliostat location). Test parameters that were varied included motor speed and direction and sign of the turn count. Power was interrupted at both random times and at times selected to give worst-case conditions. Updates were then performed and the computed motor turns count compared with those obtained from mechanical counters attached to the motors. The requirement was for the HC to be within one turn of the mechanical counter.

During bench breadboard testing, it was found necessary to add:

- A reinitialization flag, sent to the HFC as an absolute indicator of a reference loss.

- A flag updating the gimbal sensor value only at a helicon crossing in order to assure finding the correct reference helicon during full update.
- A flag to stop the azimuth motors at the gimbal sensor switch.

Following these additions, computed turn counts were within the one-count allowance.

Final tests were run on a stand-alone downloaded HFC operating under control of either the HAC or a HAC simulation program executing on the Intel MDS.

Full Reference Update

In the full update tests, during the operating mode in which the gimbal position is being commanded to the helicon crossing, a motor rate of one-fourth maximum motor rate and an HC status polling frequency of once every 8 sec was used. In over 30 tests, the motor positions calculated by the full update module were within one turn of the turns recorded on the mechanical counters.

Mini Reference Update

Twelve tests of the mini update module were conducted. In each of these, the heliostat was in track when power to the HC was momentarily interrupted, after which the HFC was commanded to perform a mini update. In all cases the motor positions calculated by the mini update module were within one turn of the turns recorded on the mechanical counters.

In addition to these subsystem tests, the accuracy of the reference update scheme was verified using a full heliostat and complete control system. In this test the beam centroid on a target was determined after each reference update. The results indicated that the reference update scheme was repeating within the accuracy of the beam centroid measurement (<0.5 mrad).

3.1.3.4 Motor Control Algorithm

Precise sun tracking by the heliostats requires knowledge of how the heliostats respond to given input commands. Achieved motor turns versus commanded turns are affected by switching logic, motor characteristics, heliostat dynamics, elevation position, etc. Characterization of these parameters is necessary to determine the HC control algorithm gains and to verify that these gains would be stable over the operating range.

To gather data on the effect of the various parameters, tests were run early in the development program on the pilot plant heliostat and the Second Generation HC/motor bench setup. Commands in increments of one-half AC cycle were sent, and the time from the commands to each achieved turn as well as the total turns was recorded. Several repeats of each command were used to achieve a statistical sample. From the data such items as rate versus time, number of turns versus time, and turns versus AC cycles were computed. Gain numbers were then calculated for the control algorithm.

Tests on the Second Generation Heliostat indicated that the gains calculated from the earlier data were accurate enough to meet system requirements. Test data indicate that optimizing the gains would achieve a probable reduction in heliostat power requirements.

3.1.3.5 Controller Extreme Temperature Test

The control system must meet the beam pointing performance requirements in ambient temperature range from 0°C to 50°C (32°F to 122°F). In order to achieve morning operational position or evening stow position, the heliostat will be capable of functioning with ambient temperatures down to -9°C (16°F) and component temperatures that are colder or hotter than ambient temperatures due to thermal lag self-heating and/or absorption of direct insolation. The control system does not have to meet beam pointing performance requirements until the temperature reaches 0°C.

The objectives of this test are to:

A. Verify that the control system meets specification requirements.

B. Evaluate control system performance during cold soak and extended high temperature tests.

The heliostat controller box, elevation motor, and elevation helicon sensor were subjected to operational tests with the ambient temperature ranging from -30°C to +70°C (-22°F to +158°F) (see Figure 24). The operational test consisted of commanding a number of motor turns and then determining the number achieved. The motors were commanded back to zero turns and the achieved value was again determined. The helicon crossing points were recorded for travel in each direction. The elevation reference switch closings were also simulated.

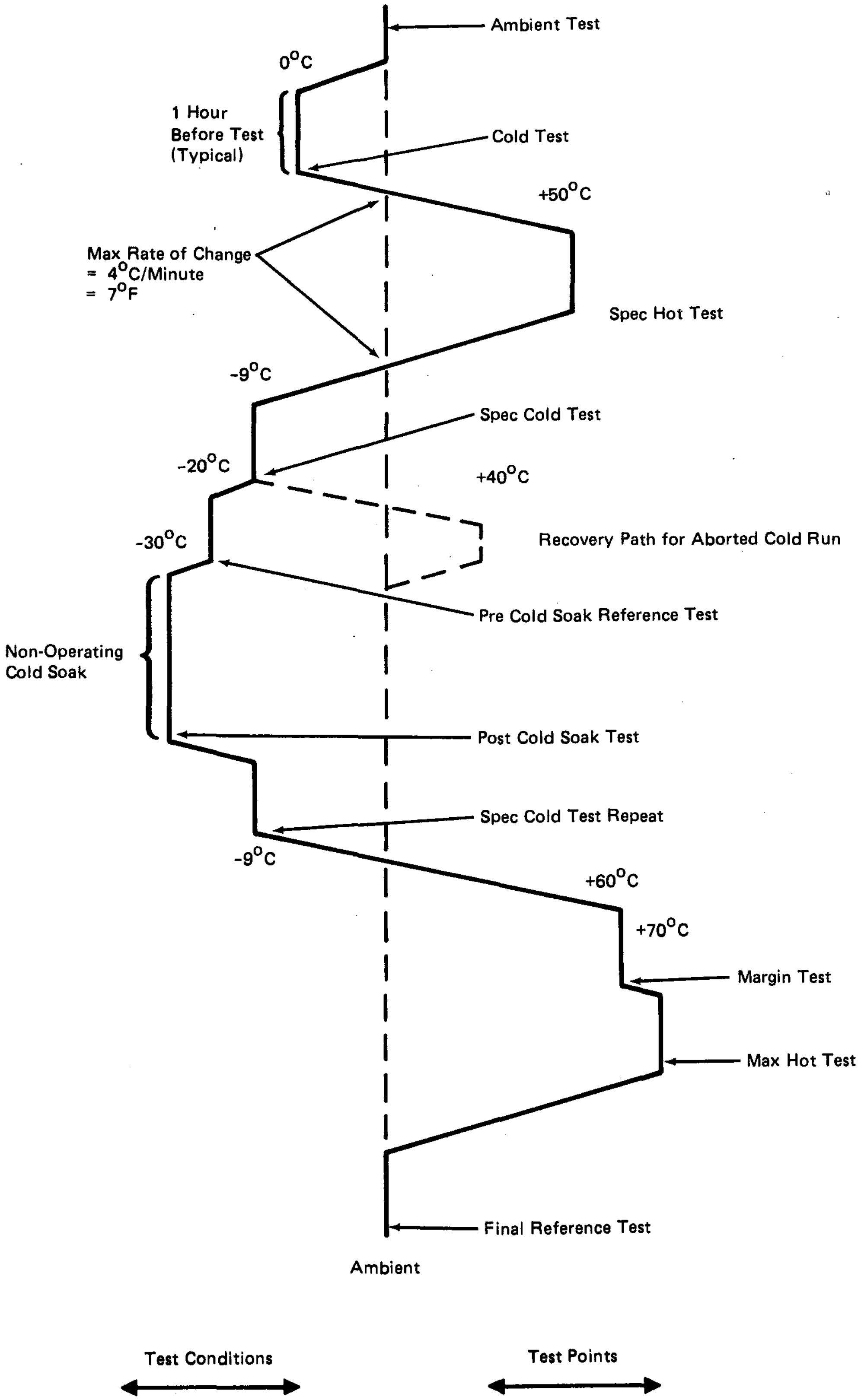


Figure 24. Controller Temperature/Time Test Profile

The tests were run with power applied to the box and the ambient chamber temperature set to the desired level. Temperatures in the box were allowed to stabilize and the operational test was then performed. The one exception to this was at -30°C where the box temperatures were allowed to stabilize with power off. Power was then applied and the operational test immediately performed. During this test, electronic parts in the box ranged in temperature from -30°C to +77°C (self-heating at +70°C ambient).

All test objectives were met. All test results were in tolerance at even the extreme temperatures. The hottest spots in the controller were the microprocessor chip and the upper chamber air temperature. Both were about 10°C higher than the chamber temperature.

3.1.3.6 HC Controller Life Tests

During the Second Generation development, many hours of life testing were completed. Some occurred as part of normal test and development while others were planned life tests. The following paragraphs detail some of the more significant ones.

Life Cycle (Mini)

These tests consisted of going from stow to standby, to track, 10 min of track, to standby, and to stow. From 7:30 AM to 5:00 PM these were done in real time. From 5:00 PM to 7:30 AM, the time was set to 10:30 AM at the beginning of each cycle. Each cycle corresponds to about 0.6 of the normal gimbal measurement a heliostat would see in one day of normal power plant usage. Before going to CRTF, heliostat No. 1 accumulated 2033 cycles and heliostat No. 2 had 1977 cycles. Besides the mini life cycle, the heliostat also made many operational cycles during the checkout and test period. The average operational cycle involved about the same gimbal movement of the mini life cycle. Heliostat No. 1 made 268 operational cycles and heliostat No. 2 made 179 operational cycles.

Contactor Cycling

To verify contactor life, a contactor cycling program was started in April 1980. The contactor was closed in one direction and 5 AC cycles were applied to the motor gear drive used as a load. When the motor stopped coasting, the contractor was closed in the opposite direction and 5 AC cycles were applied to drive the motor in the opposite direction. When the motor stopped coasting, the whole cycle was repeated. By the end of December 1980 when the test was stopped, 3.8 million of these cycles were accumulated. This is approximately 52 yr of plant operation, as it is estimated that a contactor will make less than 200 cycles per day under normal operation.

Electronics Life Tests

Many hours were accumulated on the electronics as part of normal testing and software development. These hours are summarized below.

Controller Box (HC)	Accumulated hr
SN1	1012
SN2	2229
SN3	1209

In addition several HC processors were used in special tests setups. One processor had 5040 hr of operation and another had 3598 hr of operation.

3.2 SUBSYSTEM OPERATION

Following manufacture and component testing, the two prototype heliostats and the subsystem control were assembled in the MDAC solar test facility at Huntington Beach, California, and subsystem operational testing was performed. In this activity, data were obtained from two sources: results from the specific tests planned on the subsystem assembly and results from the assembly and operation experience with the heliostats (which was a test objective in itself). During this testing approximately 2000 mini life cycles and 300 operational cycles were performed on each heliostat.

3.2.1 Subsystem Assembly Level Tests

Three assembly level tests were performed: a determination of heliostat power consumption; large field communications capability; and a control system acceptance test.

3.2.1.1 Power Consumption Test

The purpose of this test was to determine the power consumption of the heliostats. Data were taken for the following conditions:

A. Gimbal rate changes. Motors were commanded to turn rates of 30, 15, 5, 1 and 0.5 turns per sec. In elevation, this was accomplished for both up and down rates and at elevation angles of 0, 45 and 90 deg to fully assess the gravity effects. Azimuth requires one direction only.

B. Functional power consumption. The heliostat was commanded from stow to standby, to track, to standby, and to stow again.

C. Static. The motors were not moving but all electronics were on.

D. Starting transient. This was a measurement of motor starting current.

Results of these tests are summarized below.

Mode	Requirement
Electronics on only	40 W
Unstow - vertical to track	620 W
Stow - track to vertical	290 W
Track	72 W
Elevation gimbal slew (retract)	300 W
Elevation gimbal slew (extend)	150 W
Azimuth gimbal slew	170 W
Motor starting current	11.3 amps
Motor running current	1.0-1.5 amps rms
Daily power consumption (10 Hr)	775 W-hr

The motor starting current decays to its running value in about 5 AC cycles. Power requirements for the track mode are higher than predicted in the DDR but are lower than predicted for stow and unstow. More detailed test results are found in Appendix C.

3.2.1.2 Communications Test

The HFC was designed to communicate with up to 32 HCs on a party line that could be up to 2000 ft in length. The party line is a twisted shielded pair with the shield tied to chassis ground. Each HC is tied to the line by a pigtail approximately 10 ft long which goes from the junction box at the pedestal base up to the controller box.

The HAC/HFC communications interface is identical to the HFC/HC interface. Therefore, test data from one interface are directly applicable to the other.

The objectives of this test are to:

A. Verify that waveforms are not excessively degraded by the long communications line and HC loads.

B. Verify the ability to communicate between HFCs and HCs under various line and load configurations.

C. Verify the ability to communicate with the CRTF line and load configuration.

D. Determine if the termination resistors are essential.

Two active HCs and 13 inactive HCs were used in the test. The active HCs were the bench test setup (H1) and the forward heliostat (H2). The inactive HCs consisted of transceivers wired as used in the HCs, but with the receive line enabled and the transmit line disabled.

Six configurations were tested. These were:

1. Normal distance. This configuration is the one used in hardware, software and integration testing, and since communication was known to be good, it provided a reference point. It was about 50 ft from the source to the tie point, another 50 ft to H1, and about 250 to 300 ft from the tie point to H2.
2. Maximum distance. A total of about 2,000 ft of line was placed between the source and H2. H1 was at the normal distance and 13 inactive loads were spaced along the line at various intervals.
3. Same as No. 2, but with the terminating resistors switched in on H2.
4. About 400 ft of line to H1 and 1600 ft to H2. The inactive loads were on the line.
5. Same as No. 4, but with the termination resistors switched in.
6. Same as No. 2, but with the inactive loads removed.

The wire used in this test was Belden 9460, 18 gauge. Measured values were 6.7 milliohms and 54.8 picofarads per foot.

Maximum roundoff of the signal leading edge occurred with the normal distance between loads. Squaring of the signal leading edge with longer cables is apparently due to line reflections occurring at the appropriate time. The signal level at H2 dropped from about 4.5 V line-to-line to about 2.5 V when 2000 feet of cable was inserted. The part specification is 0.5 V so there is a 5 x margin.

Communication was established with the HCs under all configurations tested. Although only 15 HCs were on the line, the configurations used were representative of the actual configurations a field would assume. It is concluded that a HFC could communicate correctly with 32 heliostats on a line and in any configuration of layout and distance as long as 2000 ft. With the margin available, these numbers could undoubtedly be increased.

3.2.1.3 Control System Acceptance Test

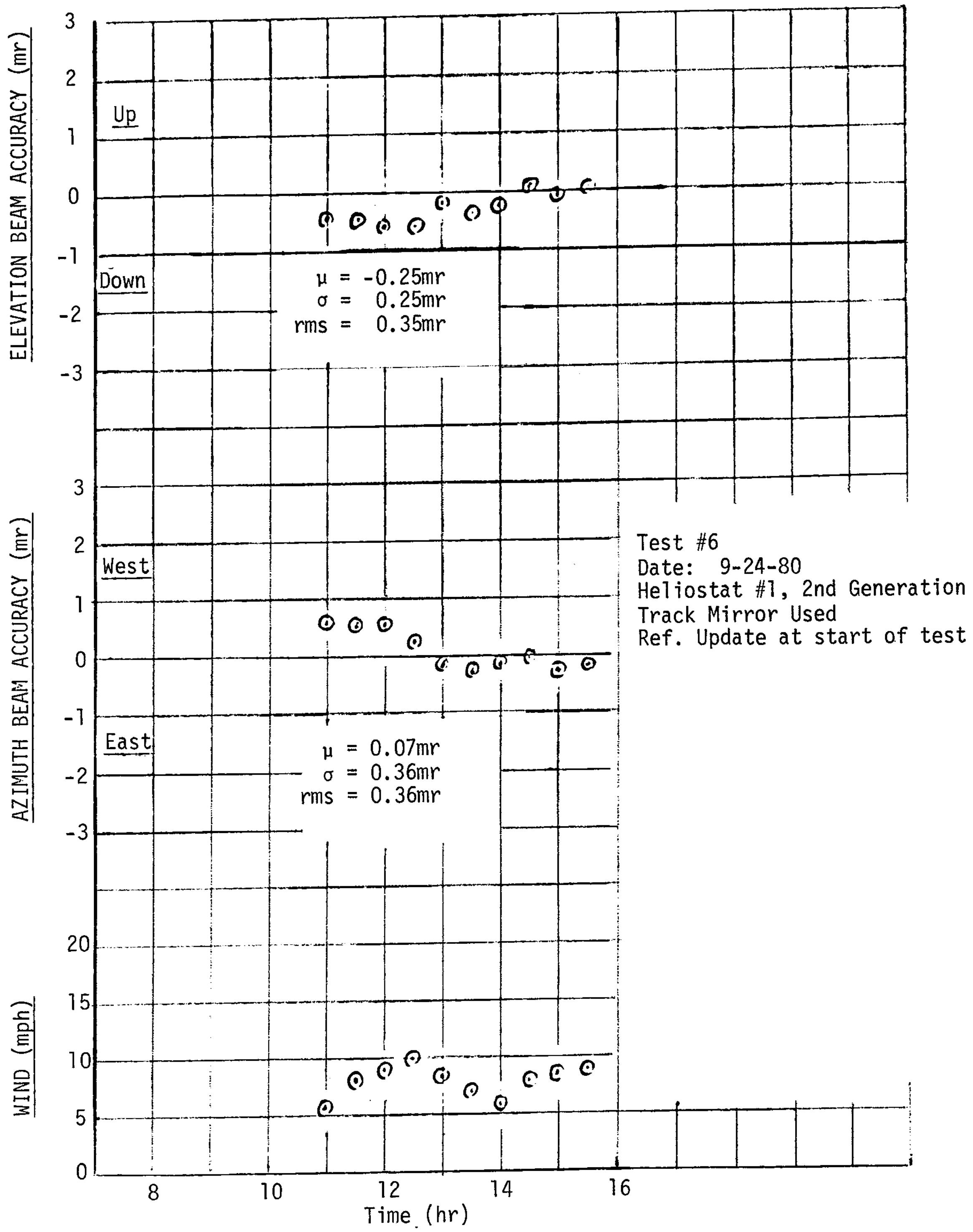
The purpose of this test was to verify that the total operating system (heliostat, controller, HFC, HAC, and operating terminal) meets the subsystem requirements. This included the following tests:

A. Beam pointing tracking test
B. Data base verification
C. System startup
D. Reference update
E. Mode test
F. Alarms
G. Life cycle

All test requirements were met. The detailed results are found in Appendix C.

The beam pointing accuracy of the control system was determined by using a digital image radiometer (DIR) to calculate beam centroid. Centroid data were taken at half-hour intervals over the day and then the rms value of all points was calculated. The results for heliostat No. 1 are shown in Figure 25. The rms value of 0.36 mr is approximately 4 times more accurate than the requirement of 1.5 mr. This was with wind blowing from 5 to 10 mph. Because of morning clouds/fog at the time of this test, the test could not be started before 11:00 AM.

The other tests were primarily a comfirmation of software design and readiness. Minor problems encountered during the tests were corrected and retested. The results verified that the subsystem was fully operational and ready for the CRTF demonstration.



μ = -0.25mr
σ = 0.25mr
rms = 0.35mr

μ = 0.07mr
σ = 0.36mr
rms = 0.36mr

Test #6
Date: 9-24-80
Heliostat #1, 2nd Generation
Track Mirror Used
Ref. Update at start of test

Figure 25. Beam Pointing Accuracy for Heliostat No. 1

3.2.2 Assembly and Operation Experience

The goals of this part of the program were to develop and prove the procedures for heliostat installation and checkout; to identify assembly time and manpower requirements; and to verify the heliostat design, operations, and maintenance procedures as required. The experience in this phase of the program was substantially a confirmation of the design expectations. It did, however, highlight some of the features and characteristics of the heliostat in this mode. This experience resulted in changes incorporated prior to the CRTF installation as well as sources of future cost reduction.

3.2.2.1 Foundation Installation

During the installation of the two foundations, the one special operation is the vertical alignment of the tapered pedestal, which requires verticality within 1 deg. It was found that leveling provisions were desirable on the cone to hold it in position, once leveled, during the concrete pour. For CRTF, two nuts were added to the cone base 90 deg from the pull-down nuts. A tool with an adjusting leg was used, as shown in Figure 26, installed in the four

CR15

Figure 26. Foundation Installation

nuts, and bearing on a board placed at grade to level the cone in each quadrant. A standard carpenter's level with a shim bonded to one end to compensate for the cone angle was used in the leveling process. The ease and accuracy of this installation is demonstrated by the verticality achieved on installed pedestals, which was less than 0.5 deg for all four installations (MDC and CRTF).

3.2.2.2 Pedestal Installation

For the test installation of the two prototype units at Huntington Beach and the two installations at CRTF, dual hydraulic cylinders were used in the installation process as shown in Figure 27, with proper installation determined by the preload and final position of the pedestal on the foundation. The preload, required to provide the torsional rigidity of the joint, is 20,000 lb. In all four installations, it has been found that the pedestal easily guides itself down the foundation cone without special alignment considerations. Before load is applied, the pedestal is engaged enough to be in a stable condition. Preloading up to the required value placed all four assemblies within the ±6 in. final height range. One of the pedestals was deliberately overloaded to 34,000 lb without incident. Radial alignment of the pull-down fixture attachment to the pedestal and foundation. Azimuth location is required within 3 deg.

Once the pull-down tool is installed, the seating of the pedestal requires only the time required to pressurize the cylinders, which is less than 1 min. This assembly process is very adaptable to the use of high-rate installation techniques such as the use of tractor mounted tools for transportation to the foundation, installation, and pull-down. In this mode, installation may be accomplished by one person.

3.2.2.3 Reflector Assembly Installation

The reflector assembly is installed by placing the alignment and bolting holes on the inboard cross-beam over the alignment pins and bolting holes on the main beam, then installing and torquing eight bolts. Attachment of a lifting fixture to the reflector assembly consumed most of the time in this installation. This installation, shown in Figure 28, was accomplished eight times at MDAC. The maximum time required was 10 min per assembly. A crew of four was required: the crane operator, a guide and bolt installer located at the main

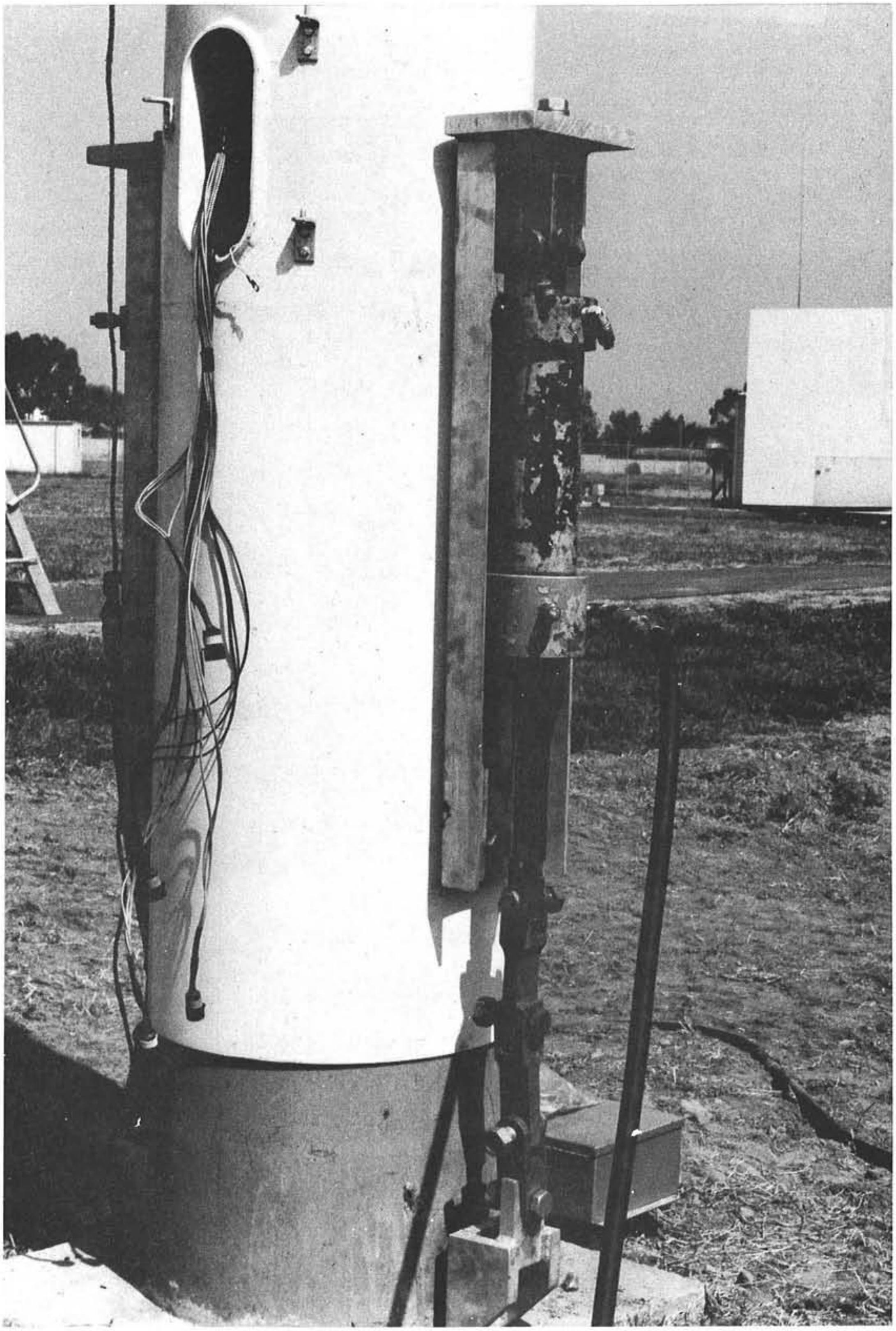


Figure 27. Pedestal Installation Test

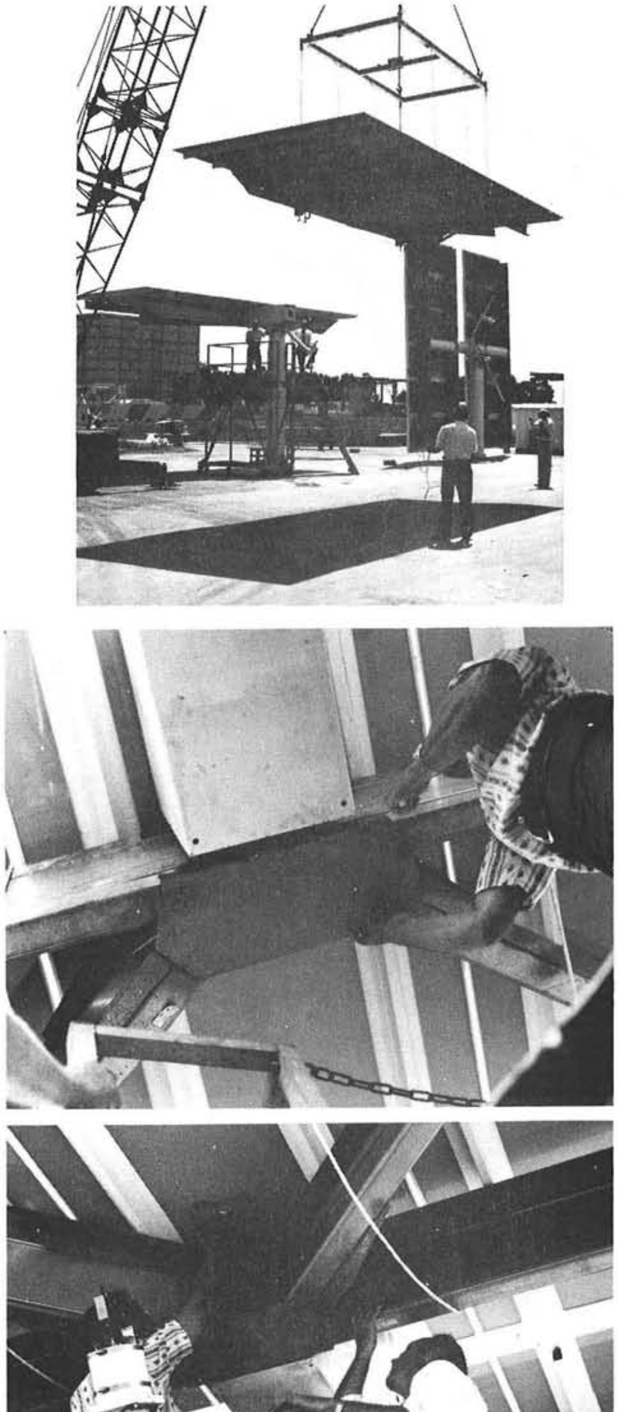


Figure 28. Reflector Assembly Installation

beam reflector joint (on a platform), and two assembly guides operating ropes attached to the ends of this assembly.

This assembly process also lends itself to acceleration with special handling gear. However, an overhead lift with cable support provides excellent maneuverability for this operation. The only critical maneuver is guiding the second assembly to the beam without contact of the outboard mirrors on the previously installed assembly. For this maneuver, foam pads placed on the outer corners of each reflector assembly aid visibility and cushion any contacts made. The 6-in. gap provided between the reflectors when assembled aids this operation.

3.2.2.4 Mirror Module Replacement, Handling and Cleaning

On several occasions during the test program, it became necessary to remove and replace mirror modules from the heliostat. This was accomplished by lifting modules off vertically from a horizontal-stowed heliostat with a lifting sling and with a forklift with the tongues inserted under the module hat sections. It has also been accomplished with the heliostat vertical. In this case, the module was placed on its short edge on foam pads on a forklift and raised and guided into place, as shown in Figure 29.

The PVB laminated glass is in essence a safety glass, which does not shatter when it breaks. This has been demonstrated in incidents both at MDAC and at CRTF. This feature reduces the hazards associated with handling the mirror modules.

Another feature of the MDAC design is the potential ease of mirror cleaning. The large uninterrupted vertical orientation of the modules is highly amenable to conventional window cleaning techniques and should lend itself to innovative automated methods utilizing gravity effects.

3.2.2.5 Mirror Alignment and Canting

For testing at MDAC, two mirror attach schemes were evaluated along with the concept of factory alignment and canting prior to delivery to the field.

Figure 29. Mirror Module Replacement – Heliostat Vertical

The first heliostat assembled had one reflector assembled with three-point support of the mirror modules and one with four-point suspension. The assembly of the mirror modules to the support structure, and alignment and cant were performed in the factory prior to installation.

The three-point support proved to be inadequate due to the inherent lack of torsional rigidity of the mirror module. Alignment and cant were found to be no more difficult in a four-point support than in a three-point.

Once the four-point support was adopted and the short-span stiffness of the mirror modules increased by the addition of the short-span brace (as described in Section 3.1.1.2), alignment of both heliostats was accomplished by the factory procedure to the heliostat location ranges at the MDAC test facility which are shorter than the CRTF ranges. Good images were obtained on both heliostats.

Following the testing at MDAC, the mirror modules were realigned to the CRTF range locations prior to shipment.

3.2.2.6 Control Sensor Anomalies

Two minor problems with the position sensors were discovered during the MDAC testing. They could not be corrected during the prototype effort but will be corrected in the production hardware.

An interference problem can arise in the encoder between the rotor and the magnets. This is evidenced by a contact noise during motor operation. This results from a larger tolerance on motor shaft end play than allowed by the magnet, rotor installation. For production the encoder tolerance will be increased. Custom fitting of parts for the prototype units minimizes the interference.

A wider than anticipated switching range was found on the azimuth location sensor. This was determined to be caused by selection of an inappropriate magnet for this position, in conjunction with a switch problem which the manufacturer has resolved for production units. Replacement hardware was not available in time for the CRTF tests. The problem is currently resolved by setup procedure and software. However, production units will utilize the changed hardware.

3.3 SHIPMENT AND INSTALLATION AT CRTF

The teardown at MDAC, and shipment to the CRTF and installation in Alburquerque provided additional data and experience in factory alignment, installation times, and procedures.

3.3.1 CRTF Drive Pedestal Main Beam Assembly

Following testing at MDAC the drive main beam assembly was removed from the test pedestals and installed on the pedestals for CRTF. The oil was drained from the drive units in order to start with new oil for the CRTF demonstration. Installation at CRTF was accomplished with the same equipment used in the pulldown tests at MDAC. The ease and rapidity of this procedure was again demonstrated. A small delay was encountered on one heliostat associated with the fit of the test pull-down fitting and bolts which do not reflect the production procedure.

3.3.2 Shipping of Factory-Aligned Reflector Assemblies

Prior to shipment of the heliostats to CRTF, the mirror modules were aligned and canted for the range locations at CRTF. The alignment was accomplished with the reflector assemblies in a horizontal position using a mini level. Predetermined slopes were applied. The assemblies were loaded into shipping containers in the horizontal position and transported by air ride trailer to CRTF for reassembly of the heliostats. Horizontal shipment was used since equipment for handling and transporting the reflector assemblies in the vertical position was not developed in the Second Generation program. At CRTF the assemblies were removed from the shipping containers, as shown in Figure 30, and installed directly to the previously installed pedestal drive main beam assembly. Installation by Sandia personnel for the first time took less than 20 min for the heliostat. When the heliostats were placed on the target, the images were checked with the BCS and were found to be close to specification. This result, in conjunction with improvements to be made to the mirror modules for short-span stability, provides high confidence in the plan to ship aligned reflectors from this factory.

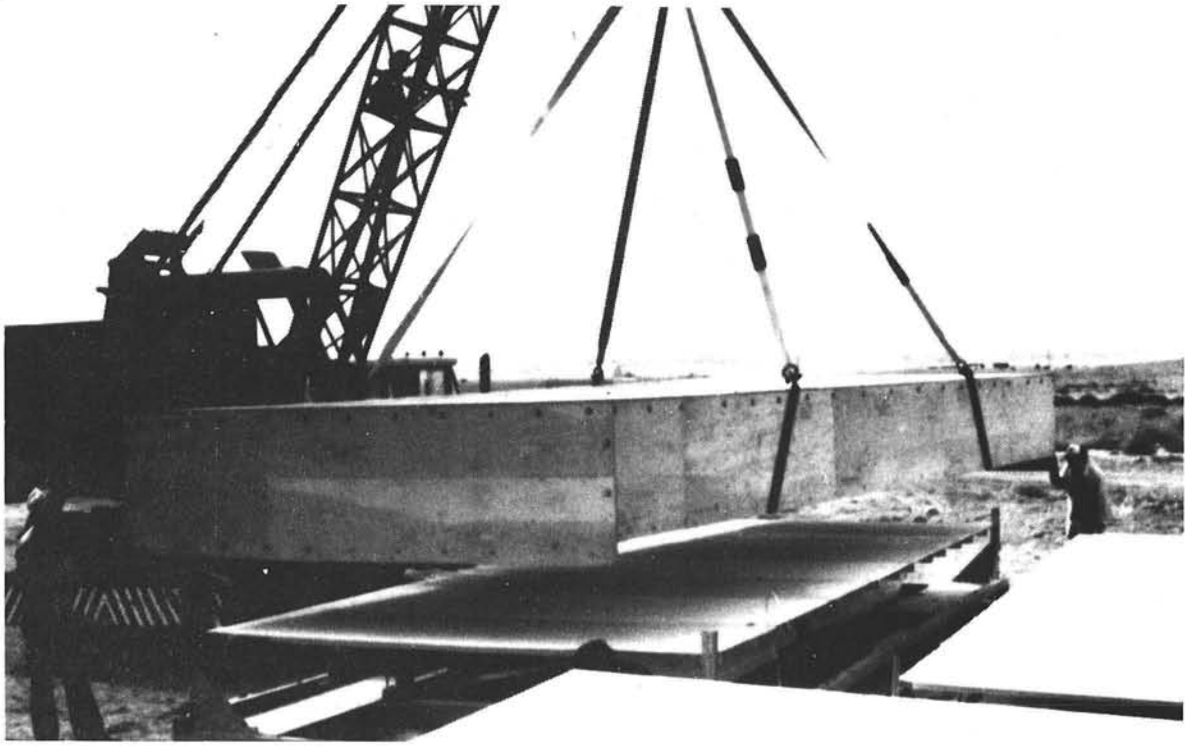


Figure 30. Installation-Ready Reflector Assembly

3.3.3 CRTF Installation Component Discrepancies

Three component discrepancies were uncovered following shipment of the heliostats to CRTF. They were mirror module attach bolt material, silver defect, and loose mirror edge members.

3.3.3.1 Mirror Module Attach Bolt Material Discrepancy

When the reflector assembly shipping containers were opened at CRTF, five mirror module attach studs were broken. All five were located on the outermost mirror modules at the outermost connection to the inboard cross beam. The broken bolts were replaced, and the installation proceeded without incident. A subsequent failure analysis revealed that the bolts had failed due to fatigue. It was further determined that the bolts were not per print requirements. The strength had been lowered in the process of brazing a shoulder nut to the bolt. Additionally, the threads were unevenly cut rather than rolled. As a result of this investigation, all the attached bolts on the CRTF heliostats were replaced with parts meeting the design requirements.

3.3.3.2 Silver Defect

Upon uncrating the reflector assembly in Albuquerque, an approximately 7-in.-diameter silver defect was seen on Mirror Module SN017. The defect was located exactly in the short-span center of the panel, 4 ft from the end, and gave the appearance of distorted or pulled off silver. No defect was visible from the backside. This mirror module was replaced with SN07 and the heliostat assembly completed.

A review of the log on SN017 showed no abnormality in production, no trace of defect in an image photograph taken 26 August 1980, and no noticed defect when washed on 7 November 1980. SN017 was fabricated from the second batch of mirrors delivered by Binswanger on 1 July 1980.

The defective portion of the panel was cut out and shipped to Binswanger for evaluation. It was found to be a mechanical pull-off of the silver. It was exactly the size of a vacuum lifting cup used to handle the mirror module during production at MDAC. In subsequent production, several vacuum lifting devices will be used if required. It is suspected that a single cup caused high localized stresses which caused the silver pull-off.

3.3.3.3 Mirror Edge Members

On handling the mirror modules subsequent to the shipment from MDAC, some of the metal edge protections were loose. This may be due to an incompatibility of the acetic acid released during cure of the silicone and the metal galvanized surface. Materials compatibility analysis is ongoing, and a modification will be implemented for production.

Section 4
QUANTITY PRODUCTION

The results of the conceptual design task for a heliostat manufacturing facility sized to produce 50,000 heliostats per year are summarized in this section. The design consists of manufacturing process definitions and requirements; manufacturing flows and equipment selection; equipment and manpower loading and scheduling; and plant layout. MDAC was assisted in this task by a subcontractor, General Motors Energy Systems. Volume II of this report contains the detail results of this effort. The F Jos Lamb Company was a major subcontractor to General Motors (GM) and developed processing, tooling requirements, machine estimates, and the print layout. Edgar G. Wright, P.E. of Lockport, New York, provided industrial engineering consulting. The Harrison Radiator Division of GM developed the labor estimates and performed the cost extension required to develop factory costs, which are discussed in Section 6 of this report. In addition, support was provided in the material and process definition by Corning Glass Works of Blacksburg, Virginia; Binswanger Mirror Production of Memphis, Tennessee; roll-formed parts supplier Van Huffel Tube Corporation of Warren, Ohio; and welding equipment supplier Dollar Electric Company of Madison Heights, Michigan.

GM performed the study based on a data package provided by MDAC which contained a complete set of drawings for the prototype heliostats and production changes; detail indentured parts list; and manufacturing process descriptions and specifications.

The production heliostat description, the manufacturing process definitions developed by MDAC, and the manufacturing facility definition performed by GM are summarized in this section.

4.1 PRODUCTION HELIOSTAT DESCRIPTION

The production heliostat configuration is the same as the prototype units. Changes have been made at the component level to reflect production capabilities resulting from the extensive tooling which will be made available. Material changes are made to reflect lower costs in volume. In all cases they can be adopted with no heliostat retest and with a minimum of component verification.

4.1.1 Mirror Module

The only change to the mirror module for production is the use of 0.060-in. fusion glass instead of the 0.090-in. float glass used in the preproduction mirror. This change is projected for mirror performance and is based on cost projections by the supplier, reflecting volume costs competitive with other glass on a performance equivalent basis.

4.1.2 Reflector Support Structure

The change in this hardware is cosmetic only and includes elimination of the inboard beam end taper, and special right hand, left hand joggle of the diagonal beam outboard edge. Spot welding is used at all welded joints rather than the plug weld used at the inboard beam gussets on the prototype units.

4.1.3 Elevation Support

Based on a cost trade study performed by GM, a casting replaces the weldment assembly.

4.1.4 Azimuth Drive Assembly

The changes made to the azimuth drive assembly include plug welds to join the flex spline to the drive housing; a deep drawn housing eliminating one filler block; and a can fabricated from two draw die formed parts to replace the remaining filler block.

4.2 MANUFACTURING PROCESSES

The manufacturing process definition for the heliostats starts with decisions of what will be purchased and what will be fabricated in the factory. This is followed by the definition of processes for each of the elements of the heliostat. They are defined at the component level, flowing to assemblies which are delivered out of the factory.

4.2.1 Make or Buy

The make-or-buy determination for 50,000 heliostats per year is based primarily on the previous work performed by MDAC and GM on evaluation of 25,000 per year and 250,000 per year facilities under the Prototype Heliostat study and the SERI repowering analysis. The reader is cautioned that these determinations are for this study only and are aimed at identifying cost projections for the heliostats based on high-volume manufacturing processes. In the realization of high-volume heliostat production, suppliers will be encouraged to enter this activity and supply parts at costs competitive with the factory processes defined. Different volume levels will also produce different make-or-buy determination based on existing or potential industry capabilities.

The make-or-buy decisions for this study are defined below. A detailed make-or-buy list is provided in Volume II.

Mirror Module Assembly

The float glass is purchased. The fusion glass is purchased mirrored to specification. Mirroring may be performed at a captive facility collocated with the fusion glass manufacturer.

The PVB is purchased and laminating is performed in the factory. This decision is based on a trade study which concluded that the volume requirement dictated a new facility for laminating, and multiple suppliers were unlikely to make this investment.

The fusion glass production also requires a substantial investment in facilities. However, this investment is best made at the existing glass factory.

All adhesives as well as roll-formed hat section stringers and edge members are purchased. The mirror module is assembled in the factory due to the unique tooling required for assembly and curvature control.

Reflector Support Assembly

The inboard beams, outboard beams, and diagonal beams are purchased from an existing commercial roll-form production facility designed for very high volume. The supplier will obtain special tools for heliostat component production. Die cutting and shaping of the diagonal beams is performed in the manufacturing plant. The support structure is also assembled in the plant due to special tooling, materials handling, and next assembly considerations.

The mirror attach hardware is a commercial configuration and is purchased.

Azimuth Drive Assembly

The helicon gear, the bearings, and the shims are purchased from specialty suppliers. The motor is also purchased to specification. Mounting hardware and brackets are purchased as near-commercial parts. The incremental encoder electronic components, micro switch, and magnets are purchased. All other components are fabricated in the factory.

Elevation Actuator Assembly

The jack actuator and motor are purchased to specification. The trunnion bearings and encoder components are purchased commercial components.

Elevation Support Assembly

The casting is purchased from a commercial custom casting company.

The bearings and attach hardware are purchased as near-commercial hardware.

Main Beam

The main panels are purchased as roll-formed parts. Other details and the welding assembly are performed in the factory.

Raw Material and Standard Parts

The remainder of the heliostat components are fabricated in the factory from purchased raw material and standard fasteners, connectors, and other small commercial parts.

HC, HFC, HAC

The HC, HFC, and HAC are buy items for this study.

4.2.2 Plant Processes

The material below summarizes the processing plan for the major component fabrication in the factory. The detail processing, defined on tool and labor routine sheets, is contained in a 53-page appendix of the GM report (Volume II).

4.2.2.1 Mirror Module Assembly

Processing for the reflective surface involves handling of the float and mirrored fusion glass lights, laminating the glass lights together, bonding the hat section stringers to the back of the float glass, and curing of the assembly in an oven.

A. Fusion glass is mirrored in a conventional mirror line with white mirror backing paint applied. The paint is allowed to dry for a minimum of 1 wk before transfer to the laminating facility at the heliostat factory.

B. Float glass is loaded from shipping containers at the beginning of the line, "tin" side down, on the conveyor.

C. The float glass is washed, rinsed with deionized water, and dried with warm air.

D. PVB adhesive from rolls is cut and placed on the float glass.

E. Fusion glass is loaded from shipping containers onto the adhesive covered surface of the float glass with the mirrored side down.

F. The sandwich is conveyed through a heater at 130°F and through pinch rollers which press the laminate together to ensure an initial tack of the adhesive.

G. The laminate is then autoclaved.

H. With the fusion glass face down, the float surface is washed with a detergent wash, rinsed with tap water, buff slurry, rinsed with tap water again, then rinsed with ionized water, and blown dry.

I. Adhesive primer is applied on the float surface in a pattern matching the shim bond footprint, and cured.

J. Adhesive is applied by an extruder in the shim section areas on the back of the float glass.

K. Two shims are loaded on the back of each glass laminate.

L. The assembly proceeds through a pinch roller and then to a storage area where it is allowed to cure.

M. Adhesive primer is applied on the shim surface in a pattern matching the hat section bond footprint and cured.

N. Adhesive is applied by an extruder in the stringer section areas on the shim.

O. The stringer assembly is placed on the adhesive.

P. The sandwich and stringer assembly is conveyed on to the rollerized pallet which clamps the stringers in place on the back of the float glass. The rollerized pallet surface is curved to provide mirror curvature after bonding.

Q. Pallets are conveyed into the curing ovens.

R. After exiting the oven, the edge seals, previously coated with silicone sealer, are applied.

S. Reflector assemblies are then removed from the rollerized pallets and loaded into racks for the completion of the curing cycle. Rack capacity in the plant is sufficient to allow a 3-hr cure before assembly of the reflectors onto the support structure.

4.2.2.2 Mirror Support Structure

The mirror support structure is fabricated from roll-formed sheet steel sections which are used for the inboard, diagonal, and outboard beams and braces. In addition the mounting area is reinforced with formed doublers and gussets. Prior to welding of the beams, the ends of the diagonal beams are cut and formed in pressing operations. All components are then assembled into the welding machine for spot welding. After welding, the assembly is drilled for the beam mounting bolts and alignment pins and the frame is straightened.

Diagonal Beam

The roll-formed sections for the diagonal beam, received from the metal forming supplier, are loaded into the transfer press. After loading, the beams are automatically transferred through the three stations of the double ended transfer press. The first stage of the press forms the end of the web section. The second stage of the press removes the flange sections of the beam. In the third section, flanges are bent up for the weld attachment to the inboard and outboard beams. The part is then transferred to the unloading section.

Inboard Beam

The inboard beams are received from the supplier with pretrimmed ends and punched for the mounting bolts.

Outboard Beam

The outboard beam is received from the metal-forming supplier precut to length and punched for the mounting bolts. No die forming operations are required in this part.

Doublers and Gussets

These parts are formed from raw stock inplant.

Welding Process

The welding line for the assembly of the mirror support structure is fed by the die line which formed the diagonal beams and in addition lines providing doublers, gussets, and inboard and outboard beams.

A. The doublers and the gussets are welded to the inboard beam.

B. Outboard beams, braces, and diagonal beams are loaded into the line and spot welds are completed at the joints between the diagonal beams, the gussets, the inboard and outboard beams and the braces.

C. The structure assembly is drilled and counterbored for the mounting bolts and dowel pins which are used for assembly to the torque tube.

D. Finally, the structure assembly is straightened.

4.2.2.3 Reflector Assembly

Assembly of the reflector unit consists of bolting the seven mirror module units to the mirror support structure.

Mirror module units are transported to the reflector assembly area and loaded face down on the canting tool.

The module bolts are installed, with the positioning nuts in place.

The support structure is brought overhead, dropped over the bolts, and held with the main beam interface referenced to the mirror alignment plane. The attach nuts are then tightened.

After assembly, the reflector assembly moves down the conveyor to the inspection station. When inspection is complete, the reflector travels upward along the conveyor and travels to the shipping area. In the shipping area, the reflector is removed from the conveyor and put into a shipping rack.

4.2.2.4 Pedestal

The pedestal tube is purchased to the correct length and is sawed only as needed to square the ends for subsequent welding operations. The tube sizing area contains a tube expander station. The station will form the truncated conical sections for the pedestal/foundation joint as well as the upper mounting section for weld mounting of the drive assembly mounting flange. The hydrosizer incorporates wedges which force the tubes radially outward to permanent set diameters. The wedges are fitted with shoes to shape the conical sections of the tubes to fit the outside and inside diameters.

The drive mounting ring and the controller mount hole doubler are fusion welded onto the pedestal tube directly following the sizing operation. The bolt hole pattern for mounting the drive assembly is then drilled followed by the azimuth sensor and controller box hinge attach holes.

The unit is then painted.

4.2.2.5 Main Beam

The critical operations performed on the main beam are welding of the components, the abrasive machining of the two sides to hold parallelism, and drilling of the pivot hole locations, and the structure mounting holes in the ends. Following painting the final operations are insertion of the guide pins and the spherical bearing.

4.2.2.6 Azimuth Drive

The manufacturing processes for the azimuth drive consist of fabrication of the components and assembly.

Components

The components fabricated in the factory are the drive housing, the splines, the wave generator, the drive shaft and the bearing retainer.

The drive housing is fabricated by welding lower housing, bearing sleeve, mounting ring, draw formed upper housing and bearing ring, and motor mounting plate. Machining then provides the bearing installation areas, the flex spline attach holes, the motor mount provisions, and various holes for the expansion chamber, lubrication and site ports, and the lubepan.

The flex spline is fabricated by I.D. honing a purchased deep drawn shell, broaching the teeth on the exterior, and heat treating.

A purchased roll ring is used for the circular spline. The ring is ground to thickness, the wire race bearing groove is ground on the outer diameter, attach holes are drilled and tapped, and the teeth are broached on the inner diameter. The wave generator tube is turned and ground to size, a drive shaft hole and key way are drilled and broached, and the shape is provided by a profile grind. The drive shaft is machined from bar stock received with the inner hole predrilled. The stock is cut to length and machined and threaded. The bearing and wave generator pilot diameters are ground. The key ways are cut with a mill. The bearing retainer is a rolled ring, abrasive machined to size. Attach holes are drilled, and the bearing race is turned on a lathe. The housing, the bearing retainer, and the cover are painted.

Assembly

The flex spline is plug welded to the housing using a centering fixture.

Drive Assembly

The drive housing is assembled on a mobile assembly fixture which enables the assembly to be inverted using locking trunnion supports.

The wire races are installed into the retainer section of the housing and upper retainer by overlapping the ends until the wire diameter can clear the inside retainer diameter surfaces and snapped into the machined race ways. The two wire races for the circular spline are stretched open to clear the outside diameters and also snapped into place. The circular spline with two preassembled wire races is lowered by a handling fixture into position between the flex spline and the housing. The ball bearings are installed between the wire races. The circular spline is further lowered until the ball bearings are in contact with the three wire races. The mobile assembly fixture is transported to the next assembly station for the bearing retainer installation.

The retainer with its wire race and two seals is loaded over the circular spline onto the housing and the shim gap is measured. The spacer shim is then installed between the retainer and housing to enable full seating of the fourth wire bearing and the bolts are torqued to the proper preload. The wave generator and drive shaft assembly is lowered into the unit with a portable electromagnetic chuck. The threaded end of the drive shaft is then captured with a sleeve, allowing the unit to be inverted for the shaft bearing installation. The drive shaft seals, bearing, and support ring are installed. The helicon gear is then assembled into the drive shaft and the counter magnet is installed.

The motor and pinion are assembled into the helicon gear and secured to the motor mount. The lube pan assembly is installed, the expansion chambers are installed, the electrical installation is made, and the unit is again inverted. Oil is added to the upper chamber at the expansion chamber and grease is added to the lower chamber through a grease plug. The control cable and wiring guide are installed on the drive.

4.2.2.7 Elevation/Azimuth Drive Main Beam Pedestal Assembly

The bearings are installed in the elevation support. The elevation support is then assembled onto the azimuth assembly and bolted in place.

The main beam is brought to the station, and the flanges of the beam are then lowered to align with the pivot points of the elevation support, centered, and secured by the mounting pins. The elevation drive is then assembled to the beam and elevation support with the clevis and trunnion pins. The elevation sensors and actuator electrical plugs are mated.

The elevation and azimuth drive assembly is then positioned and lowered onto the pedestal and bolted in place.

The heliostat controller is then installed on the pedestal and the electrical connections to the drive assembly are made.

The azimuth and elevation position sensors are adjusted and operational rotation and continuity are checked.

The drive/main beam/pedestal assembly is then loaded into a shipping pallet.

4.2.3 Manufacturing Analysis

This task involved analysis of the manufacturing process described above to define manufacturing equipment, tooling, fixtures, aids, and supporting material to perform the process. This information is then analyzed for operation rate requirements and manpower to meet the plant volume requirements. The process steps are detailed in sequence lists and equipment layouts to integrate the equipment and manpower into the process flows. The results of this analysis are documented in the tool labor routing sheets. Examples are provided in Volume II. The operation identifying number relates to more detailed operation description sheets. The data from these sheets are summed to determine the factory equipment requirements and the factory direct labor. The results of these activities are provided in Section 6.

4.3 PLANT DESIGN

The plant design consists of a one-view layout of the equipment and area required for performing the previously defined manufacturing processes, and development of storage, staging, and office support requirements. Environment considerations are determined and utility service requirements defined. Finally, the building construction type is determined in conjunction with site location data.

The site location is based on an economic analysis considering geographic area to be served as well as transportation of materials to the plant and product to the user sites. Available land, land costs, and local labor costs are also included in the analysis, as well as the availability of skilled and unskilled labor and supporting industry. A description of the plant design and plant layouts are found in Volume II.

The plant is a single-story design incorporating high and low bay areas. The enclosed area is 260,280 ft^2. It has a slab floor and a steel structure. The plant is air conditioned with humidity control by a 1200-ton unit. It is fully furnished with sprinklers and has waste water treatment. Support equipment is included for arc welding, compressed air, and process water. Plant electrical power requirements are estimated to be 7500 KVA, including the air conditioning.

The total land area required including the staging area and parking lot is 40 acres.

The general area for the site location is Tucson, Arizona.

Section 5

INSTALLATION, OPERATIONS, AND MAINTENANCE SUMMARY

The installation, operations, and maintenance requirements for the 50 MWe field are summarized in this section. The described activity is the basis for the related cost data found in Section 6. The data in this section are an update of material presented in the Detail Design Report. This is primarily based on the experience from building, testing, and installing the prototype units.

5.1 PRODUCTION INSTALLATION AND CHECKOUT CONCEPTUAL DESIGN

Major emphasis has been placed in the heliostat design on low-cost installation and checkout. Extensive factory assembly and prealignment of the drive pedestal assembly and the reflector assembly are the most obvious examples. These two units in their field site delivery configuration are shown in Figure 31.

5.1.1 Installation and Checkout Tasks

The tasks associated with installation and checkout start with a site survey and grading. This is followed by foundation installation and field wiring. Finally the heliostat is installed and checked out for operation. The capability to perform these tasks efficiently is dependent on plant facilities such as power, initially, and control centers, tower-mounted targets, and a BCS in the final checkout stage. The heliostat subsystem installation and checkout include all the tasks up to subsystem readiness to integrate with the other plant subsystems: master control and the receiver.

The site survey and grading functions and the field wiring task are common to all heliostat designs, and a previous data bank is used in assigning costs in these areas. Similarly, the HAC and HFC installation tools are not unique to the Second Generation subsystem design. The remainder of the installation tasks are summarized below.

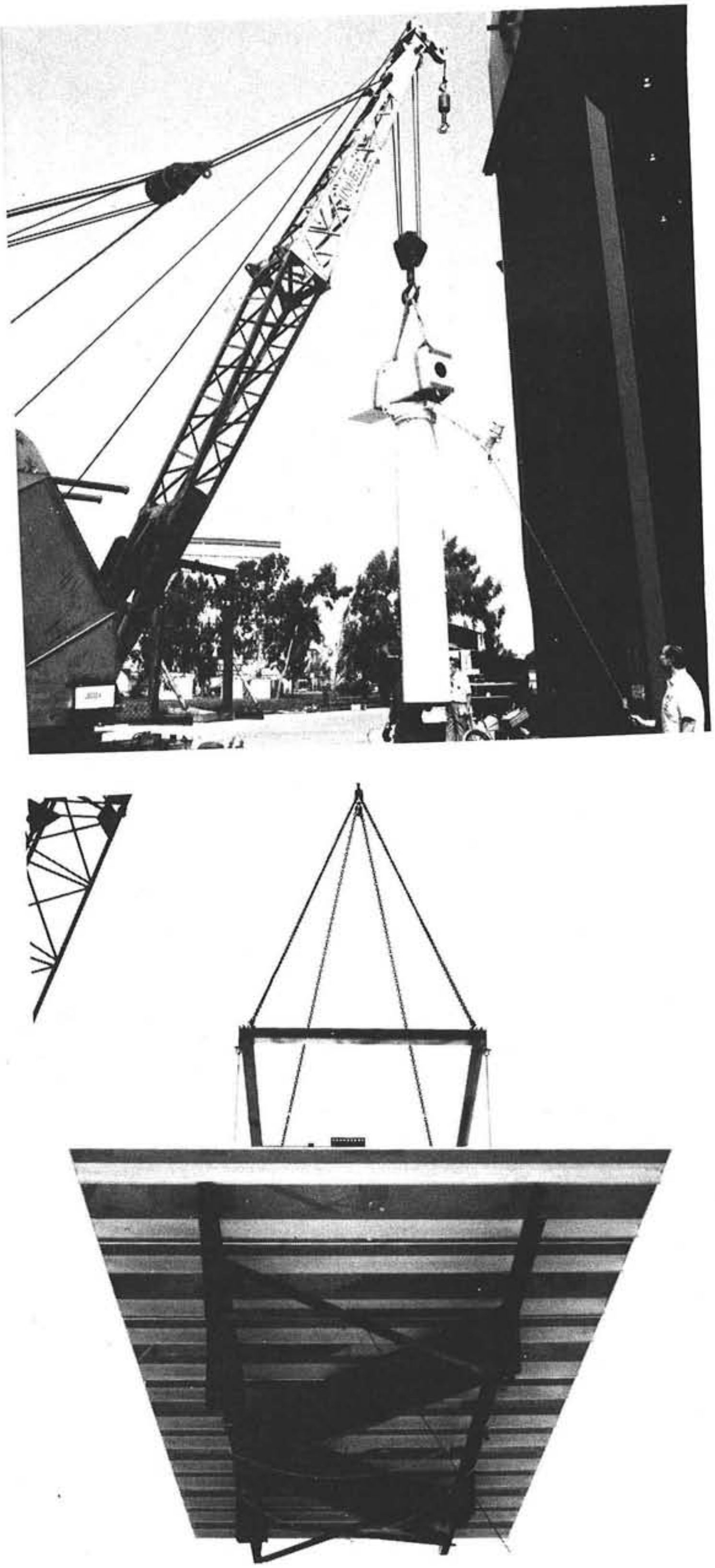


Figure 31. Field Installation Assemblies

5.1.1.1 Foundation Installation

The foundation will be formed in place by drilling holes approximately 2 ft in diameter by 15 ft deep, installing a prefabricated rebar cage with a tapered form, both of which extend approximately 4 ft above grade, and filling the cage and the form with concrete. The rebar cage and the tapered form are welded together at a factory and brought to the site on a standard flatbed vehicle. This assembly also includes the conduit and drain pipes which are plugged at both ends.

This foundation design accommodates most soil conditions. Drilling can be accomplished with the standard equipment. This process, as shown in Figure 32, was accomplished at CRTF in approximately 20 min. The auger is rotated in, lifted out, and unloaded by reverse rotation.

The cone, rebar cage assembly is inserted into the hole, and the cone is leveled with the gradual leveling tool as previously discussed. The


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Figure 32. Foundation Drilling

concrete pour is then made, with a junction box mounting stake inserted into the over pour at grade.

5.1.1.2 Field Wiring

Conduit and drain pipe plugs are removed from the foundation. The field wiring is then threaded in and terminated at a junction box installed at each pedestal and at the field controller and power distribution sites. These will be distributed through at the field based on minimum field wiring lengths.

5.1.1.3 Drive/Pedestal Main Beam Installation

The drive/pedestal main beam assembly is removed from the shipping crate, installed on the foundation, and loaded into place. This operation will be accomplished with installation equipment which performs the setting and the pull-down operations. The engagement of the pedestal with the foundation is greater than 2 ft before interference requiring force is achieved as shown in Figure 33. Consequently, no vertical control is required in this opera-

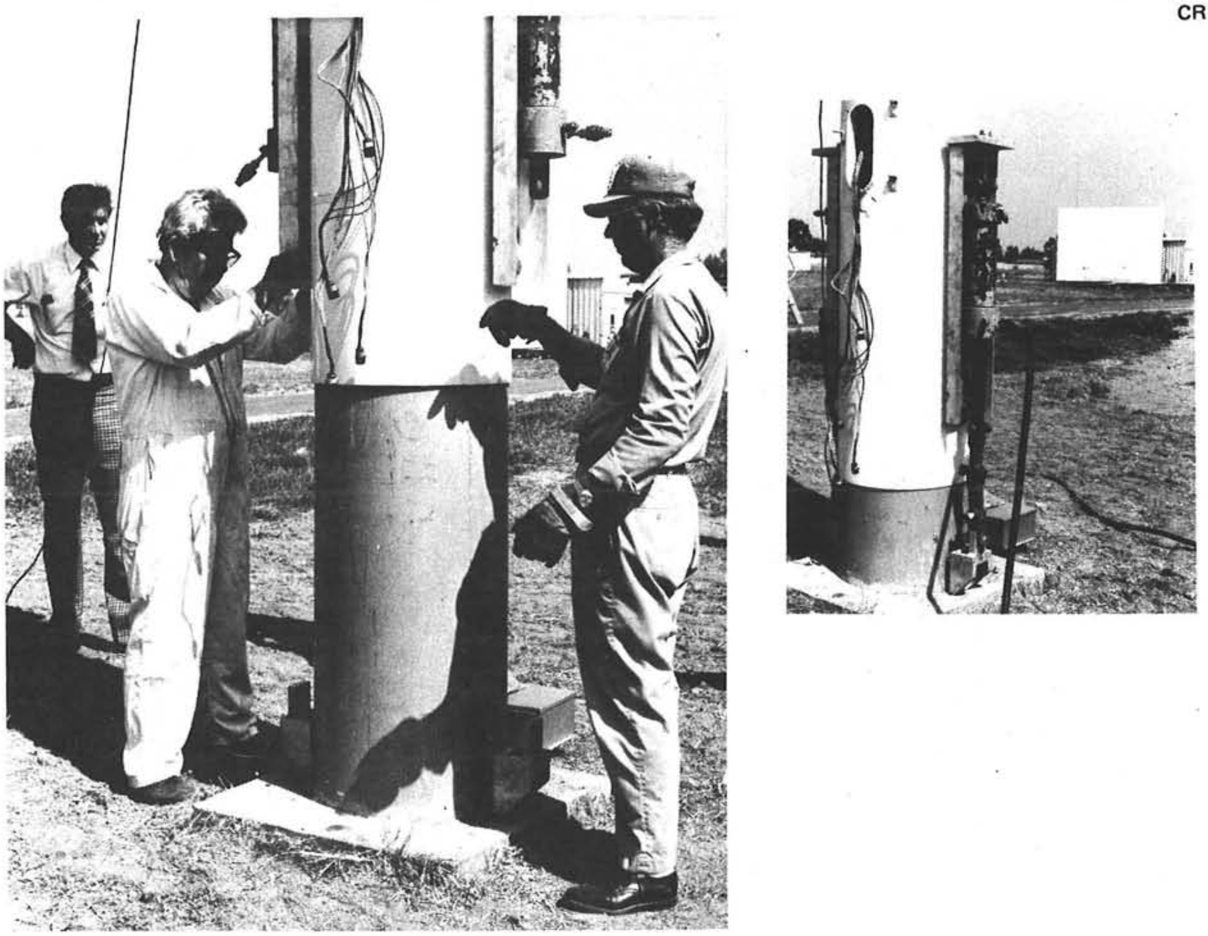

Figure 33. Pedestal Installation

tion. Rotational control within 3 deg is provided by alignment of scribe marks on the foundation cone and the pedestal. Transportation to and from the foundation and insertion are the time-controlling tasks. Pull-down requires less than 1 min.

5.1.1.4 Electrical Connection

The exact sequencing of this task is flexible in that it may be accomplished before or after the reflector assembly installation. However, the logistics of equipment in the field will delay reflector assembly until after pedestal installation equipment clears the field. This task, which does not require large equipment, may therefore be accomplished without impacting the others.

The interface connection task requires pulling the heliostat cable assembly, which is plugged into the heliostat controller, through the conduit in the foundation, and terminating the power and data wires in the junction box.

5.1.1.5 Set Heliostat Address Code

Each heliostat in the field has a unique address for communication which must be set. This task requires opening the heliostat controller box and adjusting the DIP switch mounted on the processor board as shown in Figure 34. The switch is set in accordance with the master field layout plan so that each heliostat address code corresponds with the surveyed coordinates of the heliostat.

5.1.1.6 Reflector Assembly Installation

The reflector assemblies are canted at the factory and identified based on field zone locations. The zones have overlap areas where two different cant configurations may be installed to avoid installation delays.

Installation occurs by removal from the shipping container and emplacement on the main beam interface, and fastened by bolt installation. This is accomplished by a special handling machine. This device was not defined in this study. However, installation times achieved with the preproduction hardware are within the predictions from the prototype heliostat study.

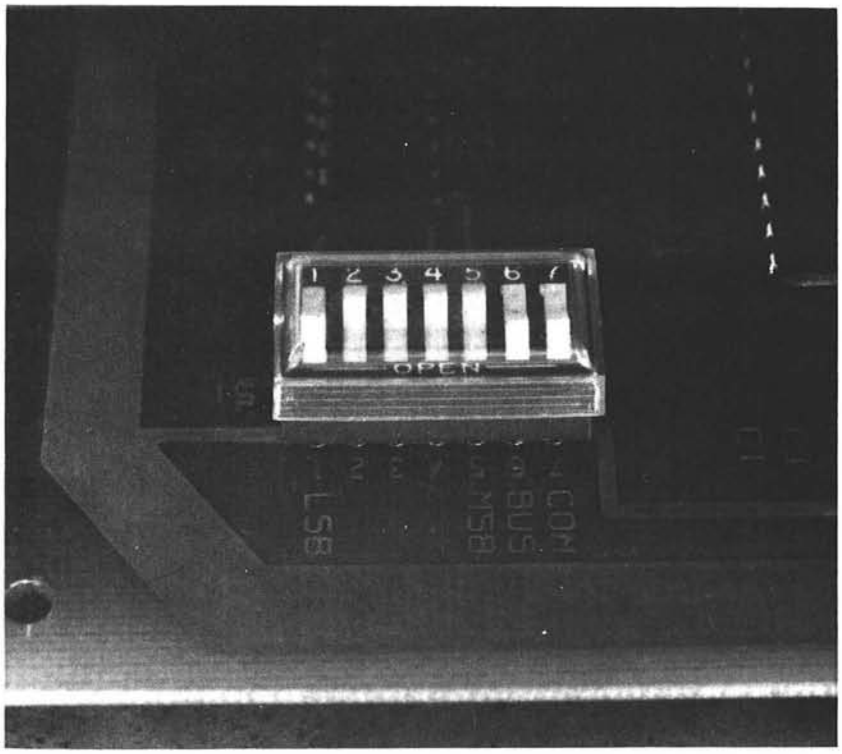

Figure 34. Heliostat Address DIP Switch

Consequently the prototype scenario has been used for this installation in the costing effort. The hardware experience indicates this is a conservative approach.

5.1.1.7 Heliostat Alignment and Check

Once the HAC, HFC, and power distribution system have become operational, heliostat alignment can begin. For a 50 MWe surround field four BCS cameras are available for this operation.

A coarse track alignment is done in order to acquire the BCS target. First the heliostats are commanded to move to the gimbal reference sensors where an estimate of 0.0 is used as the elevation and azimuth reference position. A standby aimpoint is then commanded that is a distance from the BCS target aimpoint. A search mode is used to find the target and acquire the target center. A second estimate is then made of the azimuth and elevation reference position. This estimate is accurate enough for the control system to keep the beam on the target or find the target the next time it is unstowed.

In the final step the beam is put on the target and the BCS is used to take measurements and calculate the beam centroid. This is done at 1/2- to 1-hr intervals from early morning to late afternoon. Using these measurements, the errors in the heliostat orientation are determined. These error terms are then used by the HFC to determine the gimbal position which should be commanded in order to move the beam to the desired aimpoint. Some of the errors which are accommodated are tilt of the foundation, pedestral and azimuth drive, reference errors, position location errors, azimuth drive pivot point errors, and mirror support pivot point errors.

Operational checkout of the heliostats, including proper response to HFC commands, is accomplished as part of the alignment task. This approach is feasible because of the operational checkout each heliostat is subjected to at the factory. A very small percentage of heliostats could exhibit anomalies during alignment; however, the cost savings realized by eliminating a separate checkout task is expected to outweigh the cost of repair of consequential damage.

5.1.2 Resource Requirements

The resources required for installation and checkout are summarized in Table 10 with the associated work conditions. The task sequence and times are shown in Figure 35.

5.2 MAINTENANCE

The two primary aspects of maintenance are the frequency of occurrence and the difficulty of the task. With the exception of mirror washing, which will be required on a periodic, site-dependent basis, there are no planned maintenance tasks for the life of the heliostat -- 30 yr. Maintenance frequency then is a function of the reliability of the hardware. Maintenance task difficulty is an assembly design function which is influenced by the expected frequency of occurrence. The MDAC design approach is structured for failed component replacement, with repair away from the field. This influences maintenance times, down times, and the field maintenance crew skill requirements.

Table 10. Installation and Checkout Resource Allocation (50 MWe Plant)

Task no.	Time/Heliostat	Resource allocation
1. Foundation excavation, iron and concrete	30 min/heliostat	Furnished by Subcontractor
2. Drive unit installation	8 min/heliostat	Pedestal/Drive Assy Installation Equipment
		3 Installation Equipment Operators
		3 Millwrights
		3 Laborers
3. Reflector panel installation	21 min/heliostat	Reflector Panel Assy Installation Equipment
		3 Installation Equipment Operators
		3 Hi-Lift Forklifts
		3 Forklift Operations
		6 Millwrights
		6 Laborers
4. Connect, check, and close out	15 min/heliostat	2 Electricians
		2 Laborers
		2 Test Sets
5. Align heliostat	10 min/heliostat	1 Controls Engineer
		(also requires BCS support)
6. Site support		1 Site Manager
		1 Assistant Site Manager
		1 Material Control
		2 Inspectors
		1 Field Engineer

Conditions:

Installation rate	52/day/site - (4 sites consume plant output)
Labor hours	40/week - 48 weeks/yr
Site locations	Within 400-mile plant radius

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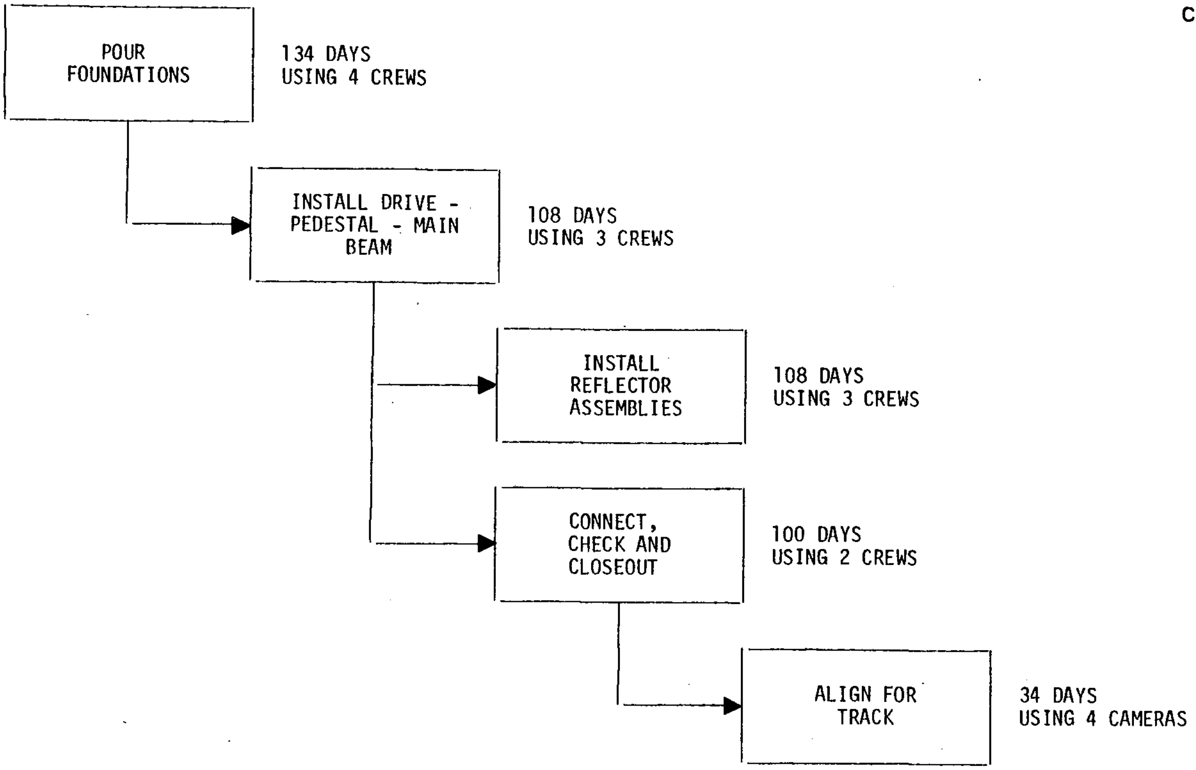

Figure 35. Heliostat Installation Task Flow – 50 MWe Field

5.2.1 Maintenance Requirements

Maintenance activities are categorized as:

A. On-equipment maintenance.

- Removal and replacement of line replaceable items (LRU) identified and the lowest assembly to which replacement will be performed.
- Washing reflectors.
- Minor structure repair.
- Minor electric cable repair.

B. Off-equipment on-site repair.

- Bench repair of LRU.
- Test and recertification of LRU.

C. Off-site repair.

Tasks accomplished at a supplier's facility or a centralized repair facility. Recycle time for LRU is estimated as:

- 1 wk for on-site repair .
- 4 wk for off-site repair.

Most of the Category A tasks for the MDAC heliostat consist of removing and replacing a malfunctioning or discrepant LRU. Some minor repair-in-place activities on the structure and electric wiring items are expected. Maintenance tasks identified as Level A are listed in Table 11, along with their predicted frequency, predicted mean time to repair (MTTR), and estimated man-hour requirements. The quantities shown in Table 11 are the results of calculations using the predicted failure rate, the number of units in the field, the operating time per year and the repair cycle time.

Repairable LRUs, upon failure, are removed from the system, placed in the repair cycle, and subsequently returned to spare stock inventory. Initial spares quantity for these items is the sum of the pipeline quantity and a 30-day contingency supply. The pipeline quantity is equal to the maximum number of items in the repair pipeline at any given time and is based on the failure rate and the repair cycle time. The 30-day contingency quantity is equal to the number of predicted failures in a 30-day period and provides a cushion of the event of delays in repair or delivery, as well as provides for a nonlinear failure rate, over time. The initial spares quantity will be procured and stocked at the appropriate repair location when the first year of operation begins.

The discard factor represents the number of failures which result in the LRU being discarded instead of repaired, primarily due to extensive damage. The product of the total number of failures per year and the discard factor equals the number of replacement LRUs to be procured at the beginning of the second and subsequent years.

Since Categories B and C tasks are similar, except for the repair location, both categories are listed in Table 12. Further overlapping of the two categories is unavoidable because of minor repair may be done onsite, while a major repair or overhaul of the same item is done in an offsite facility. The nature and extent of such overlapping will be determined at each site over a period of time.

Table 11. Annual Predicted Maintenance Summary Failure Rate

					Level A on-equipment maintenance			
Item	FR 10^{-6}/hr	Time	Population	Maint actions	MTTR	Crew size	Man-hours	*Spare qty
Heliostat controller	1.65	3326	5412	29.7	1.3	2	77.2	37
Data distr interface	3.95	3326	18	0.24	1.6	2	0.8	1
Hel. pwr/data cables	0.11	3326	27060	9.9	1.8	2	35.6	14
Field pwr/data cables	0.22	3326	5430 sets	4.0	3.5	2	28.0	7
Pwr. distr. panel	1.5	3326	18	0.09	1.6	2	0.3	8
Mirror module	0.1	7884	75768	59.7	2.0	2.5	298.5	70
El. actuator jack	2.73	3326	5412	49.0	2.2	2	215.6	6
El. drive motor	4.73	3326	5412	85.1	1.9	2	333.4	44
Az. drive motor	4.73	3326	5412	85.1	1.7	2	289.3	44
Incr. encoder	1.35	3326	5412	Included with drive motor				31
Incr. encoder	1.35	3326	5412	Included with drive motor				31
Az. drive	2.94	3326	5412	52.9	4.0	5	1058.0	7
J-box	1.0	3326	5412	18.0	1.6	2	57.6	24
Motor control	1.38	3326	10824	Included with drive motors				59
Pedestal	0.11	7884	5412	4.7	1.0	2	9.4	8
Ref. supt. structure	0.12	7884	10824	10.2	1.5	2	30.6	14
Power transformer	2.0	3326	18	0.1	2.4	3.5	0.9	1
							2435.2	

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*Quantities for discard items (all except elevation jack, azimuth drive and transformer) derived using the Poisson distribution for a 90% probability of having a spare available when needed. Quantities for repairable items based on turnaround time and pipeline requirements.

Table 12. Level B Off-Line Repairs

Component	Location	Annual repairs	Repair man-hours	Annual man-hours	Field quantity
Elevation jack	On site	49.	4.5	220.5	5,412
Azimuth drive	On site	52.9	11.	581.9	5,412
Transformer	Off site	0.1	10.	1.	18
*Drive motors	On site	98.	1.	98.	10,824
			TOTAL	901.4	

*Repair consists of replacement of incremental encoder and motor control. Failed motors are discarded.

Although only washing of heliostats has been specifically identified as a scheduled maintenance task, periodic inspection and equipment certification are required as shown in Table 13.

In the cleaning procedure postulated, two trucks with spray heads move continuously across the field at approximately 1 ft per sec. The lead truck sprays the washing solution on the heliostat as it passes. The second truck lags behind the lead truck to allow for soak time. The lag truck sprays the heliostat with deionized water to rinse off the cleaning solution to complete the task.

The frequency of reflector cleaning is very site-dependent, seasonal, and weather-dependent. MDAC has chosen a 1-month interval for cleaning as perhaps representative of long-term average cleaning rates. The MDAC one-fps spray-soak method has been used for man-hour and cost projections.

5.2.2 Support Equipment

The maintenance support equipment includes special equipment and tools and commercial equipment and tools. Most items in the commercial category should have common usage in the support of heliostat and other subsystem maintenance activities. Special items of equipment and tools are designed by MDAC for specific use during heliostat maintenance.

Table 13. Periodic Inspection and Equipment Certification Requirements

			Scheduled maintenance	
Requirement	Task	Frequency	Task Man-hours	Annual Man-hours
Collector subsystem	Area/corrosion Control Inspection	Annual	360	360
Heliostat reflector	Wash	12/Yr	200	2400
Heliostat array controller and peripherals	Inspect and service	36/Yr	(Service Contract) ROM Cost Estimate $5400	
Lifting slings	Load certification	Annual	8	8
Portable control unit	Calibrate	2/Yr	6	12
Total				2780 man-hours $5400

The support equipment and tools identified for use during Category A, on-equipment maintenance, are listed in Table 14. Shop repair equipment and tools needed to support Category B, off-equipment on-site maintenance, are standard tools considered to be available for general plant maintenance.

5.2.3 Maintenance Features

Certain features of the heliostat provided in the design for fabrication or assembly ease also facilitate maintenance. These features are discussed and illustrated below.

5.2.3.1 Drive Assembly Removal

A lifting fixture installation hole is provided through the top of the main beam, (see Figure 36) and a 6-in. gap is provided between the mirror modules to allow installation of a lifting tool to remove the combined main beam and two mirror module assemblies for removal and replacement of the azimuth drive. The main beam may be disconnected by removing the pivot pins and the elevating actuator clevis pin. Or the elevation support and elevating jack may be left assembled to the main beam by removing four bolts between the elevation support and the azimuth drive.

Table 14. Support Equipment Summary

Item	Use
Commercial items	
1. Mobile crane 10-tons, with standard rigging	Remove and hold heliostat reflector during removal and replacement of azimuth drive.
2. Forklift with hoisting adapter	Remove and replace azimuth drive.
3. Hydra-Set, 2-1/2-tons	Precise positioning of reflector during reinstallation on the azimuth drive.
4. Pickup truck	General.
5. Wyler minilevel	Measurement of mirror module cant angle.
6. Oil injector	Fill drive housing with oil.
Special items	
1. *Portable control unit	Fault isolation and control of an individual heliostat.
2. Service link kit	Stabilize heliostat reflector during removal and replacement of elevation jack.
3. Jack adjustment tool	Set elevation jack extension to a design point for initial track calibration.
4. Clinometer mount	Provide interface between clinometer or minilevel and main beam reference point.
5. Hoisting tool, azimuth drive	Remove and replace azimuth drive.
6. Hoisting tool, reflector/support assembly	Remove and replace reflector/support assembly during azimuth drive change out.
7. Tool, panel leveling	Measure mirror module cant angle. Used in conjunction with Wyler minilevel.
8. Sling, mirror module lifting	Remove and replace mirror module.

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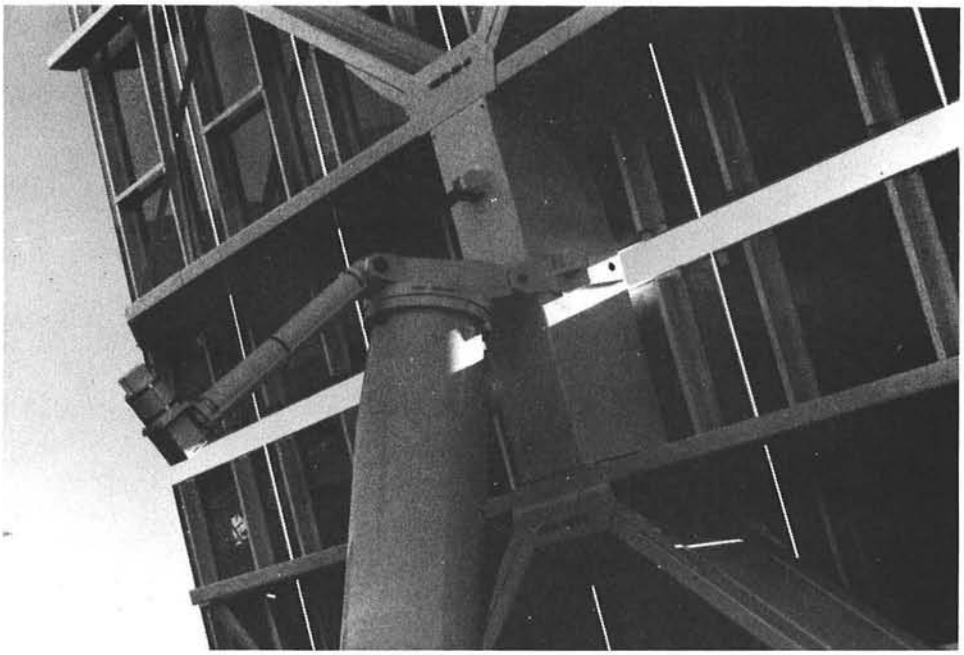

Figure 36. Elevation Jack Removal and Reflector Lifting Pin Hole Access Through the Gap Between the Reflector Assemboies

5.2.3.2 Elevation Drive Removal

The elevation drive may be removed by unscrewing the two trunnion pins at the elevation drive support as shown in Figure 36 and removing the clevis pin.

5.2.3.3 Motor Encoder Assembly

The azimuth and elevation drive motors use identical encoders. The motor is supplied with the encoder and motor wiring feeding one connector. Motor pinion alignment is aided by a guide diameter. These features are shown in Figure 37.

5.2.3.4 Controller

The controller is hinge mounted to the pedestal accessible from the ground without special access equipment. The connectors are enclosed inside the pedestal, they are individually color coded, and each is unique to avoid attachment errors. These features are shown in Figure 38.

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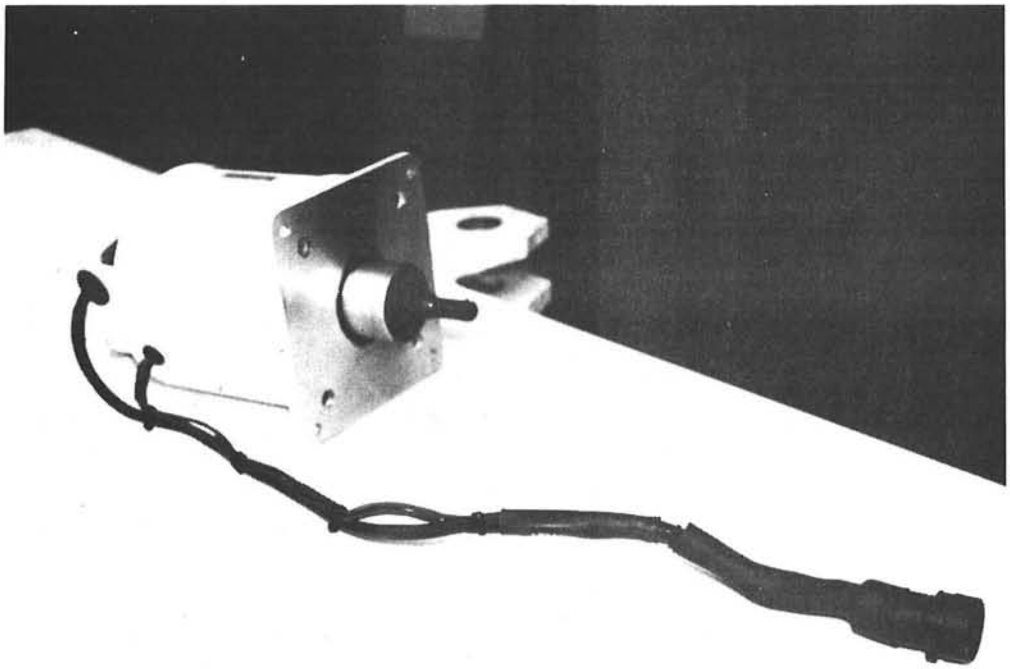

Figure 37. Motor Installation Guide Diameter

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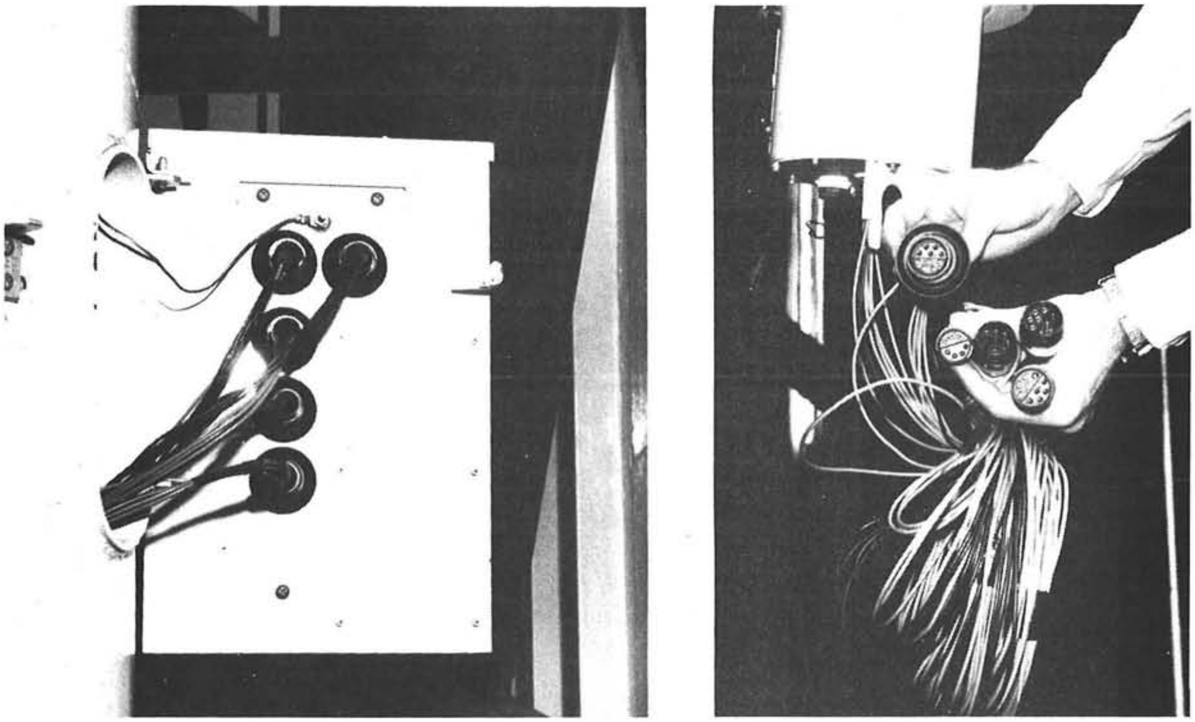

Figure 38. Controller Cabling Interfaces

Section 6

COST ANALYSIS

This section contains the results of the cost analysis of the MDAC Second Generation Heliostat when produced at an annual rate of 50,000 units per year and installed and operated in a field of 5,412 heliostats. The analysis addresses the cost of the manufacturing facility, the installed price of heliostats, and the associated operating and maintenance costs during the first year of operating the heliostat field which collects the energy for a 50 MW_e power plant.

Commercial heliostat costs are based on and reflect the design portrayed in Figure 39 as supported by the technical descriptions and programmatics provided in Sections 1 through 5 of this report. However, this scenario is only one of many possible design/production resource combinations. There is no best and final answer that can survive the scrutiny of continual cost reduction evaluation. The prices that are presented for the particular scenario described in the previous sections do compare favorably to those shown in the Prototype Heliostat Study. This result is reassuring, considering that the study costs were based on a conceptual target design, while the Second Generation results are based on a prototype/test article that has been built and is operational.

This section is initiated with a costing overview. Further details are provided in subsections on production facility costs, installed heliostat costs, and operations and maintenance costs. The appendixes contain in-depth cost and descriptive details.

6.1 COST OVERVIEW

The Second Generation Heliostat provides a working hardware baseline design that projects volume production costs which equate to the DOE target costs. It is well within the expectations of an ongoing design-to-cost/cost-reduction program that the target will be maintained or surpassed as costs are

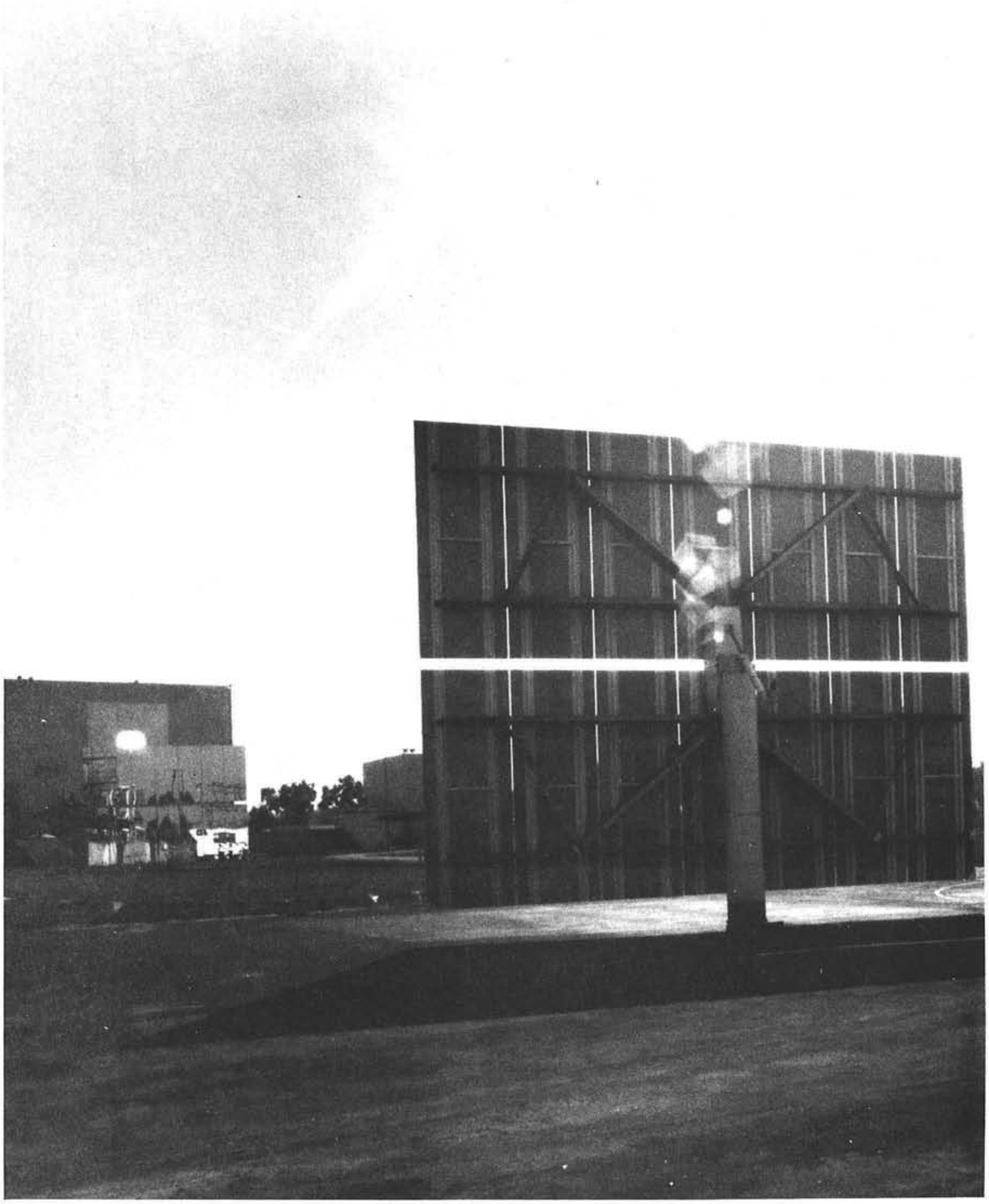

Figure 39. McDonnell Douglas Second Generation Heliostat

competitively driven down from the Second Generation baseline. The following overview summarizes the price and cost projections at various stages of production, provides a comparison between current and prior cost projections, and touches on the basic scenarios and costing approaches used in developing the projections.

6.1.1 Pricing Results

Summarized pricing results for the studied production rates are shown in Table 15 in terms of first half 1980 dollars per square meter: Heliostat investment prices represent those that may be charged during the tenth full year of production facility operation under a strategy of pricing at a fixed percentage margin over each year's cash expenditures. These results are associated with both the design depicted in Figure 39 and a specific production scenario conceived and costed by General Motors and the F. Jos Lamb Company in order to produce 50,000 heliostats per year. The transportation and installation scenario is based on the analysis accomplished on the Prototype Heliostat contract.

Table 15. Second Generation Heliostat Subsystem Prices

	Average $/m^2 (1980$)		
Price element	25K/ year	50K/ year	67.5K/ year
Installed heliostat price	$ 99.60	$ 87.90	$ 84.20
50 MWe plant related (5412 heliostats):			
Heliostat array controller (plant control)	$ 0.40	$ 0.40	$ 0.40
Maintenance equipment	$ 1.14	$ 1.14	$ 1.14
Initial spares	$ 0.14	$ 0.14	$ 0.14
O&M - 1st year	$ 1.32	$ 1.32	$ 1.32
- Follow-on	$ 0.91	$ 0.91	$ 0.91

The installed heliostat price assumes an average transportation distance of 288 miles, round trip. This is based on a weighted average of expectations considering an eventual optimal location of the factory within the concentration of demand. If an average round trip of 566 miles (283 one way) is used, reflecting full area weighting of a 400-mile radius, the price at 50K/yr would increase $3.85 per square meter.

The alternate prices shown represent what may be charged were the baseline production facility, costing 88 million dollars, operated at 50% and 135% of designed capacity. Operation at 50% of capacity is very inefficient, and a lower price may be expected in a facility specifically designed for 25,000 per year. The overcapacity scenario is accomplished by operating certain critical production lines on extended shifts and weekends, plant control, maintenance equipment, and operations and maintenance are costs that are associated with a field of 5412 heliostats. These prices would decrease with larger fields and may increase somewhat with smaller fields. However, these elements may be provided as a service, and the costs shared by several users where field sizes become small enough that the costs would otherwise be burdensome.

6.1.1.1 Prices Versus Cumulative Production Volume

The prices shown in Table 15 suggest what may be expected during a specific era of production. However, prices may continually change from year to year with the first year or two exhibiting higher prices, if only because of the less efficient use of capacity while the factory is coming up to rate production. Figure 40 shows the impact of a pricing policy which

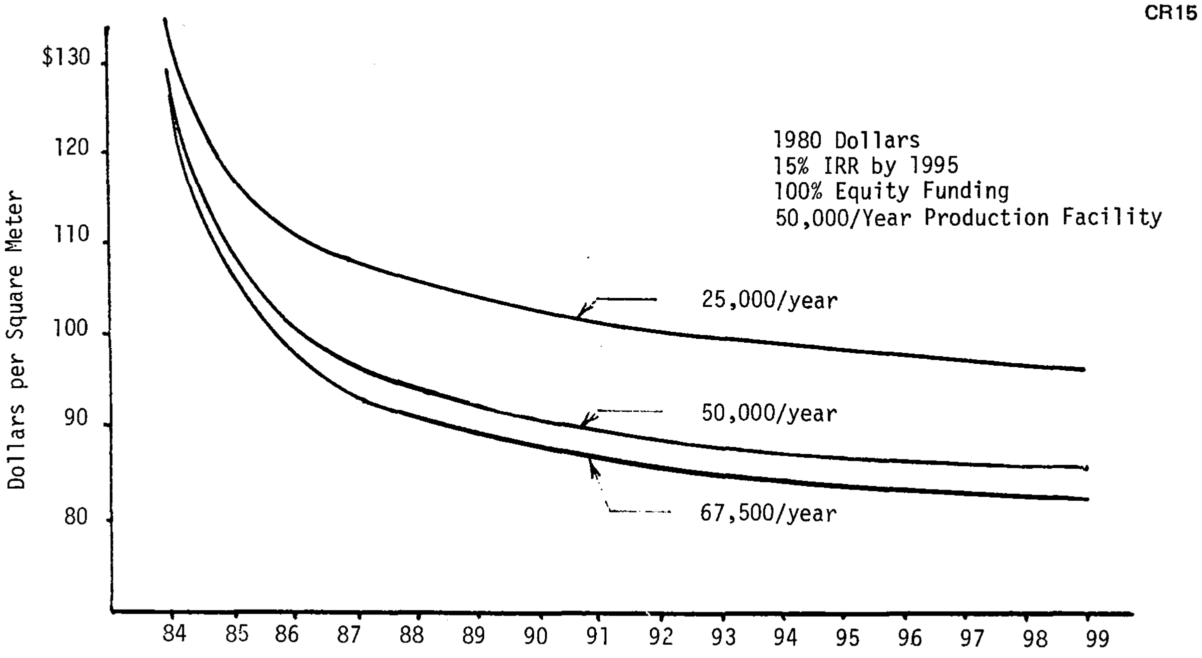

Figure 40. Installed Heliostat Price by Year

allows a 15% internal rate of return (IRR) by the end of the tenth full year (1995), and 18% or more by 1999. The upper and lower curves cover the under- and over-capacity situations.

The yearly price, shown in the figure, is that which would be charged under an annual repricing policy. Except for the 25,000 per year case, the price changes shown are based on only 10,000 and 35,000 units of production in 1984 (6 months operation) and 1985, respectively. Production is at rate in 1986 and thereafter. For the 25,000 per year case, rate production is reached in 1985. Reductions in price occur due to improved utilization of capital and capacity especially in the early years, improving supplier relationships, and industrial and manufacturing engineering efforts. The degree of reduction shown reflects conservative expectations and does not consider the potential, additional impact of an aggressive cost reduction program.

Risk tolerances and associated pricing approaches will vary with the producer, and numerous financial goals are possible. Each producer must project and consider many variables that influence their pricing, including:

- Market characteristics.
- The success of cost reduction programs.
- The evolution of heliostat design requirements.
- Aggressiveness of competition.
- Financial constraints or policy.
- Approach to stimulating a market.
- Special incentives.
- Production capabilities and capacity utilization.

The various possible perceptions of these inputs suggest a wide range of potential prices over time depending on the characteristics of the producer.

6.1.1.2 Costing Results

Table 16 shows a further breakdown of the costs that have been developed. The drive and reflective unit still account for the greatest costs, being 34 and 38%, respectively, of the total. The drive actually includes the drive, pedestal, main beam and pedestal/drive electrical. Factory costs are

Table 16. Second Generation Cost Breakdown

(1980 Dollars - 50,000/Year Rate - 10TH Year - 5412 Heliostats/Field)

Cost element	Cost per Heliostat	$/m^2
Heliostat investment		
Reflective unit	$1,648.00	$ 28.98
Drive unit	1,837.00	32.32
Control/instrumentation	191.00	3.36
Foundation/site preparation	569.00	10.00
Heliostat support structure	158.00	2.78
Field assembly and checkout	168.00	2.95
Transportation	237.00	4.17
Total	$4,808.00	$ 84.56
Plant control (HAC)	$ 22.00	$ 0.38
Initial spares	$ 8.00	$ 0.14
Maintenance equipment		
Handling equipment	$ 26.00	$ 0.46
Tools and calibration	7.00	0.12
Washing equipment	32.00	0.56
Total	$ 65.00	$ 1.14
Operations and maintenance		
Spares	$ 6.79	$ 0.12
Repair parts	1.62	0.03
Other	19.36	0.34
Corrective maintenance	31.92	0.56
Scheduled maintenance	15.52	0.27
Total	$ 75.21	$ 1.32
Follow-On	$ 57.78	$ 1.02
Memo: Factory Cost		
Plant and land	$ 36.8M	
Equipment	42.9	
Tools	8.2	
	$ 87.9M	

already included in the dollars per heliostat numbers, but are shown for reference. These costs and all the backup details shown in the following subsections and in Appendix D3 cover the 494,000th unit, which is produced in 1995.

These projections are considerably lower than the costs projected for the MDAC Barstow heliostat, as well as those actually being experienced at Barstow. An analysis has been performed comparing the 50,000 per year costs with pricing projections for the Second Generation design produced in a low-volume facility, and virtually all of the difference in cost has been specifically identified with justifiable causes. Over 90% of the reduction is due to mechanization, both through direct reduction of task times for activities performed within a low-volume facility and because of material cost reduction caused where major purchased parts and assemblies are brought in-house, thereby replacing a high purchase part cost with a much lower cost for raw material, amortized equipment and tools, and very little labor. Just six assemblies account for over 85% of such material cost reduction. The remaining 10% of the overall reduction is due to changes in field methods, an advanced electronics concept, and some minor production design changes.

6.1.2 Comparison with Prior Study Results

Table 17 compares the pricing results developed for the last several commercial Heliostat Evaluation Studies. All costs have been adjusted to 1980 dollars at an annual inflation rate of 9.4%. The column labeled PDR shows updated data that was presented in the May 1977 Preliminary Design Report (PDR) for the Central Receiver System. The costs are significant because they are a commercialization study of a working heliostat design--that is, the heliostat Subsystem Research Experiment. The study was accomplished with the assistance of Stearns-Roger and A. D. Little, as was the MDAC analysis of the Prototype Heliostat.

The Prototype Study determined a feasible commercial heliostat design, a production method and the associated production costs. Battelle and General Motors restudied the MDC Prototype design under contracts to the Solar Energy Research Institute and determined revised production methods and the costs shown in the other Prototype columns of Table 17. Although the differences

Table 17. Comparison With Previous Results
(1980 Dollars/m^2)

Element	PDR MDAC	Prototype Study (25K/Year)			2nd Gen MDAC/GM
		MDAC	Battelle	GM	
Reflector unit	$ 24.81	$20.58		$ 36.00	$29.05
Drive unit	45.49	30.43	$77.42	61.70	32.40
Control and instrumentation	6.07	2.64		4.30	3.37
Heliostat support	4.51	3.18		8.30	2.79
Foundation and site	11.65	14.20			10.02
Field assembly and checkout	22.36	3.67	16.50	16.50	2.96
Transportation		.82			4.18
Site plant activation	2.63				
Subtotal	$117.52	$75.52	$93.92	$126.80	$84.76
Scrap and rework		3.78	3.00	3.20	2.94
Total installed price	$117.52	$79.30	$96.92	$130.00	$87.90
Annual operations					
First year		$ 1.36			$ 1.32
Average	$ 2.31	0.76			1.02
Date of study	May 77	Aug 78	Oct 79	Dec 79	Jan 81

appear substantial, a reconciliation of the results indicate that all three studies substantiate each other.

6.1.2.1 Installed Heliostat Comparison

Almost all of the cost difference between the MDAC and Battelle prices are accounted for in the cost of the fusion glass and the screw jacks. The fusion glass cost difference is due to concern at the time about the cost impact of potential glass factory modifications which have since been resolved. MDAC's jack costs are based on what was a proprietary design at the time of Battelle's study so that quotes were not available. However, the costs had been verified in writing to MDAC by the manufacturer.

Table 18 shows a reconciliation between GM and MDAC costs. The fusion glass cost difference is due to the same concern over glass factory modifications. Also, MDAC integrated a mirror line in its reflector assembly line. In the Second Generation scenario, the line is integrated at the glass plant. The differences in steel costs are mainly due to difference in the make/buy scenario which had an impact similar to that just discussed in the cost subsection. The GM cost for electronics and electrical provides a more accurate representation of currently desired component quality and has been incorporated in the Second Generation costs. Differences in burden are mainly due

Table 18. Prototype Study Heliostat Reconciliation GM to MDAC

(1980 Dollars)

Element	Amount	Comment
MDAC Cost	\$ 79.30/m^2	
Labor	(0.40)	Make/Buy Scenario
Material		
Mirror	10.00	Fusion glass and mirror line
Steel	19.00	Purchase parts verses raw material/make
Electronics/Electrical	6.10	Added connectors and quality
Miscellaneous	0.40	
Subtotal		
Burden		
Taxes and depreciation	8.57	2nd verses 10th year of depreciation
Fringe benefits	1.16	Rate variance
Other	3.37	Rate variance
Subtotal	\$ 13.10	
Profit margin	2.50	Higher base
Total requirements	\$ 50.70	
GM cost	\$130.00/m^2	

to depreciation accounting differences and fringe benefit experience. However, MDAC's experience is with higher labor content manufacturing facilities, and hence, lower burden rates. MDAC did not make a special overhead study, and the GM fringe and other burden may be more appropriate. Since GM's costs were higher, the profit margin is also greater.

Based on the reconciliation analysis, the MDAC Prototype Study cost should be increased to reflect a more appropriate overhead rate before comparing Second Generation and Prototype Study costs. In addition, the upgraded electronics and electrical should be considered, as well as differences in the assumed distance from factory to installation site. On the other hand, foundations have been resized for Second Generation and the Prototype Study would also benefit from a redesign.

These adjustments are shown in Table 19. The table also shows a potential reduction in Second Generation cost relating to elimination of metal edge seals and shims which were not part of the Prototype Study design. A significant amount of other hardware and design safety has been added to the Second

Table 19. Price Adjustment Second Generation and Prototype Study

(1980 Dollars)

Elements	Price/m^2
Prototype Study	$79.30
Add burden	4.53
Subtotal	$83.83
Add - E&E upgrade	6.10
- Transportation	3.37
Less- Foundation size	(3.30)
Adjusted prototype	$90.00
Second Generation Study	$87.90
Less- Edge seals and shims	(3.80)
Adjusted Second Generation	$84.10

Generation test article in order to assure performance. This hardware has been carried into the commercial cost. Design refinement in these areas offers a potential for further cost reduction as confidence is gained. Comparison of the adjusted prices shown in Table 19 foretells this circumstance because as significant as the difference may seem, it falls far short of the full theoretical potential of the cost reduction design changes made during the Second Generation Heliostat study.

6.1.2.2 Installed Price Relative to the Prototype Study Price/Volume Curve

The Prototype Heliostat final report published a curve showing dollars per meter square, reflectivity ($\$/m^2R$), versus cumulative production volume. Based on the forgoing discussion, that curve has been normalized, adjusted for inflation, and related to projected $\$/m^2R$ for the Second Generation Hardware. Figure 41 indicates the progressive rational and impact of the adjustment procedure.

Figure 42 shows the fully adjusted curve with the Second Generation price per m^2R of $95.50 superimposed over the area of the 494,000th unit. The range shown for this figure of merit includes the currently visible, potential cost reductions that are listed on the chart. This is by no means the total list of possible reductions that may become apparent as the program evolves. The Second Generation overlay falls well within the revised curve, and a portion of the visible potential reduction would overlap the original curve were it adjusted for nothing more than inflation. Indeed, the results of the study do not eliminate the possibility that the Second Generation projections are still part of the original probability population.

6.1.2.3 Operation and Maintenance Comparison

The average annual operation and maintenance (O&M) comparison costs provide a most direct comparison of operation and maintenance because of the impact of the upgraded electronic components on the first-year costs. The average Second Generation heliostat O&M costs are 34% greater than those shown in the Prototype study. Eighty-seven percent of the difference is accounted for in three areas--maintenance of service equipment, fuel for service equipment, and washing time per heliostat. The maintenance of service equipment was assumed included in the maintenance labor rates in the Prototype study,

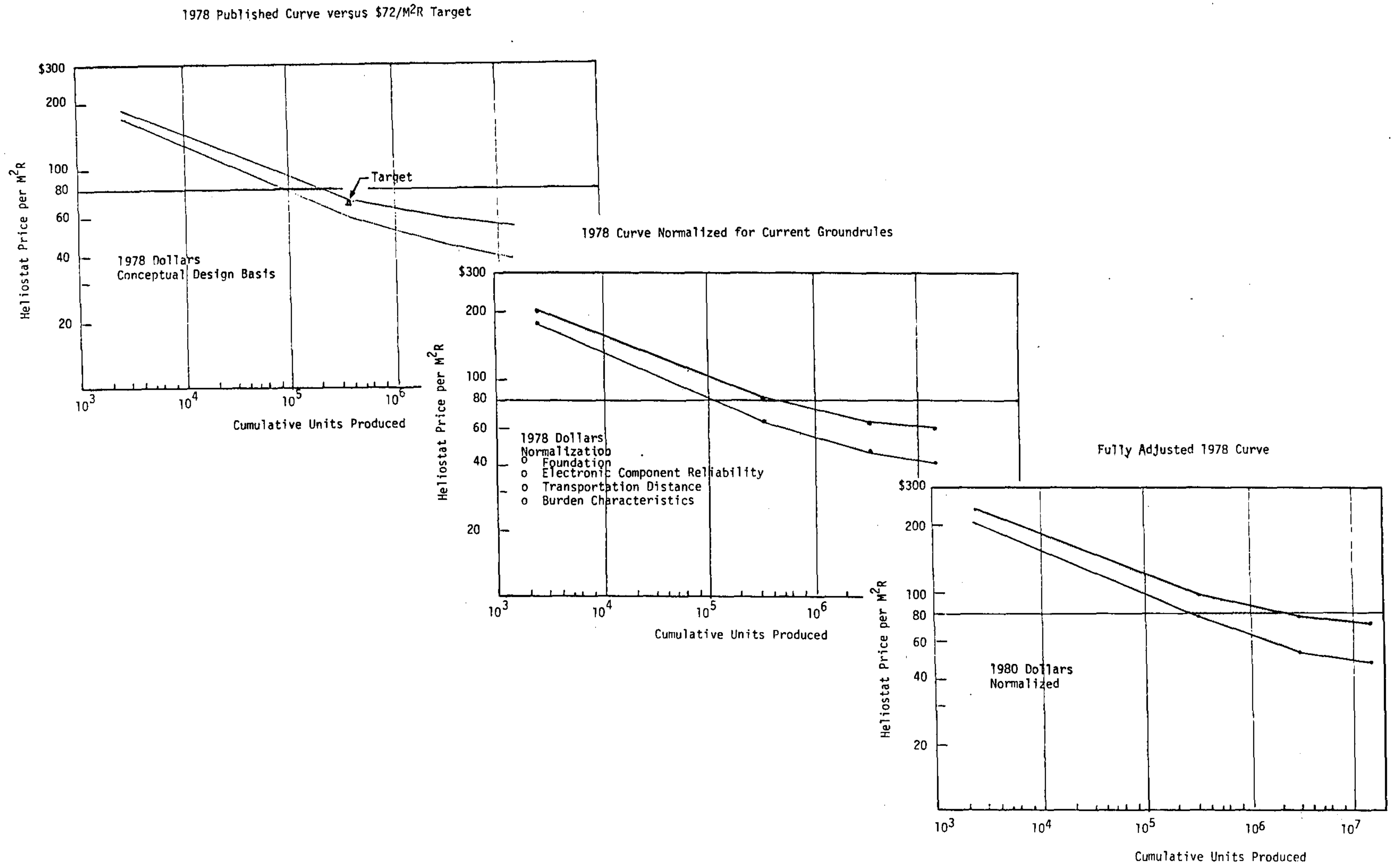

Figure 41. 1978 Curve Adjustment

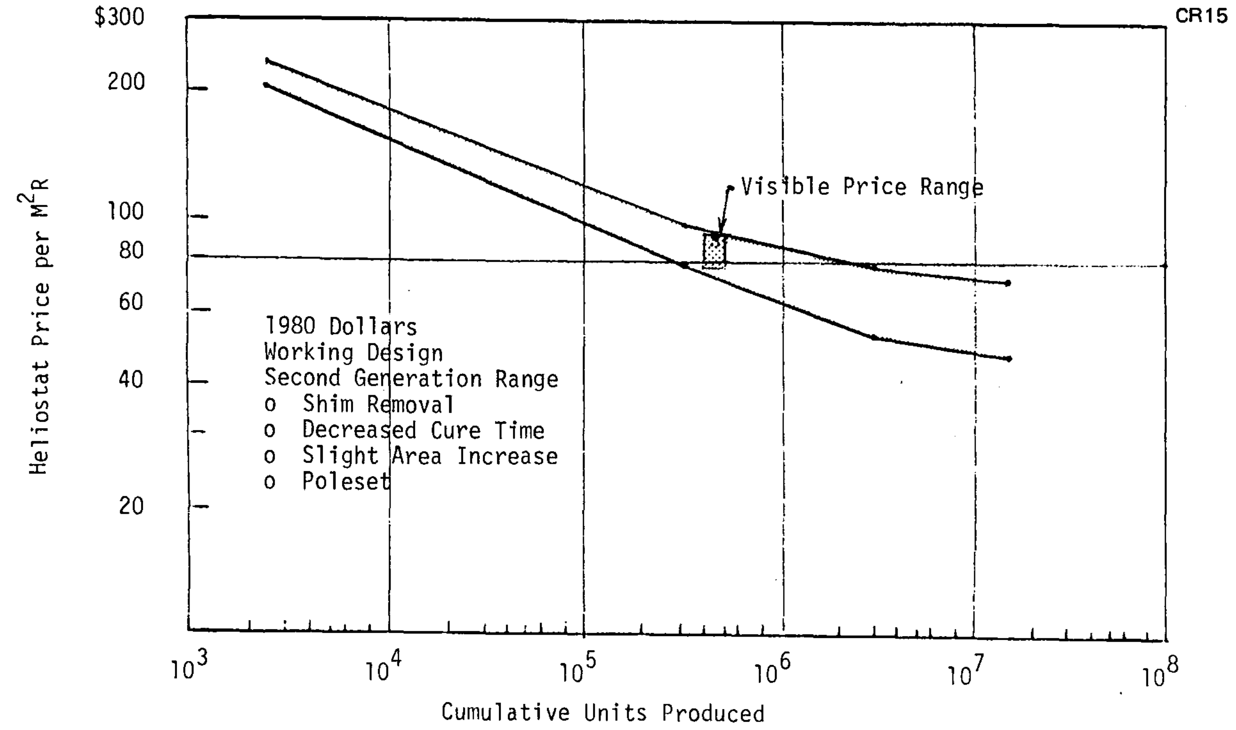

Figure 42. Inflated and Normalized Curve versus Second Generation Price

but has been added as a direct cost for Second Generation; it amounts to almost 22% of the total difference. Fuel costs have escalated greater than general inflation, and based on MDAC's heliostat washing study, more fuel is required. The fuel cost difference accounts for approximately 22% of the total additional cost. Washing time per heliostat increased due to increased size and field layout changes, accounting for 42% of the change. The remaining 13% of the difference is caused by numerous small changes in failure rates, hours required for repair, and increased hardware quantities per heliostat.

6.1.3 Factors that Influence Cost

As indicated, the Second Generation Heliostat projections are based on a specific set of cost-driving ground rules and assumptions, design characteristics, and production and installation scenarios. Although covered in detail in previous sections of this report, a summary of the major drivers is useful in understanding costing results.

6.1.3.1 Major Costing Ground Rules

The costs that are presented assume the following major ground rules:

A. April 1980 dollars, but produced and installed in mid-1980's to late 1990 time frame.

B. Cost Breakdown Structure (CBS)

1. Sandia advanced systems CBS (same as for Prototype Study)
2. Parts, drawing, vendor or cost identification number at lower levels.

C. Factors

1. Installation and O&M - Prototype Study.
2. Factory (direct, support, overhead) - relate to GM inputs. Depreciation to be adjusted to straight line.

D. No site assembly facility, and use of Prototype Study installation equipment and a centralized, near-site rebar cage assembly facility.

E. 5412 heliostats per field with Prototype Study ratio of Data Distribution Interfaces and transformers to heliostats.

F. Field layout for electrical from Prototype Study, but consider impact of heliostat size.

G. Prototype Study electronics concept. Adjust from commercial parts to commercial parts inspected to mil standards, and in accordance with the SERI/GM analysis which added some hardware left out of the Prototype Study analysis. Interface with Second Generation configuration at the controller box.

H. No land or specific site grading cost.

I. Land area - 1.268 km^2.

J. Factory labor rates provided by GM-- 7-state average.

K. Site rates based on Barstow/Riverside Trade Union contracts.

l. Utility O&M rate assumed at $18/hr.

M. Private and specially equipped fleet employed during construction to ship from factory to site.

N. Common carrier assumed for spares and repair parts transport.

O. 50 MWe plant costs cover a plant built in the 10th full year after IOC of the 50,000 heliostat per year production facility.

P. Fee calculated to allow a 15% internal rate of return to the heliostat vendor at end of the 10th year.

Q. Costs exclude interest during construction (IDC) of electric power plant.

R. State sales tax excluded due to uncertainty of potential tax rulings and variation between states.

S. Cost reduction methodology applied to represent normal expectations in a going factory where baseline costs have been developed using studied resource loads as follows:

1. Material Ta 325,000 - CRC 95%
2. Factory labor Tu 50,000 - CRC 94%
3. Site Labor Tu 25,000 - CRC 98%

T. Special collector profit center.

U. Installation and O&M baselined from "Prototype" but adjusted to reflect later data where available.

V. First production: June 1984. Rate production: June 1985

W. Average distance factory to site - 288 miles round trip.

X. Bench labor performed at Electrical Plant.

6.1.3.2 Technical Characteristics

Table 20 summarizes the technical characteristics of the design. A weight statement is provided in Appendix D-2. Key top-level cost factors include the 1.27:1 aspect ratio and enlarged reflector area (57 m^2) that has been divided into two main panels for ease of transport and installation; non-inverting stowage which is accomplished with a single screwjack; the inverted harmonic azimuth drive; and the factory integrated drive/pedestal/electronics/main beam assembly which may be checked and calibrated in the factory. Other important factors include the deep pile foundation which features a 1.17-m above-grade tapered pipe interface extension; the use of a stamping/weldment for the drive housing; and the stringer/semiradial beam mirror backing structure configuration. These design characteristics generally allow a relatively simply production and installation scenario as well as favorable purchased part and material economics.

6.1.3.3 Baseline Scenarios

Main features of the baseline production/installation scenario are listed below.

A. 50,000 units per year.

B. 260,000 ft^2 production facility (no site assembly plant).

Table 20. Technical Description - Collector Subsystem

Reflector - 7 laminated reflector mirrors bolted to the reflector support structure - 1.27:1 aspect ratio	
Reflective surface	
Reflective surface area	56.856 m^2 (612 ft^2)
Mirror	1.5 mm (0.059 in.) Fusion Glass
Back lite	4.78 mm (0.188 in.) Float Glass
Reflector support structure	
Inboard cross beam - 14 gage	324.5 in. - 18.75 in. Deep
Outboard cross beam - 14 gage	324.5 in. - 8 in. Deep
Diagonal beams - 12 gage	121.5 in. - 18.75 in. Deep
Angles	2 in. x 2 in. x 1/8 in.
Drive - Consists of a rotary drive, a single jack elevation drive, main beam, and pedestal.	
Center main beam	
Rectangular tube	16 in. Wide x 18 in. Deep
Elevation drive	
Jack	Ball Screw (51.25 in.)
Motor	1/3 HP, 208 VAC
Motor controller (1)	
Support structure	(123.4 Lb)
Azimuth drive	
Drive unit	
Helicon input	162:1
Harmonic input	267:1
Final drive ratio	43,254:1
Motor	1/4 HP; 208 VAC
Motor controller (1)	
Pedestal (circular)	139 in. (Taper, 0.140 in./ft^2)
Power distribution equipment & wiring	4160 VAC, 3 Phase
Stepdown transformers	480 VAC, 3 Phase

Table 20. Technical Description - Collector Subsystem (Continued)

Position indicators	
Incremental encoder - motor turn feedback	Hall effect
Sensors (5) - reference point detection	Magnetic
Control/instrumentation equipment	
Heliostat array controller	PDP 11/34 (128K bytes)
Data distribution interface	DDI-to-HC ratio 315:1 8085 CPU
Heliostat controller	Nonvolatile memory 8049 ROM
Signal distribution equipment	
Foundation	
Concrete (approx)	24 in. Dia. x 15.8 ft Long
Steel reinforcement with steel from (approx)	21.25 in. Dia. x 19 ft Long

1. Central, southwestern location (Tuscon Model).
2. Integrated mirror module line and support structure fabrication.
3. Automated assembly/transfer.
4. Overhead monorial.
5. NC machining.

C. 452,000 ft^2 outdoor staging area.
D. Industrial average skill labor -- less than 400 factory direct.
E. Private fleet transportation to site - reusable racks.
F. Four basic installations - mechanized using special equipment.
   1. Foundation
   2. Pedestal/drive/electronic unit
   3. Reflector panels
   4. Power/control distribution
G. Two shift factory operation (240 days)

Changes that could have a cost reduction effect in the future would include the following:

- Improved line flow.
- Integration and/or more direct control of specialized facilities.
- Increased supplies and services control.
- Production design evolution, for example:
  - Increase output rate.
  - Reduced cure racks and area.
  - Elimination of autoclaves and area.
  - Elimination of shim equipment and area.
  - Elimination of edge seal equipment and area.
  - Reduction of assembled components.
- Expansion of capacity
- Optimized facility location.

The operations and maintenance scenario calls for the use of conventional handling equipment, and special mirror washing equipment. In most cases, defective assemblies or components are first removed and replaced with a spare or a previously repaired part and then the defective item repaired or scrapped. The main exceptions occur where certain structural damage may be repaired in place. The preponderance of maintenance actions involve repairs at high assembly levels but the scrapping of defective hardware at lower component levels.

6.1.4 Costing Approach

Figure 43 indicates the overall approach to production costing which has been to develop a data base associated with the 50,000 units per year production rate and then perturb the data base to reflect special circumstances associated with the other production volumes. The 50,000 unit data base has been developed as resource loads for labor where operator and support positions required for each item of production equipment or responsibilities are counted and classified by skill in order to accumulate staffing by CBS. Vendor quotes and major supplier agreements at ongoing 50,000 units per year requirements were obtained for important cost items and catalogs consulted for common items.

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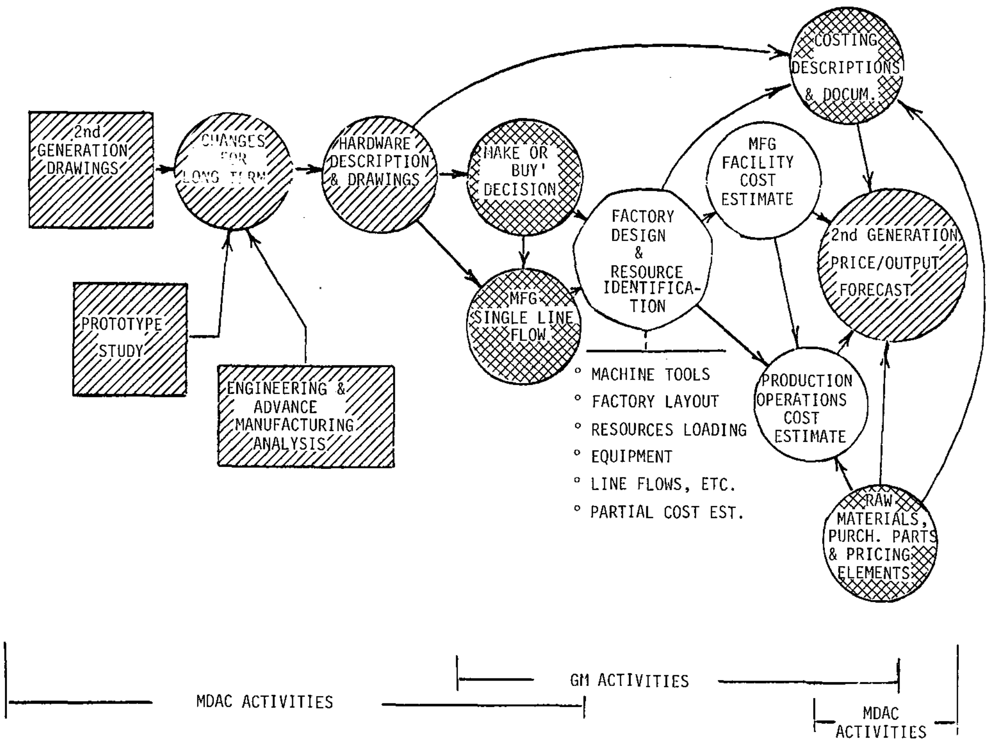

Figure 43. Heliostat Factory Price Methodology

Like-item costs were employed where certain electronic components have been projected as being available off the shelf at future dates. Burden has been determined specifically for the production facility. Appropriate factors have been applied to the data base and labor rates to arrive at total costs. Operation and maintenance cost parameters are related to failure rates and failure modes and effects analysis or required scheduled maintenance frequencies in order to arrive at annual costs.

Costs not specifically addressed at the reported volume were altered along a cost reduction curve. Each basic cost entry has been "pegged" to a specific point on a cost reduction curve. Where an item cost change associated with a new production rate is identified, the cost is repegged at its new point on the curve and the curve has no affect. Otherwise, the cost is adjusted in accordance with cost reduction curve logic to a new estimate for the new production rate. Specifics on cost reduction curve logic as well as factors, labor rates, and other cost methodology are treated in more detail in the subsections that follow.

6.2 PRODUCTION FACILITIES

The production facilities have been conceived to provide the required quality and quantity of heliostats for a near-minimum expenditure in direct labor by taking advantage of the productive leverage of capital. The facility also allows a relatively high level of heliostat assembly and test in order to limit the amount of such activities that must be accomplished in the field. This subsection further describes the facility in terms of cost and cost drivers.

6.2.1 Summary of Costing Scenario

The facility and facility operations costs cover the expenditure of resources in the tenth full year of operation of a facility geared to output 50,000 heliostats per year on a two shift basis. The plant is located in the southwest and contains 260,000 ft^2 and provides an additional 450,000 ft^2 of staging area outside the plant. The plant utilizes the following typical purchased parts and raw materials:

- Mirrors
- Pedestal tube
- Rolled steel sections
- Glass back light
- Steel stock and stampings
- Motors
- Small drive parts
- Packaging material
- Controllers
- Screwjacks
- Cable and wire
- Sensor components
- Adhesives
- Chemicals
- Miscellaneous hardware
- Paint

These elements are integrated by the production flow shown in Figure 44, and Figure 45 shows the plant layout indicating the relative locations of the costed equipment and tools as well as an indication of the mechanized nature of the facility.

In addition to the production facility analysis, special supply investigations have been performed for several key purchased components including mirrors, screwjacks, rolled steel sections, steel stampings and controllers. The only unusual arrangement involves the mirroring which will be accomplished by Binswanger Mirror Products in a special line installed at the end of an added fusion glass line, also, to be installed at the Corning Glass Works in

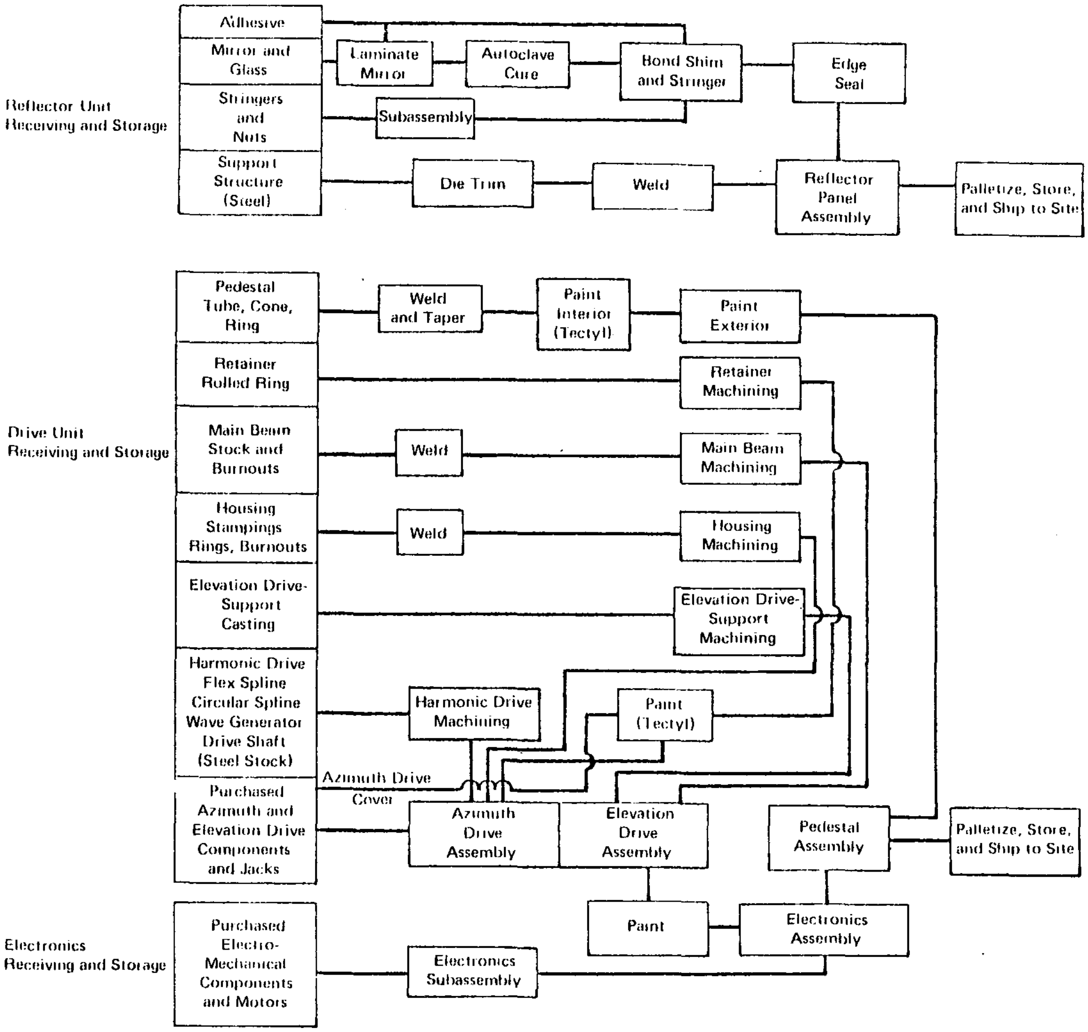

Figure 44. Production Flow

Blacksburg. The electronic controls, which are buy items, have been analyzed using resource loading as if they were make items in an existing facility employing automatic component insertion and wave soldering. This analysis was performed under a previous contract for the SERI by GM/Lamb, and studied the conceptual electronics design for MDAC's Prototype Study Heliostat. Electronics control costs are not included in the costs shown in this subsection which, except for G&A, covers only costs developed by GM under this study. Controls are covered in the installed costs shown in the following subsection.

6.2.2 Facility Costs

The cost of the production facility is summarized in Table 21.

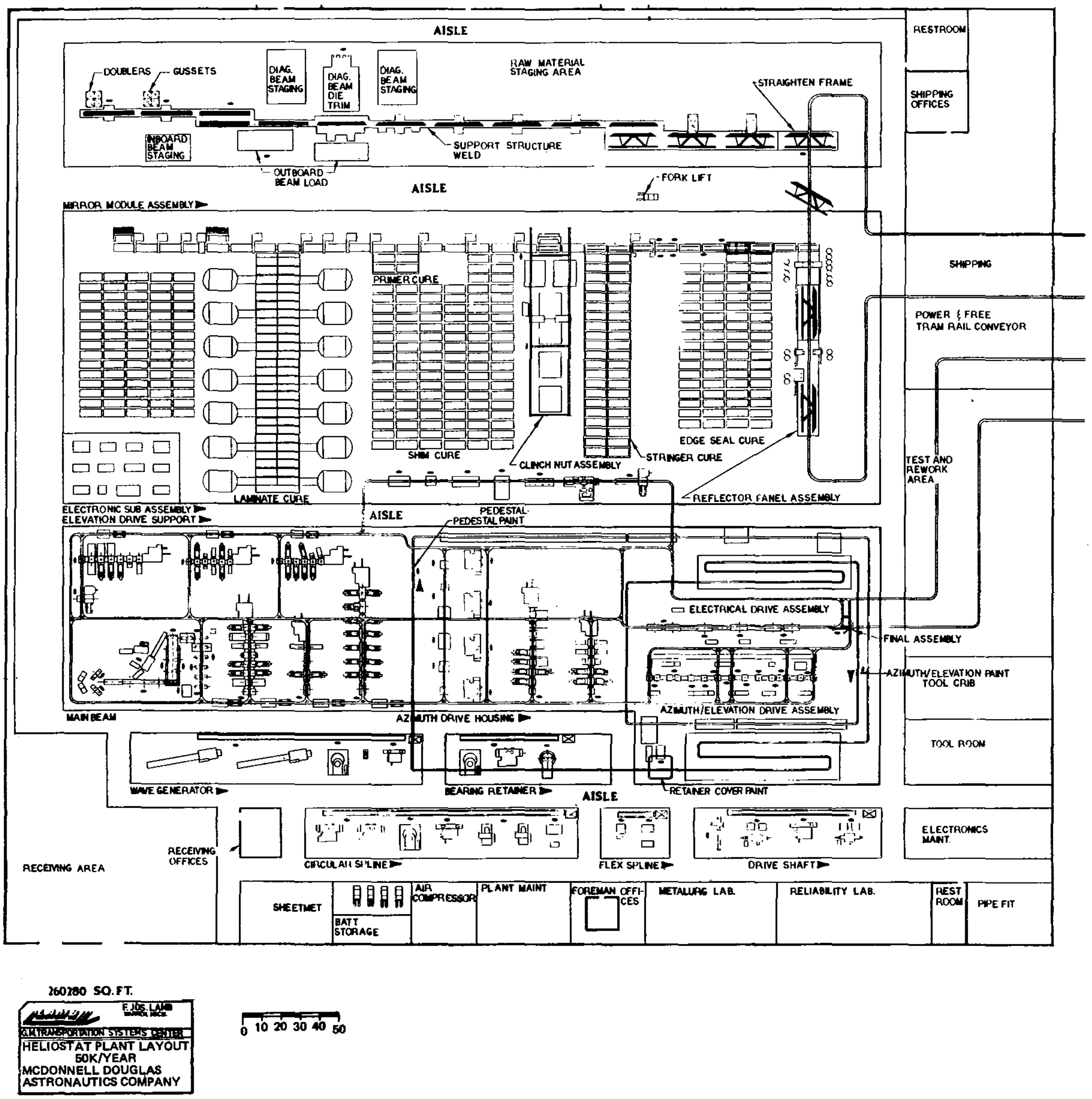

Figure 45. Layout

This investment allows the production of 50,000 drive/pedestals and 100,000 reflector panels per year when the facility is utilized 5 days per week on a two-shift basis.

Table 21. Production Facility Cost

Cost element	1980 dollars (in millions)
Plant and land	$ 36.80
Machinery and equipment	42.92
Tools	8.15
Total	$ 87.87

Approximately 42% of the cost is in the plant and land which considers the following cost elements, among others:

- Architecture/Plant design.
- HVAC (including humidity control).
- Process plumbing.
- Process sewers.
- Process waste treatment to the secondary level.
- Sanitary plumbing.
- Sanitary sewers.
- Compressed air supply.
- Makeup air supply.
- Exhaust air filtration to EPA requirements.
- Firehouse including diesel and electric pumps.
- Fire loop for water supply.
- Underground suction tank.
- Building sprinklers.
- Fire and proprietary monitoring system.
- Reinforced concrete flooring.
- Electrical power substation.
- Electrical power distribution.
- Site perimater fencing.
- Reinforced concrete staging area outside of building.
- Parking lot pavement.
- Building permits, surveys and contingencies.

Plant costs are based on GM experience factors per square foot of production facility and reflect current rates for construction in the southwest. Improved land is included at $20,000 per acre.

Table 22 details further the costs of machinery, equipment, and tools. The equipment costs have been reduced one and a quarter million dollars from those projected by GM in order to reflect shipment of four reflector panels per shipping rack versus only three in GM's scenario. This reduces the number of racks required from 2,425 to 1,820 at an estimated 10% increase in cost per rack. Shipment of four panels per rack creates a slightly oversized load which will require a shipping permit averaging $13 per shipment of four panels, but saves over $70 per heliostat in transportation costs, in addition to the shipping rack costs.

Somewhat closer examination of Table 22 reveals that most of the equipment cost is incurred in order to produce 8 to 10 parts or assemblies that are specialized or would require a considerable amount of labor if produced without the aid of mechanization. As a result, factory direct labor, including inspection, required to produce the drive, pedestal, and reflector panels is less than 11 man-hours per heliostat.

The cost of tools and equipment have been developed on tool and labor routing sheets which are based on the plant and machine designs. These forms indicate the operations to be performed, timing for manual and automatic operation, and specific prices for tools, equipment, and installation. All special machine designs have been developed to the point of detailed concept sketches, and cost estimates have been made by suppliers of similar equipment. Where standard machine tools are used, budgetary cost estimates or quotations have been obtained from the vendors.

6.2.3 Facility Operating Costs

Tables 23 and 24 indicate the annual costs of operating the production facility. The direct labor costs are based on the tool and labor routing sheets and the estimated hourly labor rate in April 1980. The latter represents the average rate published by the US Department of Labor for a

Table 22. MDC Second Generation Heliostat Tools and Equipment (Dollars)
Production Volume: 50,000 Per Year

From GM Report

		Tools				
	Special	Durable	Nondurable	Total	Equipment	Total
Drive/Pedestal/Main Beam Assembly (1D22475-1)						
Pedestal, Paint	--	--	--	--	622,167	622,167
Pedestal, Weld	282,594	39,968	17,459	340,021	838,326	1,178,347
Azimuth Drive Housing, Weld	70,168	25,060	5,012	100,240	612,910	713,150
Azimuth Drive Housing, Machine	1,452,100	58,220	19,407	1,529,727	4,171,963	5,701,690
Main Beam, Weld	125,370	44,775	8,955	179,100	867.180	1,046.280
Main Beam, Machine	1,870,000	70,500	23,500	1,964,000	3,662,400	5,626,400
Elevation Drive Support, Machine	1,899,000	147,200	23,900	2,070,100	3,734,000	5,804,100
Flex Spline	46,700	7,700	87,920	142,320	370,645	512,965
Circular Spline	81,200	23,100	50,450	154,750	2,085,740	2,240,490
Wave Generator	50,600	12,650	6,050	69,300	1,661,930	1,731,230
Drive Shaft, Azimuth	102,405	48,783	13,522	164,710	552,580	717,290
Bearing Retainer, Azimuth	190,300	77,000	13,200	280,500	1,124,875	1,405,375
Cover and Retainer, Paint	--	--	--	--	393,740	393,740
Azimuth/Elevation Drive, Assembly	120,000	35,000	10,000	165,000	2,382,500	2,547,500
Azimuth/Elevation Drive, Paint	--	--	--	--	216,500	216,500
Incremental Encoder	--	--	--	--	73,750	73,750
Sensor/Controller Cables	--	--	--	--	3,000	3,000
Motor/Controller Cable	--	--	--	--	1,200	1,200
Encoder Cable	--	--	--	--	44,300	44,300
Sensor Cables	--	--	--	--	1,000	1,000
Motor Cable	--	--	--	--	400	400
Encoder/Controller Cable	--	--	--	--	1,200	1,200
Elec. Installation, Az/El Drive	--	--	--	--	119,750	119,750
Final Assembly	--	--	--	--	45,508	45,508
Shipping Racks	--	--	--	---	1,327,690	1,327,690
TOTAL	6,290,437	589,956	279,375	7,159,768	24,915,254	32,075,022
Reflector Assembly (1D22456-1)						
Mirror Module	371,675	--	--	371,765	7,245,931	7,617,696
Reflector Support Structure	508,125	101,720	13,079	622,924	4,072,691	4,695,615
Final Assembly	--	--	--	--	559,475	559,475
Shipping Racks	--	--	--	--	6,126,017	6,126,017
TOTAL	--	--	--	--	18,004,114	18,998,803
Heliostat Total	7,170,237	691,676	292,454	8,154,367	42,919,368	51,073,825

Table 23. Annual Operating Costs (50,000 Units per Year)

Element	1980 Costs (millions of dollars)
Direct labor	$ 4.38
Variable fringe	3.16
Fixed fringe	1.85
Overtime	0.22
Night shift	0.18
Cost of living allowance	0.50
Variable burden	9.36
Fixed burden	4.64
Product engineering	0.61
Subtotal	$ 24.90
Direct material	146.07
Subtotal	$ 170.97
Depreciation	7.09
Total	$ 178.06
G&A (not in GM Costs)	8.25
Total	$ 190.92

seven-state western area. This average has been increased by a 15% industry factor in order to better reflect the level of labor skills. The labor hours have been developed by manloading operator, material handling, and inspector positions. These results are factored to allow for scrap loss, rework, machine downtime, labor efficiency, and reflief where it is necessary to operate equipment over breaks, startup and shutdown periods, lunch and personal requirements. These factors are shown in Table 25, and are applied as required for each labor operation. Other labor related elements such as fringe have been developed from experience factors.

The variable and fixed burden costs, except depreciation, are detailed in Table 24, which also indicates the estimating methods. Material costs have been determined from various sources including vendor quotes, discussions with suppliers, and catalogs. Depreciation, as shown in Table 23, has been

Table 24. Annual Burden (50,000 Units per Year)

Element	Cost (Millions) Fixed	Variable	Total	Estimating method
Supplies	$ -	$ 0.58	$ 0.58	Factor on labor
Tools	0.69	0.29	0.98	Specfic estimate by tool
Utilities	1.07	0.79	1.86	Factor on consumption estimate
Maintenance	0.13	1.42	1.55	Factor on plant and labor costs
Scrap	-	4.38	4.38	Factor on material costs
Taxes	1.36	-	1.36	Rate on property value
Indirect hourly labor	0.10	0.42	0.52	Man-loaded organization chart
Indirect salary labor	1.20	0.74	1.94	Man-loaded organization chart
Sundry	0.09	0.74	0.83	Factor on labor
Subtotal	$4.64	$ 9.36	$14.00	

Table 25. Labor Factors

Item	Rate or factor
Base rate	$ 7.01
Industry factor	0.15
Applied rate	$ 8.06
Labor efficiency	0.92
Machine down time	0.05 - 0.10
Scrap	0.02 - 0.03
Rework (5% at 4x labor)	0.20
Relief	0.167
Relief (including lunch)	0.242

determined from the costs shown for tools, buildings and equipment using a straight line method with building depreciated over 40 yr, equipment over 10 yr and special tools over 5 yr. Depreciation also covers outside tooling for the rolling mill and the stamping requirements. These methods have been used to determine average depreciation, but for purposes of the financial analysis discussed in the overview, accelerated depreciation schedules have been employed in order to consider tax incentives.

Further description and cost detail are provided in Volume II.

6.3 INSTALLED HELIOSTAT COSTS

Installed heliostat costs include additional costs beyond those incurred in the production facility that are necessary to provide an operational heliostat. These include the cost of electronic controls, transportation to the site, field wiring, foundations, heliostat installation, and heliostat checkout and alignment. This subsection provides the results of integrating the added costs with the production costs in accordance with the cost breakdown structure.

6.3.1 Cost Breakdown by CBS

Table 26 shows a breakdown into labor, raw material, and purchased parts for each CBS element. The costs are in terms of 1980 dollars per heliostat, and also show dollars per square meter. The costs represent the 494,000th unit which is produced in the tenth full year of production, and included no fee or visibility adjustment. Approximately 30% of the cost covers labor and burden with half of that being related to field effort and transportation. Raw materials account for 38% of the cost with most of the cost required in the production of the reflective unit. Purchased parts are 32% of the cost and are mainly associated with the drive and electronics.

6.3.2 Summary of Costing Scenario

The installed heliostat cost scenario includes the production facility and facility operations descriptions summarized in the prior subsection and detailed in Volume II. At this point, it is important to note that the reflector panels are assembled with each mirror module properly prefocused,

Table 26. Investment Cost Summary

SECOND GENERATION HELIOSTAT 50K/YR.

WBS NUMBER AND TITLE		NON	CAPITAL INVESTMENT					
		RECUR	LABOR		MATL DOLLAR			INVST
		(THOU)	HOURS	DOLL	PUR PT	RAW MTL	TOTAL	$/SM
	GRAND TOTAL	0.	36.2	1447.	1518.	1844.	4808.	84.57
4410	REFLECTIVE UNIT	0.	1.9	138.	8.	1501.	1648.	28.98
4411	REFLECTIVE SURFACE	0.	.9	68.	0.	1023.	1091.	19.18
4412	MIRROR BACK STRU	0.	.3	22.	0.	451.	474.	8.33
4413	ASSY-REFLECTIVE UN	0.	.7	48.	8.	27.	83.	1.46
4420	DRIVE UNIT	0.	7.3	528.	1173.	137.	1838.	32.33
4421	AZIMUTH	0.	3.6	263.	253.	31.	548.	9.64
4422	ELEVATION	0.	1.7	125.	452.	87.	663.	11.66
4423	MOTORS-TOTAL	0.	0.0	0.	109.	0.	109.	1.92
4424	POS/LIM INDICATOR	0.	.4	30.	51.	4.	84.	1.49
4425	PWR SPLY/DIST	0.	.8	55.	288.	0.	343.	6.03
4426	ASSY DR/PED/ELCT P	0.	.7	54.	20.	16.	90.	1.59
4430	CONTROL/INSTRMT EQ	0.	.3	24.	167.	0.	191.	3.36
4431	SENSOR/CALIB EQUIP	0.	.0	1.	6.	0.	8.	.14
4432	FIELD CONTROL	0.	.0	0.	2.	0.	2.	.04
4433	CNTRL/SIG EQ	0.	.3	22.	158.	0.	181.	3.18
4440	FOUND/SITE PREP	0.	13.3	342.	148.	79.	569.	10.00
4441	FOUNDATION	0.	9.6	247.	148.	79.	474.	8.34
4442	SITE PREPARATION	0.	3.7	94.	0.	0.	94.	1.66
4450	HELIO SPT ST/PR EN	0.	.4	32.	0.	126.	158.	2.78
4451	HELIO SUPP STRUCT	0.	.4	32.	0.	126.	158.	2.78
4460	FIELD ASSY & C/O	0.	13.0	384.	21.	0.	405.	7.13
4461	HELIOSTAT	0.	3.0	77.	0.	0.	77.	1.35
4462	SENSOR/CALIB EQ	0.	.0	0.	0.	0.	0.	.00
4463	ELECTRICAL/DISTRIB	0.	1.7	43.	0.	0.	43.	.75
4464	ALIGN HELIOSTATS	0.	.7	19.	0.	0.	19.	.33
4465	FIELD SUPPORT	0.	1.2	30.	0.	0.	30.	.53
4466	PACK & TRANS	0.	6.4	216.	21.	0.	237.	4.17
4300	ELECT PLT EQ	0.	.3	14.	8.	0.	22.	.38
4350	PLANT CONTROL	0.	.3	14.	8.	0.	22.	.38

aligned, and checked and that the drive/main beam/pedestal/electronics (DPE) assemblies are "aligned" and checked out prior to shipment. The completed reflector panels and DPE assemblies are placed in reusable and open shipping racks. Reflector racks hold panels for two heliostats, and a total of 1820 racks are required in order to cover daily shipping as well as pipeline requirements. DPE assembly racks hold four units, and 910 racks are required. Standard pallets are used to transport other items to the site such as power transformers, distribution panels and cables.

Assemblies are shipped to site on flatbed trailers using a private truck fleet similar to that maintained by Douglas Aircraft Company at Long Beach, CA. The average distance transported is based on a radius of 400 miles but an average round trip distance of 288 miles. This reflects an assumption that a factory is located near the center of installations, so that most sites are within a one-day drive.

Foundations and field electrical installations are accomplished in the manner described in the MDAC Prototype Heliostat Final Report using conventional equipment. Essentially, a high-power auger is employed to drill the foundation hole, and the prefabricated rebar cage, with the 4-ft tapered interface prewelded in place, is slipped into the foundation hole. Concrete is poured through the center of the 4-ft interface filling both the hole and the interface. As with the Prototype, no operation requires over 30 min. to perform. The main difference is that the Second Generation design required only 2.32 yd^3 of concrete compared to 3 yd^3 for the Prototype design. Also, less rebar is required and the hole is not as deep.

The single fiber-optic/electrical field cable is buried using a cable plow. Loops are allowed to form above ground at each heliostat position, which are later cut and the ends connected to the pedestal wiring. Wiring requires 32 min. per heliostat with a crew of three, and connections require 32 min. with a two-man crew.

Special equipment is employed to position and secure the DPE assembly to the foundation. The task involves removing the DPE assembly from the open rack and pressing the end of the pedestal over the tapered foundation interface until a tight fit is formed. This is accomplished with a three-man crew in an average of 18 min. The reflector panels are also installed with a special rig, and the interface is designed so that when bolted down they are properly aligned relative to the drive. This task averages 27 min. using six men. Other installations are made using conventional equipment, and the time required is relatively minor. Once the heliostat is in place, the only other operation is final alignment. A field engineer and a technician accomplish this task in 36 min. per heliostat using a mobile test station and beam characterization subsystem. The times indicated above include added efficiency allocations not shown in Section 5.

6.3.3 Costing Approach

The costing approach employed in developing costs for the 50,000 heliostats per year scenario is based on annual resource loading for labor, capital, and other burden, and, in the main, on vendor quotes and supplier contacts as indicated in the production facilities descriptions. However, the scenarios for several areas have not been studied as part of the Second Generation Heliostat effort. These areas include the foundation, advanced heliostat controllers, motor controllers and field controllers, the HAC, the BCS, installation and installation equipment, and field wiring and electrical distribution. The approach for these areas has been to use the same scenarios and costs as developed for the Prototype Heliostat Study, but to update the results for inflation and for cost information developed on contracts completed since the Prototype contract was completed.

Advanced Control Electronics and pedestal electric cost data have been updated to reflect labor hours and electronic component costs developed by General Motors/Lamb under their contract to study the MDAC Prototype Heliostat cost results for the Solar Energy Research Institute. These cost results reflect a high commercial grade of electronic components and some added connectors and other hardware not considered in the original conceptual design. This effort adds approximately 1.3 hr of labor which has been costed at the same burdened labor rate used for the balance of the heliostat factory.

HAC costs are based on component costs and labor determined for the repowering contracts, and the BCS costs are based on pricing obtained for the Barstow proposal. Except for reductions in foundation costs due to the lower volume of concrete and rebar and revised transportation costs, all other field costs are identical (before inflation) to those presented in the Prototype Heliostat final report.

Factors and rates applied to field effort are as follows:

Item		
Efficiency	- Field (on lapsed time)	67%
	- Support	77%
Labor Rates		$25.71
Cost Reduction Curve		98%

The efficiency factors mainly cover impacts on lapsed time while other efficiencies are implicit in the crew loads. For example, a crew of 7 may be required to accomplish a task, but at any one time only 2 or 3 members may be actually involved.

Costs have been determined at the 494,000th unit by pegging input costs at various points on a cost reduction curve. The peg points and slope of the curve depend on the source and type of data. Costs have been run down their respective curves from their peg points to arrive their cost for the 494,000th unit. Table 27 indicates the cost reduction parameters that have been applied. Since the peg points are well down the curves, the impact of the slopes are relatively minor and well within the expected range of improvement due to tooling improvements, better alignment of material flows, production design improvements, and better utilization of labor as the plant matures.

Further description and cost detail is provided in Appendix D-3. Appendix D-5 indicates adjustments to costs presented in Volume II in order to arrive at total installed heliostat cost.

Table 27. Cost Reduction Parameters

Type and source	Peg point (unit no.)	Slope
Purchased parts - Second Generation	115,000	95%
Raw-Materials - Second Generation	115,000	98%
Electronic components - Prototype	250,000	92%
Other materials - Prototype	250,000	95%
Factory labor - Second Generation	50,000	94%
Field labor - Prototype	25,000	98%

6.4 OPERATIONS AND MAINTENANCE COSTS

Operations and maintenance costs include the costs of operating a field of 5412 heliostats during the first year of plant operation.

6.4.1 Cost Breakdown by CBS

Table 28 provides a breakdown of operations and maintenance costs for spares, repair parts, other nonlabor, and corrective and scheduled labor. The other category includes transportation of spares and parts, washing solution, lubricants, fuels, service contracts, and maintenance of service equipment.

6.4.2 Costing Scenario

The operation and maintenance scenario calls for the use of essentially conventional handling equipment. The equipment includes a mobile crane, pickup trucks, forklifts, slings, and hoisting tools. In addition, calibration tools are employed along with the BCS in order to realign the heliostat when necessary. Washing of heliostats is accomplished 12 times per year with special wash and rinse trucks.

The maintenance policy followed for the Second Generation Heliostat is to replace almost all failed parts with relatively high-level spares, in the field. These spares are then repaired on the bench using, in effect, new spares of lower-level parts. Generally, maintenance actions involve locating the failure, driving to the point of failure, removal of the failed item, replacement with a spare, and return to the maintenance base for repair. Most

Table 28. Operations and Maintenance Cost Summary

"SECOND GENERATION HELIOSTAT INVESTMENT AND FIRST YEAR O&M COST - (50K/YEAR)

WBS NUMBER AND TITLE		OPERATIONS AND MAINTENANCE					
		NON-LABOR			LABOR		
		SPARES	REP PT	OTHER	CORRECT	SCHED	TOTAL
	GRAND TOTAL	37.	9.	105.	173.	84.	407.
4410	REFLECTOR ASMBLY	3.	0.	1.	7.	0.	11.
4411	REFLECTIVE SURFACE	3.	0.	1.	6.	0.	10.
4412	MIRROR BACK STRU	0.	0.	0.	1.	0.	1.
4420	DRIVE UNIT	21.	9.	4.	156.	0.	190.
4421	AZIMUTH DRIVE	1.	5.	0.	55.	0.	61.
4422	ELEVATION	1.	3.	0.	14.	0.	18.
4423	MOTOR TOTAL	15.	0.	2.	82.	0.	99.
4424	POS/LIMIT INDICATO	4.	0.	1.	2.	0.	7.
4425	PWR SPLY/DIST	1.	0.	0.	3.	0.	4.
4430	CONTROL/INSTRMT EQ	13.	0.	0.	7.	0.	20.
4432	FIELD CONTROL	0.	0.	0.	0.	0.	0.
4433	CNTRL/SIG EQ	13.	0.	0.	7.	0.	20.
4450	HELIO SPT ST/PR EN	0.	0.	0.	3.	0.	3.
4451	PEDESTAL	0.	0.	0.	3.	0.	3.
OM000	COMMON O&M	0.	0.	79.	0.	84.	164.
OM200	MAINT.MATERIAL	0.	0.	79.	0.	0.	79.
OM300	MAINTENANCE LABOR	0.	0.	0.	0.	84.	84.
4100	SITE/STRU/MISC EQ	0.	0.	17.	0.	0.	17.
4130	MISC.EQUIP	0.	0.	17.	0.	0.	17.
4300	ELECT PLT EQ	0.	0.	2.	0.	0.	2.
4350	PLANT CONTROL	0.	0.	2.	0.	0.	2.
4100	SITE/STRU/MISC EQ	0.	0.	64.	0.	0.	65.
4130	MISC.EQUIP	0.	0.	64.	0.	0.	65.
4800	INITIAL SPARES	8.	0.	0.	0.	0.	8.
4841	HELIO INIT SPARES	8.	0.	0.	0.	0.	8.

1

of the failed repair parts are scrapped and replaced with new spares. Most heliostat support structure maintenance will be performed in the field. Light maintenance of service equipment is assumed performed at site while major service such as engine repair will be performed by manufacturer service facilities.

During the first year of operation, the failure rates for electrical components will average 3.3 times the normal rate while the failure rate for control electronics will be twice the norm. The latter is considerably less than shown for the Prototype study because of the upgrade of components.

6.4.3 Costing Approach

Operations and maintenance costs are based on both resource loading and direct estimates of hours, unit investment cost for spare parts, and on quotes or prior study information on operations materials such as washing solution and lubricants. Spares and repair parts costs are the product of annual failures (based on failure rate tables), hardware unit costs, and repair or replacement factors. Corrective maintenance is the product of crew size and lapsed time or a direct hour estimate for bench labor, annual failures, repair factors, for bench labor, and burdened labor rates. Scheduled maintenance is based on direct estimates or crew size and lapsed time and labor rates, material quotes and estimated frequencies. Results are factored to consider efficiency, added first year failures or problems, and refix where the first attempt at repair is not successful and must be redone. Table 29 displays the applied factors. Finally, annual maintenance of service equipment is estimated at 5% of initial value while electrical consumption to operate the heliostats is included as a factor in field sizing by the DELSOL code.

Further descriptions and cost detail is provided in Appendix D-4. The tables in Appendix D-4 are grouped into the headings of spares, repair parts, other, corrective maintenance, and scheduled maintenance, and the totals of each heading tie directly to the column totals in Table 28.

Table 29. O&M Labor Factors

Efficiency	
Field	50%
Bench	85%
Wash and inspect	85%
Refix	
Drive and reflector	1.10
Electronics	1.25
First-year factor	
Motors	3.34
Electronics	2.00
Wash and inspect	1.20
Other	1.00
Labor rate	$18.00
CRC	100%

Section 7
FUTURE DEVELOPMENT

Future development activities aimed at further cost reduction will involve all components of the heliostat. These activities will involve parts reduction and simplification, material reduction and detail process design, and demonstration. Some early candidates are discussed below.

7.1 MIRROR MODULE

The shim used in the stringer bonding process may be eliminated by development of a rapid cure adhesive for the stringer to glass bond. This would also eliminate several steps in the assembly process as well as reduce the plant equipment and floor space requirements.

Development of an adhesive lamination process to replace the PVB autoclave process will decrease part costs as well as reduce the facility equipment and floor space requirement.

Development of an improved edge member would reduce material required and increase the effective heliostat area. Some data indicate that mirror corrosion does not progress beyond a short distance from an edge even when it does occur in laminate mirrors. A review of this data might suggest elimination of the edge seal completely.

A material with the same coefficient of expansion as glass could be used for module stiffeners of reduced height. Such a meterial could be produced with the fiberglass pultrusion process. In conjunction with this change, mirror module thickness could be reduced.

The current mirror module uses a 0.1875-in.-thick float glass back light. A reduction to 0.125 provides a 30% reduction in back laminate glass. This should result in a direct ratio cost reduction.

7.2 ERROR DISTRIBUTION AND PART TOLERANCES

In the initial design process the overall heliostat pointing accuracy and deflections requirements are budgeted to the individual components based on analysis, predications, and previous test data. For the Second Generation Heliostat this has resulted in overall heliostat performance substantially within the specification. As a result, two potential sources for cost reduction are available: relaxed component requirements providing heliostat performance still meeting the specification, and a redistribution of budgets between components. Component evaluation with revised budgets will potentially reduce material requirements, parts count, and component tolerances.

7.3 PRODUCTION DESIGN

In the factory process design development, several areas of redesign for production simplification were identified for further development. These include the main beam and the elevation support.

7.3.1 Main Beam

In the initial design of the main beam minimum material weight was stressed. A thin shell was developed with local load distribution provided by welding on components. This has resulted in a significant amount of welding. A reanalysis is required of the tradeoff of welding complexity with weight of parts.

7.3.2 Elevation Support

The GM study identified the elevation support as more adaptable to a cast than to a welded assembly. As a casting, the design may be further optimized for material reduction and to incorporate several functions which are now provided by individual parts.

7.3.3 Parts Reduction, Materials Substitution

A general parts reduction would be provided by combining functions of components and standardization of fasteners and seals. In some cases, increasing part size may reduce costs by minimization of high-cost materials, such as aluminum bronze gears. Molded plastic may be substituted for metals in covers, brackets, and fittings.

7.4 FOUNDATION

Two areas of potential foundation cost reduction are possible, reduction of foundation concrete, and use of Pole Set.*

7.4.1 Concrete Reduction

The current design uses a 24-in. diameter hole completely filled with concrete. The amount of concrete may be reduced by placing a sonotube in the center of the foundation and pouring concrete between the outside wall of the tube and the hold. This approach may reduce concrete requirements by up to 30%.

7.4.2 Pole Set Foundation Installation

At the outset of the Second Generation program, MDAC investigated two foundation approaches. The tapered, poured in place foundation was chosen as a more conventional approach with minimum development risk.

The pole set approach provided potentially lower costs, but required a test program to develop data on heliostat compatibility.

The pole set foundation installation includes drilling the foundation hole in a conventional manner, emplacement in the holes of a concrete or metal tube 2 in. smaller in diameter than the hole, and filling the gap with a foamed in-place urethane. Both labor and materials are significantly reduced from the poured in-place foundation.

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*A trademark of Forward Enterprises of Texas

Appendix A
SPECIFICATION DATA

Appendix A-1

COLLECTOR SUBSYSTEM REQUIREMENTS

SPECIFICATION SUMMARY

Spec. Para. Ref.	Requirement	Verification Method*
3.1	Collector Subsystem Definition	
	An array of Heliostats - supporting power and control Interacts with master control Reflects radiation on receiver Deviations acceptable - justifiable with cost or performance improvements	I
	(a) Heliostat	
	Mirror modules - reflector, mirror support Structure support including foundation Drive units Control sensors Pedestal - mounting interface Heliostat cabling - power control	I
	(b) Heliostat Controllers (HC)	
	Controller, power supply, AC motor control electronics	I
	(c) Heliostat Array Controller (HAC)	
	Master control interface Minimum of back-up computers Time base Beam characterization system interface Software	
	(d) Heliostat Field Controllers (HFC)	
	Controller, power supplies Interfaces - HC, HAC Software	I
	(e) Supporting Equipment	
	Alignment, washing, operation/maintenance, Installation/removal	Costing Only

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*CODE: I - Inspection

Spec. Para. Ref.	Requirement	Verification Method*
3.1.1	Collector System Diagram	
	MDAC prototype Heliostat Collector field control Control system Others not excluded	I
3.1.2	Interfaces	
3.1.2.1	Collector/Physical Site	
	Arrangement, boundaries of array Foundations Field power and wiring Supplied as part of Collector system	Costing Only
3.1.2.2	Collector/Receiver Subsystem	
	Receiver - Vertical cylinder 12M dia x 12M high Center above ground	Costing Only
3.1.2.3	Collector/Plant Power	
	Uninterruptable to HAC, HFC, Heliostat Junction box.	Req'd HAC Only
3.1.2.4	HAC/Master Control System (MCS)	
	MCS can automatically control and alarm Interfaces - control, operational data, alarm data	Costing Only
3.1.2.5	HAC/Data Acquisition System (DAS)	
	Functions, evaluation requirements and outputs	Costing Only
3.1.2.6	HAC/Beam Characterization System (BCS)	
	HAC provides Heliostat control/positioning forces HAC initiates BCS; BCS provides controls to HAC BCS requests HAC/Heliostat alignment	Costing Only
3.2	Specifications	
3.2.1	Performance	
	Plant Field - 95% of redirected energy on receiver with incidence angle <60°.	A MDAC Sandia

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*CODE: I - Inspection - A - Analysis

Spec. Para. Ref.	Requirement	Verification Method**
	A maximum beam pointing beam 1.5 RAD each axis Wind - 0, Temp. 0-50°C, all lattitudes, all field locations when sun at least 0.26 RAD above horizon.	T MDAC Sandia
	(a) Maximum pointing error 0.75 MRAD whenever sun is 0.26 RAD above horizon	A T
	(b) Beam Quality - Minimum of 90% of reflected energy shall fall within area defined by theoretical beam shape plus 1.4 MRAD fringe width.	A MDAC T Sandia
	(c) Reflective surface static and dynamic deflections limited to 1.7 MRAD.	T A Sandia
	(d) Maximum allowable foundation settlement or plastic displacement <0.05 MRAD elastic displacement <0.5 MRAD.	A T Sandia
3.2.2	Operation	
	(a) Function for all steady-state modes of plant operation. Vary flux to receiver between zero and maximum in 10% steps or less.	D Capability Only
	(b) Drive system capability to position Heliostat to any other position in 15 minutes.	T MDAC Sandia
	(c) No drive drift from command position.	T MDAC Sandia
	(d) Drive system capable of resolving singularity within 15 minutes.	Sandia
	(e) Provide for cost effective stowage to minimize beam safety hazards and dust and dirt buildup.	D MDAC Sandia
	Heliostat orientations available to master control at all times.	D MDAC Sandia
	(f) Heliostat control by computer with heliostat orientation sensors.	
	HAC - Initiate mode commands to HFC. Address commands to HFC groups or individual HC. Respond to MCS commands and requests.	D MDAC Sandia MCS not Avail.

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*CODE: A - Analysis - T - Test (prove by evaluation of data)
D - Demonstrate (minimum data required) - I - Inspection

Spec. Para. Ref.	Requirement	Verification Method*
	Interface with beam characterization system.	BCS not Avail.
	Provide time basis.	D MDAC Sandia
	HFC - Determine individual heliostat Az and El position requirements.	D MDAC Sandia
	Transmit position requirements to HC.	D
	Initiate safe stowage command upon loss of HAC communications.	D
	Control groups of HCs.	D
	HC - Control drive motors. Provide heliostat axis position data to DAS.	DAS not Avail.
3.2.3	Safety	
	(a) Emergency defocus upon command to reduce peak incident radiation on receiver to <3% of initial value within 120 seconds.	A MDAC D
	(b) Heat fluxes on tower and normally unirradiated portions of receiver are limited to TBD KW/m^2.	Non Demonstated
	(c) Beam control strategy and equipment will protect personnel and property within and outside the plant facility, including air space.	A MDAC D Sandia
3.2.4	Maintainability	
	Collectors designed to require minimum routine field maintenance	D MDAC Sandia
	Collector subsystem reports subsystem malfunctions at HAC console, provide fault isolation information on critical components.	Not Demonstrated
3.2.5	Physical Characteristics	
	(a) Reflective surface of most cost effective area and reflectivity.	D
	(b) Local override of heliostat controller and ability to stow without use of Heliostat drive motors.	Capability Provided.
	(c) Environmentally sealed systems.	T MDAC Sandia
	(d) Corrosion protection of all parts.	I

*CODE: A - Analysis - T - Test (prove by evaluation of data)
D - Demonstrate (minimum data required) - I - Inspection

Spec. Para. Ref.	Requirement	Verification Method*
3.2.6	Environmental Design Conditions	
3.2.6.1	Wind Loading	
	(a) Servodynamic Response - Gust oscillation, vortex	D MDAC
	shedding heliostat	A Sandia
	Natural freq. and operations, dynamic loads.	A
3.2.6.2	Operational Limits	
	Wind - 12 m/s	A Partial
	Temp. - 0-50°C	Demo.
	Gravity - All elevation angles	T Winds
		Gravity
3.2.6.3	Stowage Initiation	
	Track with wind speeds up to 16 m/s, maintain	T MDAC
	structural integrity in nonoperational state in 22 m/s wind any orientation.	Sandia
3.2.6.4	Hail	
	0.75 inch - 20 m/sec	T MDAC Sandia
3.2.6.5	Lightning	
	Protect adjacent heliostats	I
3.2.7	Transportability	
	Transportable by highway handling equipment within	A MDAC
	applicable Federal and State Regulations.	D
3.3	Design and Construction	
	Apply commercial standards. Design and material	I
	selection to be based on a 30-year plant life.	I
3.3.1	Materials, Processes and Parts	
	Standard materials and processes and off-the-shelf	I
	components where possible.	I
	Commercial specifications.	

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*CODE: A - Analysis - T - Test (prove by evaluation of data)
D - Demonstrate (minimum data arequired) - I - Inspection

Spec. Para. Ref.	Requirement	Verification Method*
3.3.2	Electrical Transients	
	Equipment shall not be adversely affected by electrical power transients.	A/T MDAC
	Normal operation - Voltage +10%; frequency +0.1%	A/T MDAC
	Equipment startup or shutdown - Voltage -25%, +10% with recovery within 5 cycles at 60 Hz.	A MDAC
	Emergency condition - Momentary total loss of power.	A/T MDAC
3.3.3	Electromagnetic Radiation	
	Control wiring designed to minimize susceptibility to EMI and to minimize generation of conducted or radiated interference.	A/T MDAC
3.3.4	Flammability	
	Fire in heliostat field, should not damage heliostats not directly adjacent to fire.	A/I
	If a heliostat burns, fire should not spread to other parts of field due to winds, explosions, or other means.	A/I
3.3.5	Name Plates and Product Marking	
	Required on all parts.	I
3.3.6	Workmanship	
	Conform to codes, standards, specifications applicable to the plant site and using utility.	
	Finished to present no unintended hazard to operating and maintenance personnel, be neat and clean, and present uniform appearance.	I
3.3.7	Interchangeability	
	Items with a common function shall have a common part number and be interchangeable.	I
	Components with similar appearance but different functions shall incorporate protection against inadvertent erroneous installation.	

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*CODE: A - Analysis - T - Test (prove by evaluation of data)
D - Demonstrate (minimum data required) - I - Inspection

Spec. Para. Ref.	Requirement	Verification Method*
3.3.8	Safety	
	Designed to minimize safety hazards to operating and service personnel, the public and equipment.	A/I
	Electtrical components insulated and grounded	I
	High temperature insulated against contact with or exposure to personnel.	I
	Moving elements shall be shielded.	I
	Safety override controls/interlocks provided for servicing.	I/D
	Human Engineering	
	Designed to facilitate manual operation, adjustment, and maintenance, and provide optimum allocation of functions between personnel and automatic control.	A/D MDAC Sandia
	Electrical/electronic packaging shall ensure rapid repair and replacement, placarding of hazardous work areas and equipment for item removal and handling.	A/D
	22 Applicable Publications	
	Wind Forces Environmental Conditions Winds	
	Rise Rate - 0.1 m/sec normal. Unusual, 22 m/sec thunderstorm gusts	A/T MDAC Sandia
	Survival - 40 m/sec	A/T MDAC Sandia
	Dust Devil - 17 m/sec	A
	Sandstorm - MIL STD - 810B	A
	Temperature - -30 to +50°C	
	Rain - Avg annual 750 mm max, 24 hr rate 75 mm	A
	Ice - 2 inches thick	

---

*CODE:
A - Analysis
T - Test (prove by evaluation of data)
D - Demonstrate (minimum data required)
I - Inspection

Spec. Para. Ref.	Requirement	Verification Method*	
	Hail - 25 mm, 23 m/sec (75 ft-sec) - 6.7°C	T	MDAC Sandia
	Snow - Rate .3 m/24 hr load 250 PA	A	
	Insolation - 1100 W/m^2 maximum	A	
	Earthquakes - Zone	A	
	Soil Properties - Albuquerque	A/T	Sandia

*CODE:
A - Analysis
T - Test (prove by evaluation of data)
D - Demonstrate (minimum data required)
I - Inspection

Appendix A-2
HELIOSTAT FIELD PERFORMANCE

To provide an overall plant performance of 95% of the heliostat redirected energy available to the receiver, heliostat beam pointing and beam quality specifications are defined. The purpose is to define individual parameters which may be addressed in the design, and measured in testing of individual heliostats, that yield a heliostat subsystem that is cost-effective. MDAC has analyzed the effects of the combined heliostat specification requirements and finds that the beam quality requirements may be too stringent. A less stringent beam quality requirement could provide a most cost-effective heliostat that still meets the overall field performance goal.

Two cases are presented: The overall goal of energy on the receiver being met even though individual heliostat locations in the field do not meet the beam quality specification, and the diurnal energy goal met with nonconformance to the beam quality specification.

FIELD LOCATION EFFECTS

A study was made of the optical performance of the Second Generation Heliostat in terms of the energy spillage characteristics in a representative 50 MWe array, and the single-heliostat beam quality at various locations in the array. This analysis included the effects of panel curvature changes due to temperature variations (the MDAC mirror panel curvature does change with temperature), as well as flat and fixed curvature mirrors.

Beam shapes were determined for various locations for the extreme conditions of early AM on summer solstice, ambient temperature 116°F, and early AM on winter solstice, ambient temperature 32°F. In general, the 90% power contour of the beam shape was comparable to or inside the specification contour except for the close-in heliostats. Figures A2-1 and A2-2 show diagrams for Location 1 close to the tower and 10 in the last row as determined by

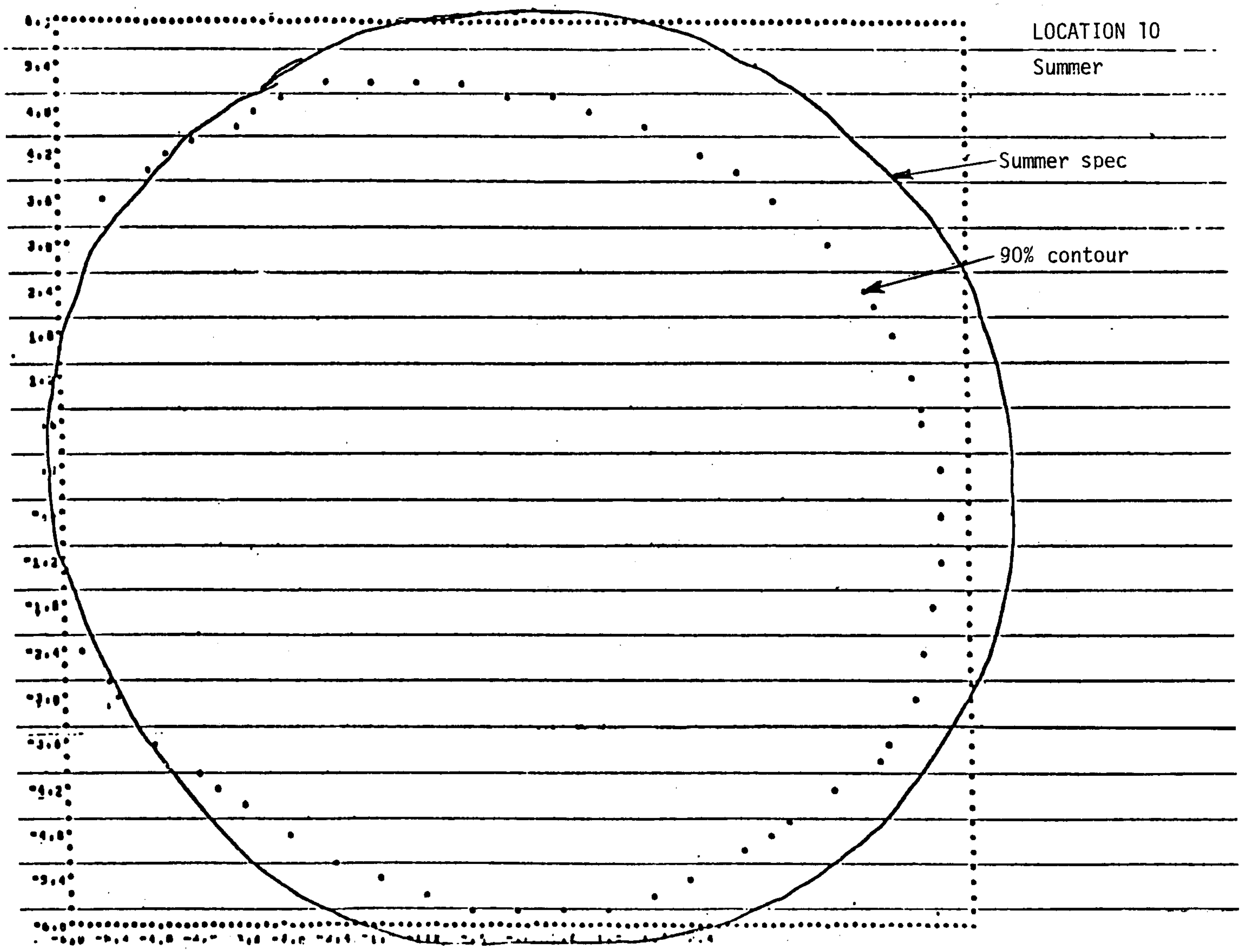


Figure A2-1. Beam Quality Compared to Specification (Location 10, Summer)

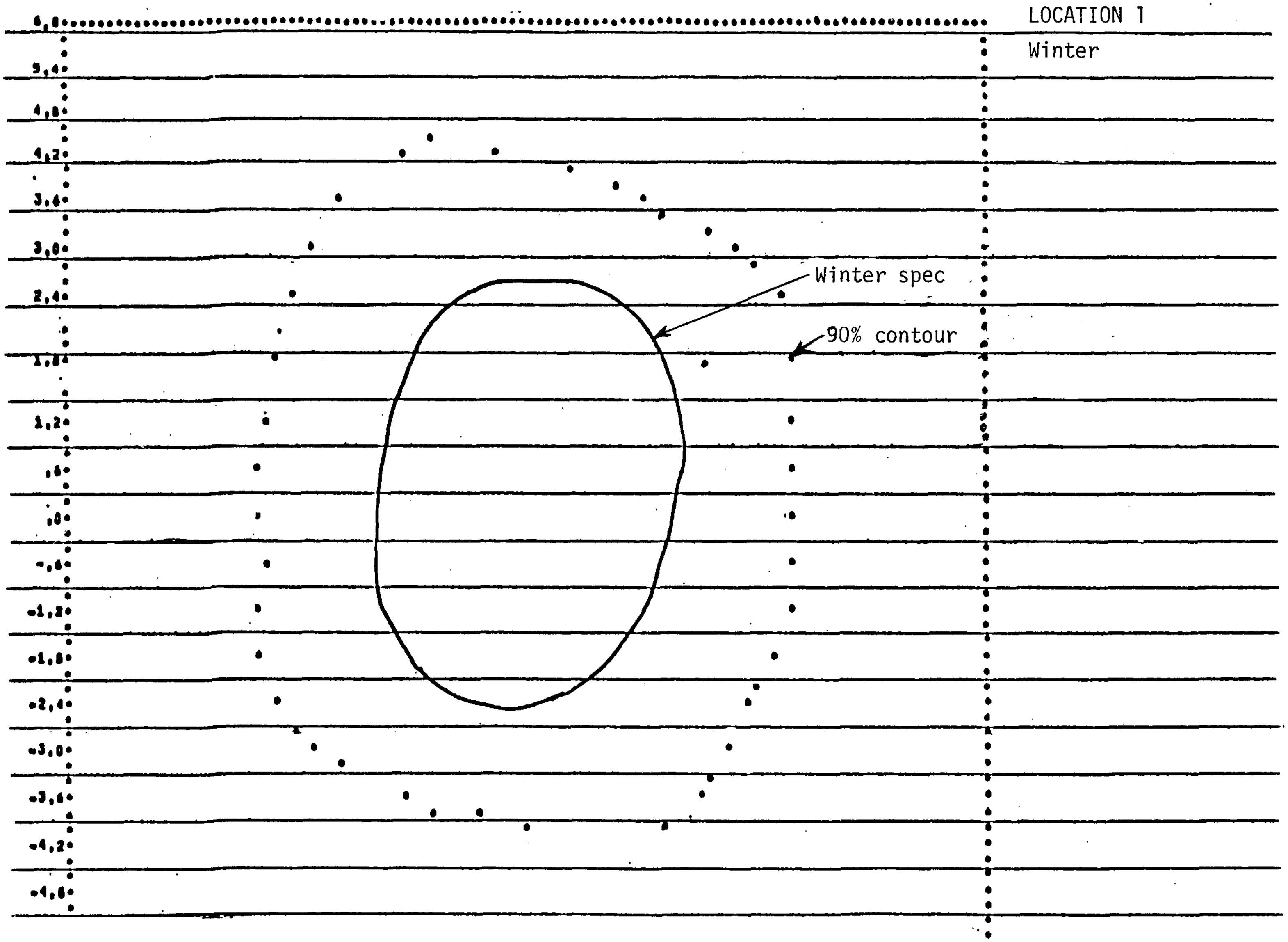


Figure A2-2. Beam Quality Compared to Specification (Location 1, Winter) interpolation in the flux distribution over an imaginary screen normal to the beam, located at the receiver. The specification contour is shown as a solid line; the computed 90% contour appears as a series of dots. It is seen that, although the beam from the heliostat at Location 1 is outside the specification, it is still well within the diameter of the receiver (indicated by the rows of asterisks at the sides). For the outer heliostat at Location 10, the 90% contour is inside the specification and comparable in size to the receiver diameter. The comparisons for the other locations for summer and winter, fall in between the extremes at Locations 1 and 10. These effects were found in the flat panel and fixed curvature cases also. Therefore, curvature per se does not resolve the issue.

DIURNAL ENERGY WITHIN THE 95% SPECIFICATION

Diurnal energy spillage computations were run for four representative days for panels initially curved with changing curvature/temperature characteristics; and flat panels and fixed curvature panels for proper focus at the location, with no temperature effect. Table A2-1 gives the energy and spillage for the three conditions. Although, as expected, the spillage figures are best for the fixed curvature condition (non varying with temperature) and worst for the flat panel condition, the differences are small and all are under 3% in the worst case shown.

Wind effects were not accounted for in this computation, but specification mirror waviness and pointing accuracy were. In addition to the representative days, the annual performance was analyzed and spillage was determined to be approximately 2%. It is evident from this analysis that the 95% energy received specification can be met without achieving the theoretical beam shape specification throughout the field, throughout the year.

Table A2-1. Heliostat Performance
Diurnal Energy Variation With Mirror Curvature

			Temperature independent			
	Temperature-sensitive panel		Flat panels		Fixed curvature	
Day	Diurnal energy (MW-hr)	Spillage (%)	Diurnal energy (MW-hr)	Spillage (%)	Diurnal energy (MW-hr)	Spillage (%)
21 MAR	1843.1	1.99	1839.0	2.36	1846.3	1.85
19 JUN	2179.0	1.57	21.75.1	1.94	2184.0	1.56
17 SEP	1571.0	1.90	1565.7	2.41	1571.9	1.85
16 DEC	1480.9	2.89	1480.7	2.86	1483.1	2.54

Annual performance:

Received energy 6.43 x 10 MW-hr
Energy spillage 2.04%

Appendix A-3
SURVIVAL STOWAGE

The specification states:

> "3.2.6.3 Stowage Initiation
>
> The heliostats will continue to track the target with wind speed up to 16 m/s (35 mph), but with degraded performance allowed, above which stowage action will be initiated as a result of an externally provided signal. The heliostat must maintain structural integrity in a non-operational state in a 22 m/s (50 mph) wind of any orientation."

The environmental appendix to the specification states:

> "3.1.2 Wind Rise Rate
>
> Under normal conditions, the maximum wind rise rate is 0.01 m/s^2 (0.02 mph/s). A maximum wind of 22 m/s (50 mph) from any direction may occur resulting from unusual rapid wind rise rates, such as severe thunderstorm gust fronts."
>
> "3.1.1 Speed Frequency
>
> 14 m/s and up (31.5 mph) less than 1%."

Because of the appendix conditions non-operational state has been interpreted to include the heliostat in motion in 50 mph winds, the 50 mph gust front preceding a severe thunderstorm.

To meet these requirements, the MDAC heliostat is driven in elevation to the horizontal stow position when winds exceed 35 mph. This satisfies the minimum energy requirement to stow the field. Maximum individual heliostat travel time from vertical to horizontal is six minutes. In this mode the azimuth drive static load capability exceeds the 50 mph wind requirements. This procedure was analyzed for operational requirements and beam safety in the heliostat inversion study* and was found to be acceptable. A discussion of the beam safety considerations is provided below.

---

*"Non-Inverting Heliostat Study," MDC G7876, July 1979.

The heliostat as delivered to CRTF for the second generation evaluation may also safely be driven in azimuth in winds up to 50 mph in all but a few adverse wind angles of attack, as shown in Figure A3-1.

If the harmonic drive is rotating in the adverse attitudes and winds are above 50 mph, it will ratchet. This is not catastrophic to the drive; however, it may produce some damage and an unknown reflector position in the field which, although it can be corrected, could be averted by not attempting to drive in azimuth in high wind loads.

Although the stow scenario will not be changed, drive capability for future heliostats is increased to allow travel in azimuth in all attitudes with winds up to 50 mph. This is a minor change which was not incorporated in the delivered second generation heliostats. Testing of this capability is under way at the time of publication of this report.

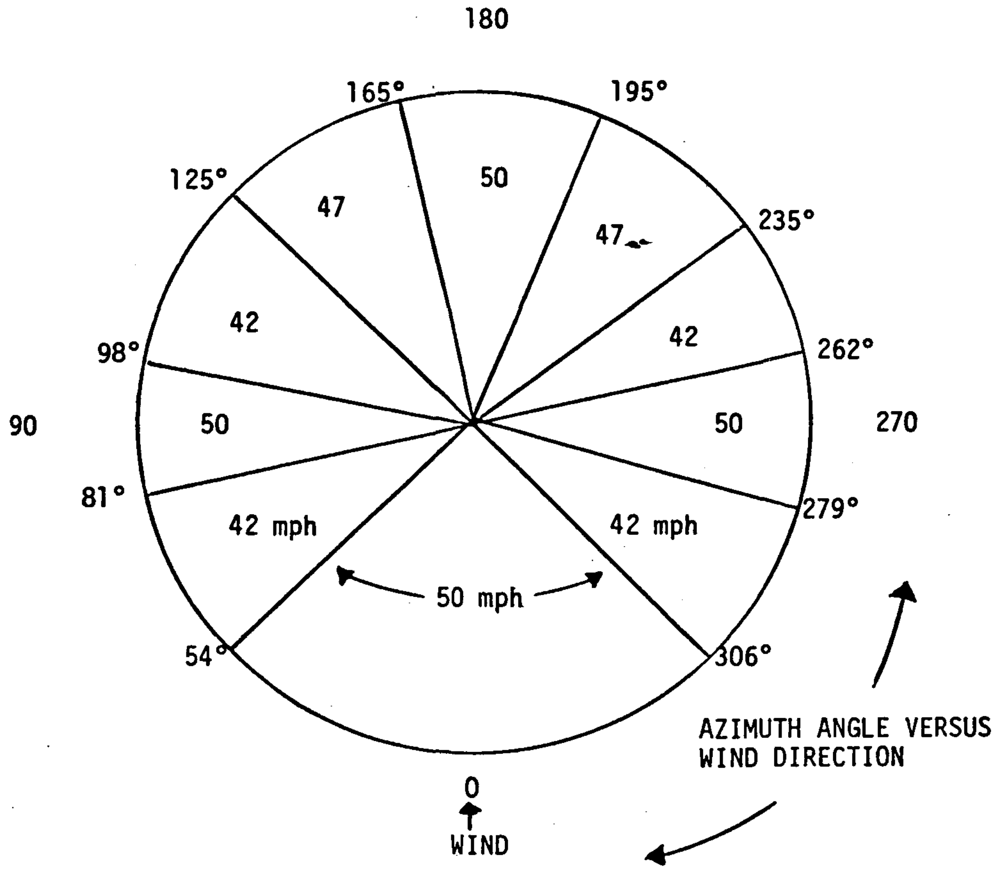
HORIZONTAL STOW BEAM SAFETY ANALYSIS

The two scenarios for heliostat travel to horizontal stow are: movement from vertical stow to face-up, and movement from the receiver to face-up.

MOVEMENT OF HELIOSTATS FROM A VERTICAL STOW POSITION TO A FACE-UP STOW POSITION

The basic consideration for moving the heliostats from a vertical stow position to a face-up stow position are beam safety, both on the ground and in the air, not to increase the field wiring power requirement, and to reach the face-up position before the winds reach critical speed. MDAC movement scheme meets these requirements by using the following basic procedure:

1. No more than three heliostats per HFC will start moving each second.
2. Only the elevation motor will be used.
3. In vertical stow, all heliostats north of the south field singularity line will be facing south and all heliostats south of singularity line will be facing north.



NOTE: This applies for elevation angles between 55° and 90°. For elevation angles less than 55°, a greater than 50 mph capability exists.

Figure A3-1. Azimuth Drive Wind Speed Capability Versus Azimuth Angle, Delivered Prototype

4. The beam centerline of each heliostat will be at least 0.5 degrees different from each adjacent heliostat.
5. For the north field, movement of north most heliostats will be initialized first. The starting heliostats will be approximately along an east-west line and this line will progress in a southerly direction.
6. Three rows of heliostats around the north side of the tower control building area will be left vertical, until beams have cleared the ground, to provide blocking.
7. Three to four rows of heliostats along the east-west road will be left vertical to provide blocking.
8. Three to four rows of heliostats south of the singularity line will be left vertical to provide blocking. These heliostats are used to block beams from north facing heliostat from crossing the east-west road to block beams from leaving the area on the ground.

As a means of illustrating this procedure, the 10 MWe Pilot Plant field has been used as shown in Figure A3-2. The cross-hatched regions contain heliostats used to block beams on the ground. The field is divided into three sections as shown in Figure A3-1; north-west, middle-east, and south-east. Initial heliostat movement starts in each of these three sections as determined by the lines AA, BB and CC. As these lines move in the direction shown, heliostats that are near the line are commanded to move in elevation only. The numbers near the heliostats in the north field of Figure A31 illustrated the sequence in which the heliostats would be commanded.

The blocking heliostats are not moved until the beams from all the other heliostats are above the ground. The heliostat elevation angle, as a function of time, is shown in Figure A3-3. Assuming a sun elevation of 80°, the heliostat would take 152 seconds to reach 40° which would make the beams horizontal.

The number of heliostats that are in transition are shown in Figure A3-4. After 140 seconds, all of the heliostats are in transition except the blocking heliostats. At 150 seconds after the initial command, the first beams, assuming a

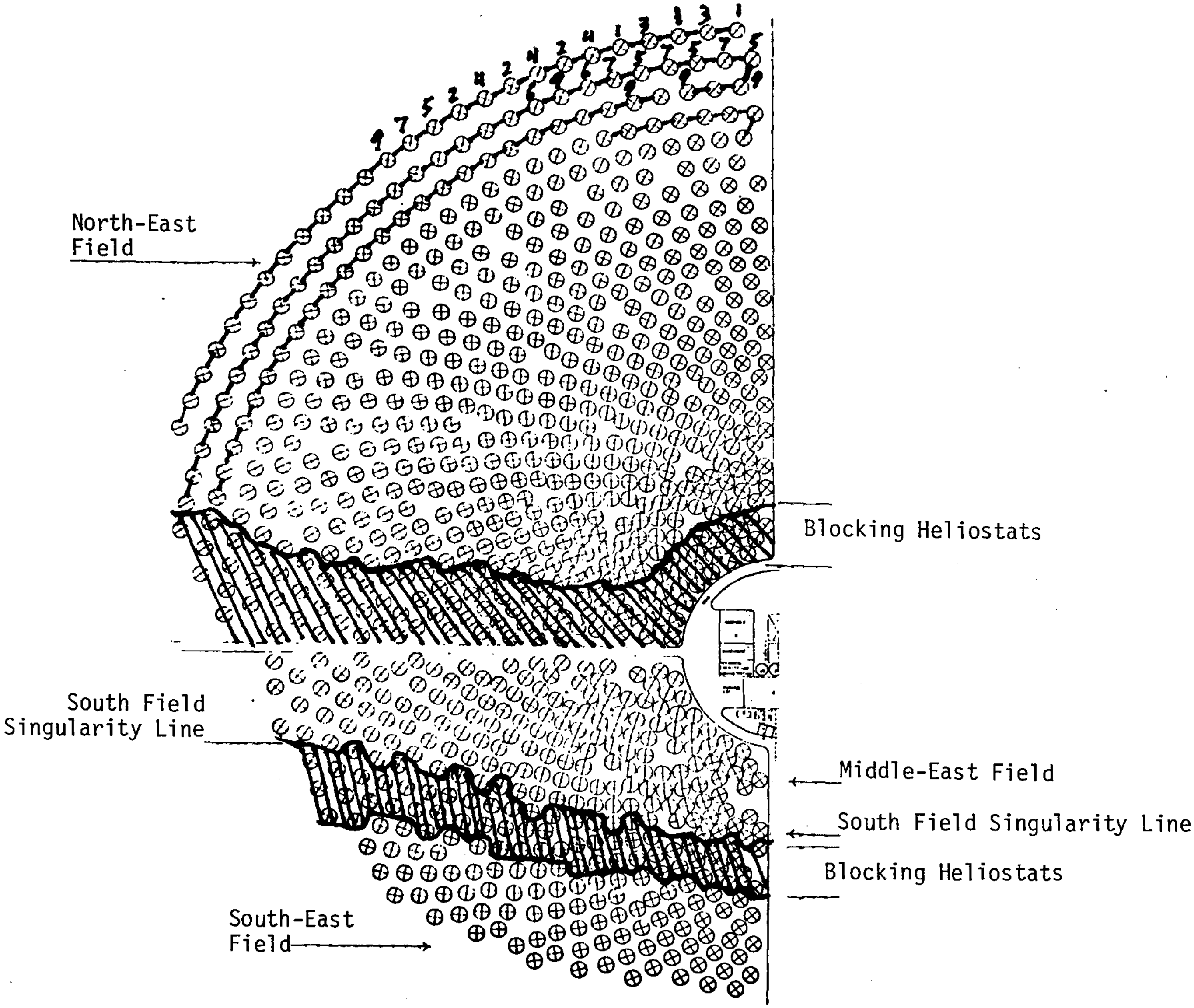
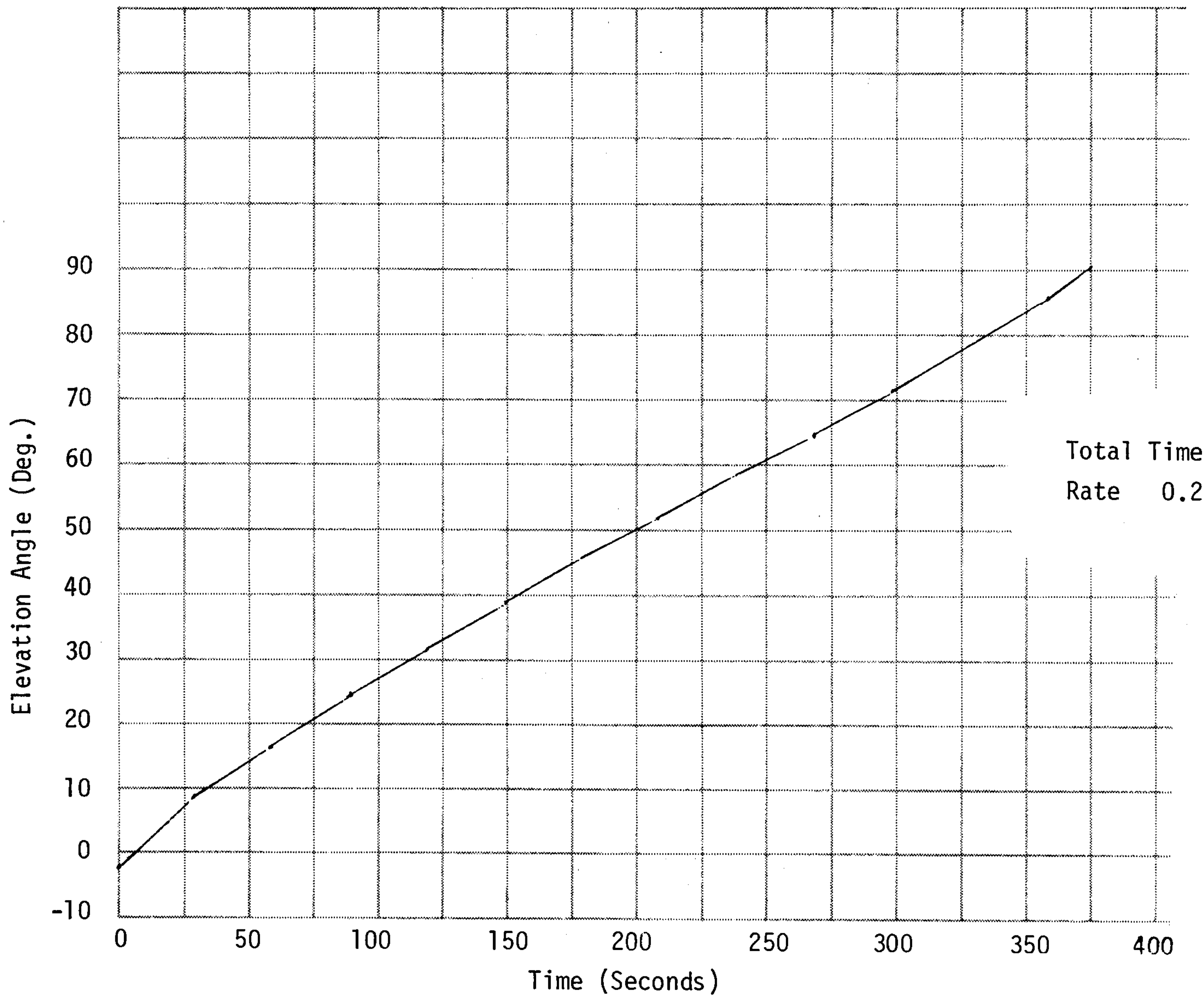


Figure A3-2. Blocking Scheme



Total Time for 90° = 374 Sec

Rate 0.247°/S = 4.3 mr/s

Figure A3-3. Elevation Angle Versus Time

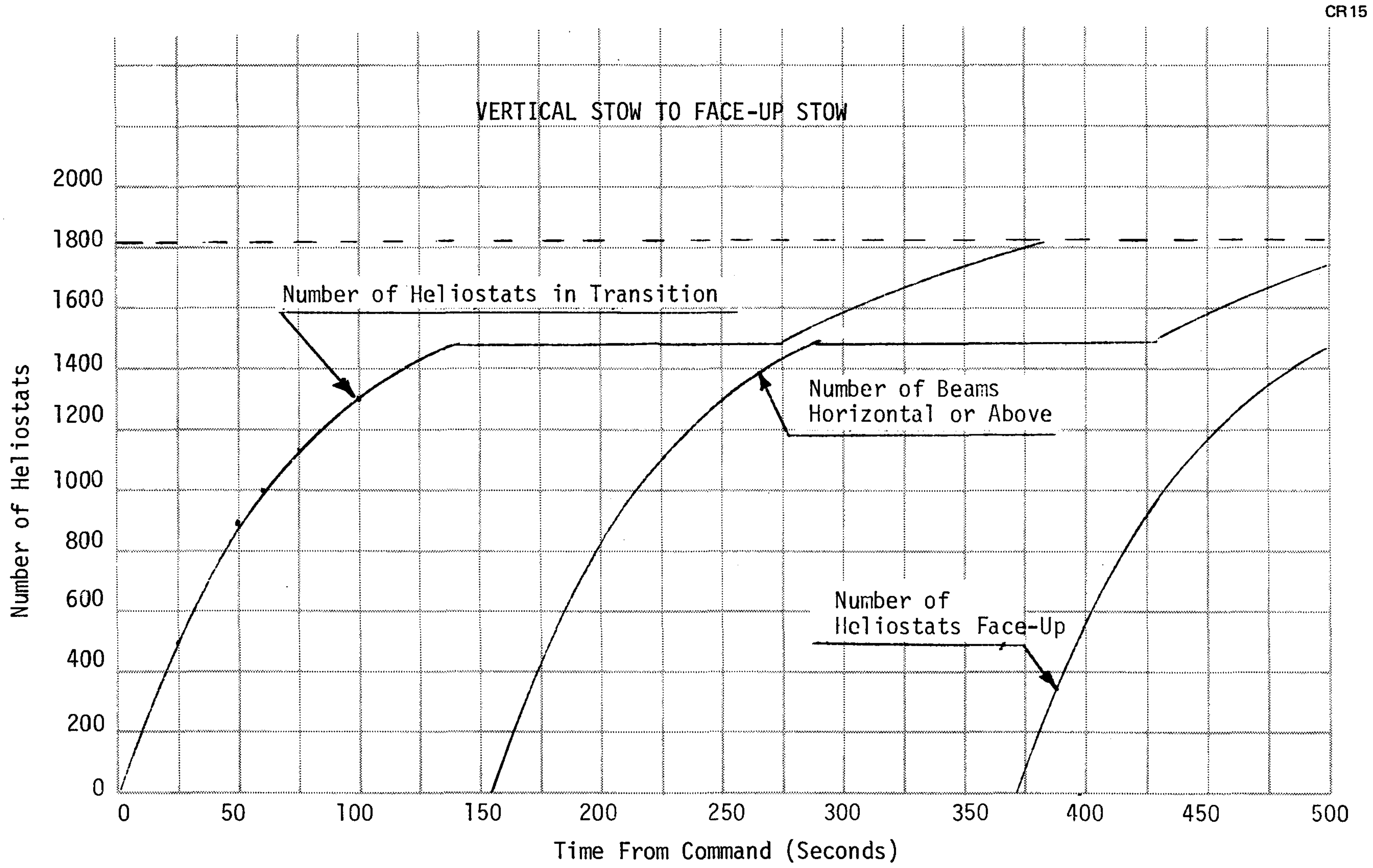


Figure A3-4. Heliostats in Transition

sun elevation of 80°, reach a horizontal position. By 290 seconds, all beams have reached a horizontal position or above; therefore, the blocking heliostats can be commanded to move. As shown in Figure A3-4 and Figure A3-5, the first heliostats reach face-up stow about 370 seconds and all of them have reached face-up stow by 760 seconds or 126 minutes.

In order to achieve these times, the number of heliostats that must be commanded each second are shown in Figure A3-6. The time it takes to command each heliostat is shown in Table 1 as 26 ms. Assuming for the moment that all HFCs are on the same trunk line, the communication time required each second is shown by the bars in Figure A3-5. As this figure shows, for the majority of the time, less than 50% of the time line is used. Most likely there would be at least 4 HFC trunk lines. The dotted lines in Figure A3-5 show the required time line assuming 4 HFC trunk lines. In this case, the average time line used would be less than 0.3 seconds each second.

Even though this scheme meets the wind requirement, beam safety requirements and minimize the required power, there are several things which could be done without sacrificing the above reuqirements to decrease the time even more.

MOVEMENT OF HELIOSTATS FROM RECEIVER TO A FACE-UP STOW POSITION

The first step in this situation would be to command all heliostats from the receiver to standby. In the current design, this would be done at a rate of 3 heliostats per HFC per second. For a 50 MW field, it would take about 60 seconds before all heliostats were moving. Once all heliostats have reached standby, a sequence would be used to command them to face-up stow. This sequence would be very similar to that used in going from a vertical stow position to face-up stow except a longer delay sequence would be used in starting between adjacent heliostats. This would give a chance for the beams from back heliostats to separate from adjacent heliostats. Since the heliostats are already at a high elevation angle (15-80°), the total time to reach face-up would still be in the 12 minute time frame.

Since the beams will not cross the ground, there is no ground beam safety problem. An in-depth analysis of the air space has not been done, but MDAC

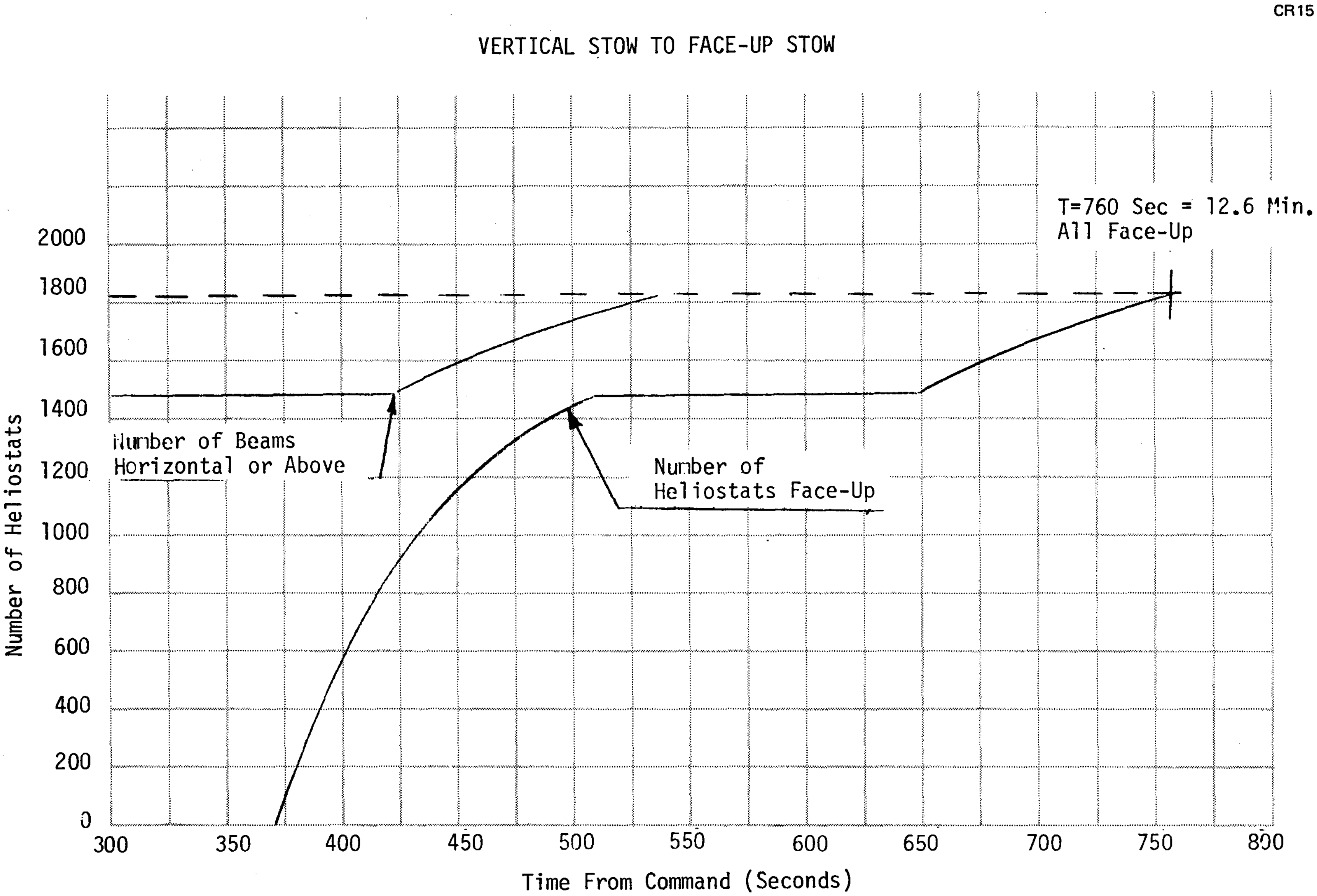
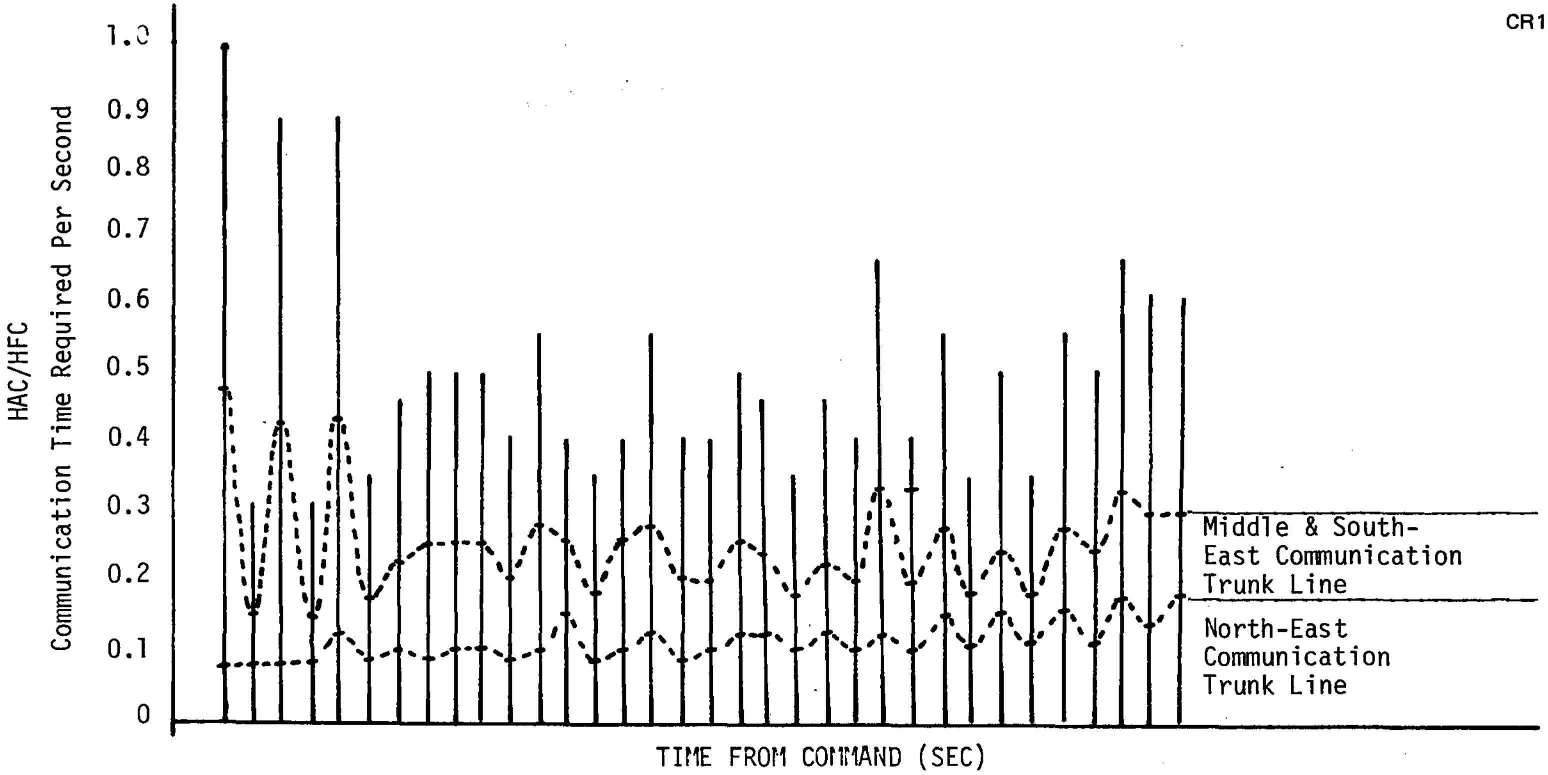


Figure A3-5. Time to Stow



Time	0		2		4		6		8		10		12		14		16		18		20		22		24	
North-East		3	3	3	3	5	3	4	3	4	4	3	4	6	3	4	5	3	4	5	5	4	5	4	5	4
Middle-East		11	0	9	0	8	0	5	0	6	0	5	0	4	0	6	0	5	0	5	0	3	0	4	0	4
South-East		5	3	5	3	4	4	0	7	0	6	0	7	0	4	0	6	0	4	0	4	0	4	0	8	0
Total		19	6	17	6	17	7	9	10	10	10	8	11	10	7	10	11	8	8	10	9	7	9	8	13	8

Time	26		28		30		32		34		36		38		40		42		44		46		48		50
North-East	6	4	6	4	6	4	7	5	7	4	5	5	6	3	8	6	5	7	6	5	5	7	7	7	3
Middle-East	0	3	0	3	0	6	0	7	0	7	0	6	0	3	0	0	0	0	0	0	0	0	0	0	0
South-East	5	0	4	0	5	0	6	0	5	0	2	0	1	0	0	0	0	0	0	0	0	0	0	0	0
Total	11	7	10	7	11	10	13	12	12	11	7	11	7	6	8	6	5	7	6	5	5	7	7	7	3

Number Commanded Each Second on East Half of Field

Figure A3-6. Command Times

feels that the keep out altitude would increase very little, if any, over that required for normal standby. The keep out or safety altitude is normally defined by the unsafe beam intensity around the standby aimpoint or the transition from receiver to standby. When allowances are made for control movement, pointing error and wind movement, and a marginal safety is added on, it is felt that the heliostats can be moved vertical from standby in small groups without increasing the safe altitude and still meet the required time.

Appendix B
COMPONENT TESTS

Appendix B-1
FULL-SCALE MIRROR MODULE TESTS

1.0 TEST SPECIMENS

The tests described in this appendix were performed on full size mirror modules.

2.0 TEST REQUIREMENTS

The mirror module used on the MDC Second Generation Heliostat embodies several features requiring test demonstration. These features are: surface control in the long and short direction, and surface curvature sensitivity to temperature.

Additionally, it is desirable to demonstrate the durability of the mirrored surface protection and the capability to survive the environmental exposure.

2.1 TEST OBJECTIVES

Objectives of the mirror module test are to demonstrate the following:

- The environmental exposure tests will demonstrate that the mirror modules can survive long term exposure to typical desert and marine environments.
- The thermal distortion test and cold water shock test will demonstrate that the curvature changes experienced at operational temperature extremes due to the differential expansion or contraction of the steel and glass components will provide cost effective performance. It will also demonstrate that cold water sprayed on a hot mirror module will not cause damage.
- The thermal cycle tests will demonstrate that the mirror module is unaffected by repeated exposure to cycling between anticipated temperature extremes.

2.2 ENVIRONMENTAL EXPOSURE TESTS

2.2.1 General

2.2.1.1 Test Location

a. Desert Exposure. One mirror module will be exposed to a desert environment at Fort Irwin, California.

b. Marine Exposure. One mirror module will be exposed to a marine environment at MDAC's Solar Energy Test Facility at Huntington Beach, California.

2.2.1.2 Test Setup

The mirror module will be attached to an exposure rack through the mirror modules 4 attachment points. The mirror surface shall be horizontal ±10 degrees and facing upwards.

2.2.1.3 Instrumentation

A Wyler mini-level shall be used to measure slope data at the locations shown in Figure B1-1.

2.2 ENVIRONMENTAL CONDITIONS

The mirror modules will be exposed to the natural weather conditions at the two test locations.

2.2.3 Success Criteria

The mirror modules will be considered to have successfully completed testing if:

Both the desert and marine exposure produces no visual evidence of damage or degradation to the test specimen.

2.3 THERMAL DISTORTION TEST AND COLD WATER SHOCK TEST

2.3.1 General

2.3.1.1 Test Location

This test will be conducted at the Structures and Environments Laboratory, Building 30, of MDAC's Huntington Beach facility.

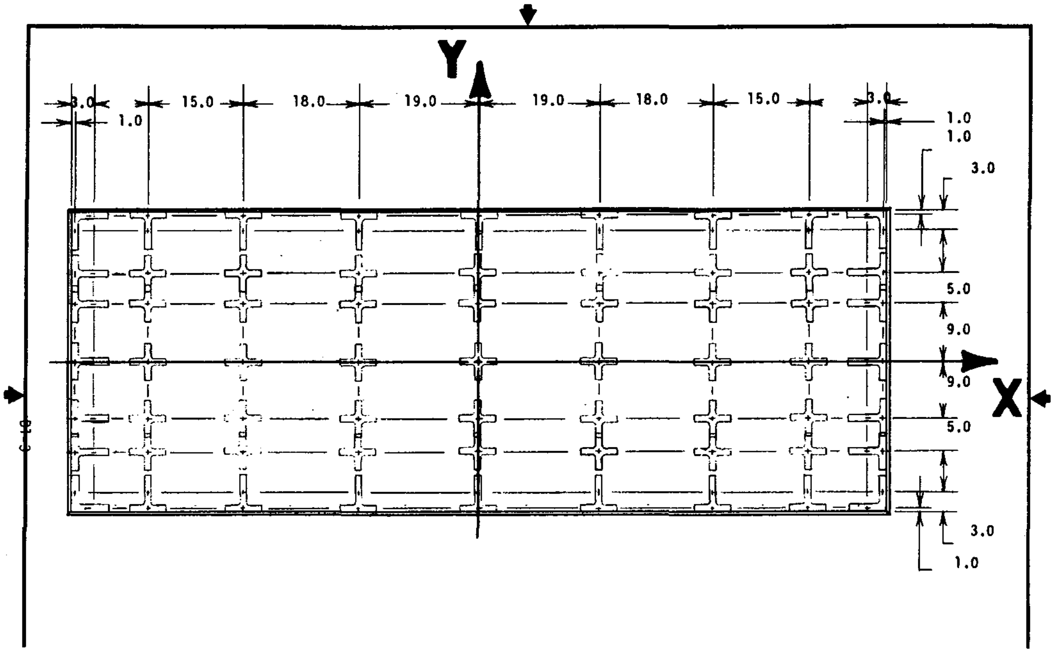


Figure B1-1. Slope Measurement Locations

2.3.1.2 Test Setup

A mirror module will be set up within an environmental chamber capable of providing the conditions required. The module shall be supported at its four attachment points, but not restrained from expansion. A means of leveling the mirror module must be provided so that the center point can be adjusted to a level position prior to taking slope data at each temperature required.

2.3.1.3 Instrumentation

A Wyler mini-level shall be used to measure slope data.

2.3.1.4 Data Reduction

Slope data in milliradians versus position will be provided for the two mirror module axes, along the length and along the width, for each temperature condition.

2.3.2 Environmental Conditions

The chamber will be operated to obtain temperatures of 77°F, 32°F, and 122°F. Slope measurements of the mirror module will be made at each temperature after the temperature has been maintained at the temperature for a minimum of one hour. Upon conclusion of the slope measurements at 122°F, five gallons of cold water at 60°F shall be thrown onto the mirror module surface.

3.1 PROCEDURE

3.2 ENVIRONMENTAL EXPOSURE TESTS

3.2.1 Inspect the marine environment mirror module test specimen at one month intervals until the conclusions of the test period in December 1980. Record observations.

3.2.2 Inspect desert environment mirror module test specimen in August 1980, and at the test conclusion in December 1980, and at any other times when MDAC personnel are visiting the Fort Irwin site. Record observations.

3.2.3 With the mirror modules level in both directions at their center point, obtain slope measurements for both directions when the mirror modules are installed in their test setup and at the test conclusion in December 1980. Perform these measurements for both the marine and desert environment test specimen.

3.3 THERMAL DISTORTION TEST AND COLD WATER SHOCK TEST

3.3.1 Mark locations to be measured.

3.3.2 Turn on and operate environmental chamber until a temperature of 77°F is obtained.

3.3.3 After soaking at 77°F for one hour, level the mirror module center point in both coordinate directions.

3.3.4 Obtain slope measurements.

3.3.5 Lower temperature in the chamber to 32°F.

3.3.6 After soaking at 32°F for one hour, level the mirror module center point in both coordinate directions.

3.3.7 Obtain slope measurements.

3.3.8 Raise the temperature to 122°F.

3.3.9 After soaking at 122°F for one hour, level the mirror module center point in both directions.

3.3.10 Obtain slope measurements.

3.3.11 Throw five gallons of cold water at 60°F ± 5°F on mirror module.

3.3.12 Record results.

3.4 THERMAL CYCLE TEST

3.4.1 Set up chamber to perform the following cycle automatically: lower temperature to -22°F, soak at -22°F for one half hour, raise temperature to +122°F, soak at 122°F for one hour. The cycle should be repeated every six hours or less for a two week period.

3.4.2 Using the same setup in the thermal distortion test, begin cycling.

3.4.3 Every other day, enter chamber during ambient conditions and inspect for damage. Record observations, if any.

3.4.4 At the end of the two week period remove mirror module and inspect for damage or deterioration. Record observations.

4.0 RESULTS

4.1 PRETEST OPERATIONS AND CHECKOUT

4.1.1 The test specimens were installed into their respective test setups. Figure B1-2 is a photograph of the thermal cycle test setup. Figures B1-3 and B1-4 are photographs of the desert exposure test setup. Figures B1-5 and B1-6 are photographs of the marine exposure test setup.

4.1.2 Equipment used during the testing is as follows:

Description	Mfg/Model	Tag No.
Temperature Chamber -100°F +300°F	Inreco 10108T	NASA 057150
Mini-level	Wyler	MDAC 790212
Dial Indicator	Starrett 25-441	DID 640, 371, 639, 380, 649, 382, 648 384 and 378

4.1.3 Fabrication acceptance slope measurement data is included in Figures B1-7 through B1-18 as follows:

S/N 07 (Temp Cycle Specimen)	B1-7 through B1-10
S/N 08 (Temp Cycle Specimen)	B1-11 through B1-13
S/N 09 (Temp Cycle Specimen)	B1-14 through B1-15
S/N 06 (Orig Marine Exposure Specimen)	B1-16
S/N 035 (Replacement Marine Exposure Specimen)	B1-17
S/N 044 (Desert Exposure Specimen)	B1-18.

4.2 ENVIRONMENTAL EXPOSURE TESTS

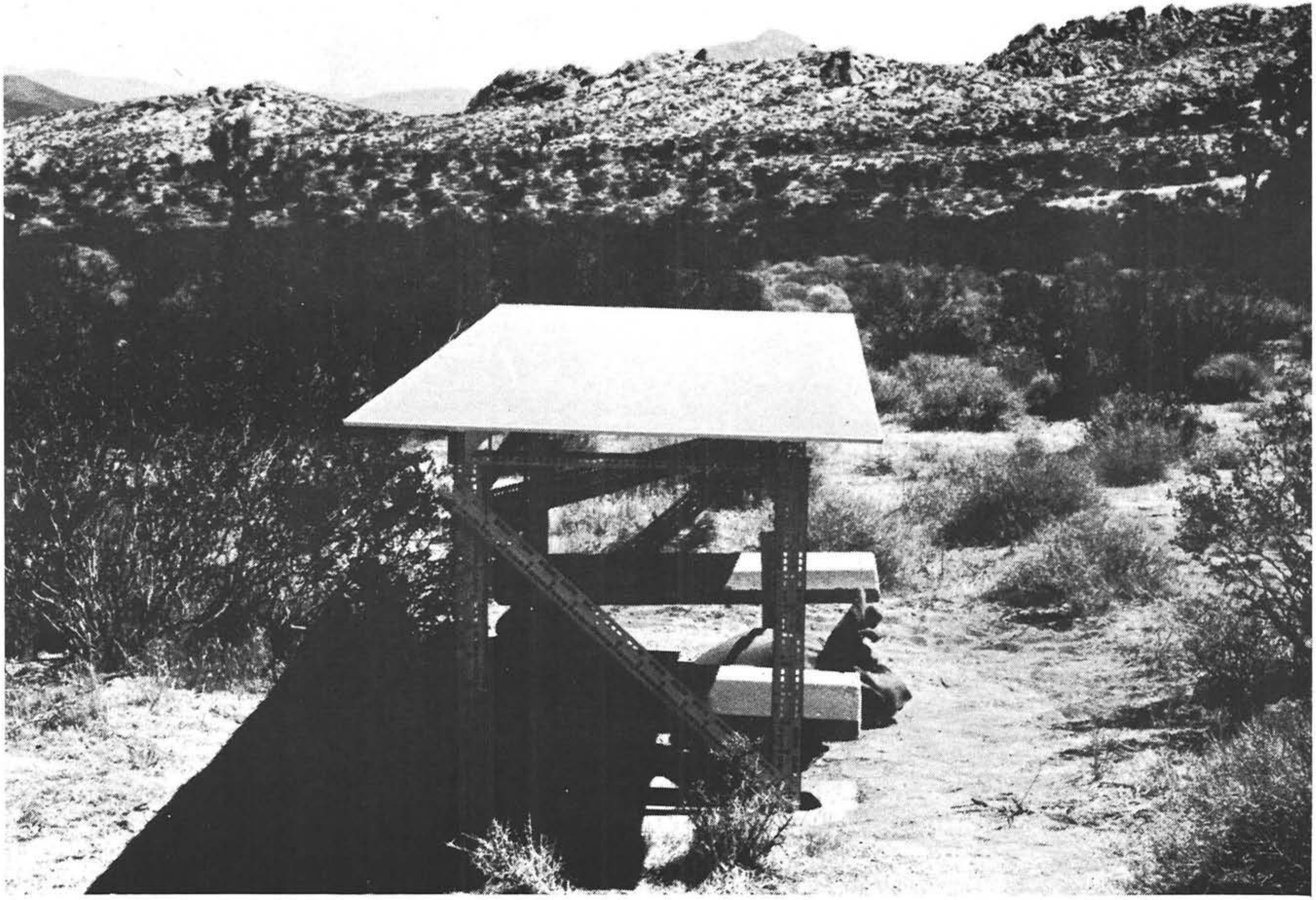
Further inspections will be made.

4.2.1 The marine environment specimen (S/N 06) had no visual defects at the time of original placement on 17 July 1980. On 17 September 1980 the specimen was removed from the setup and a stiffener added. There were no visual defects at the time of reinstallation of the test specimen into the test setup on 23 September 1980. On 23 October 1980 S/N 06 was removed from the test program and S/N 035 was substituted and measured on 5 November 1980.

4.2.2 The desert environment specimen SN044 had no visual defects at the time of original placement on 29 August 1980.

Figure B1-2. Thermal Cycle Test Setup

CR15



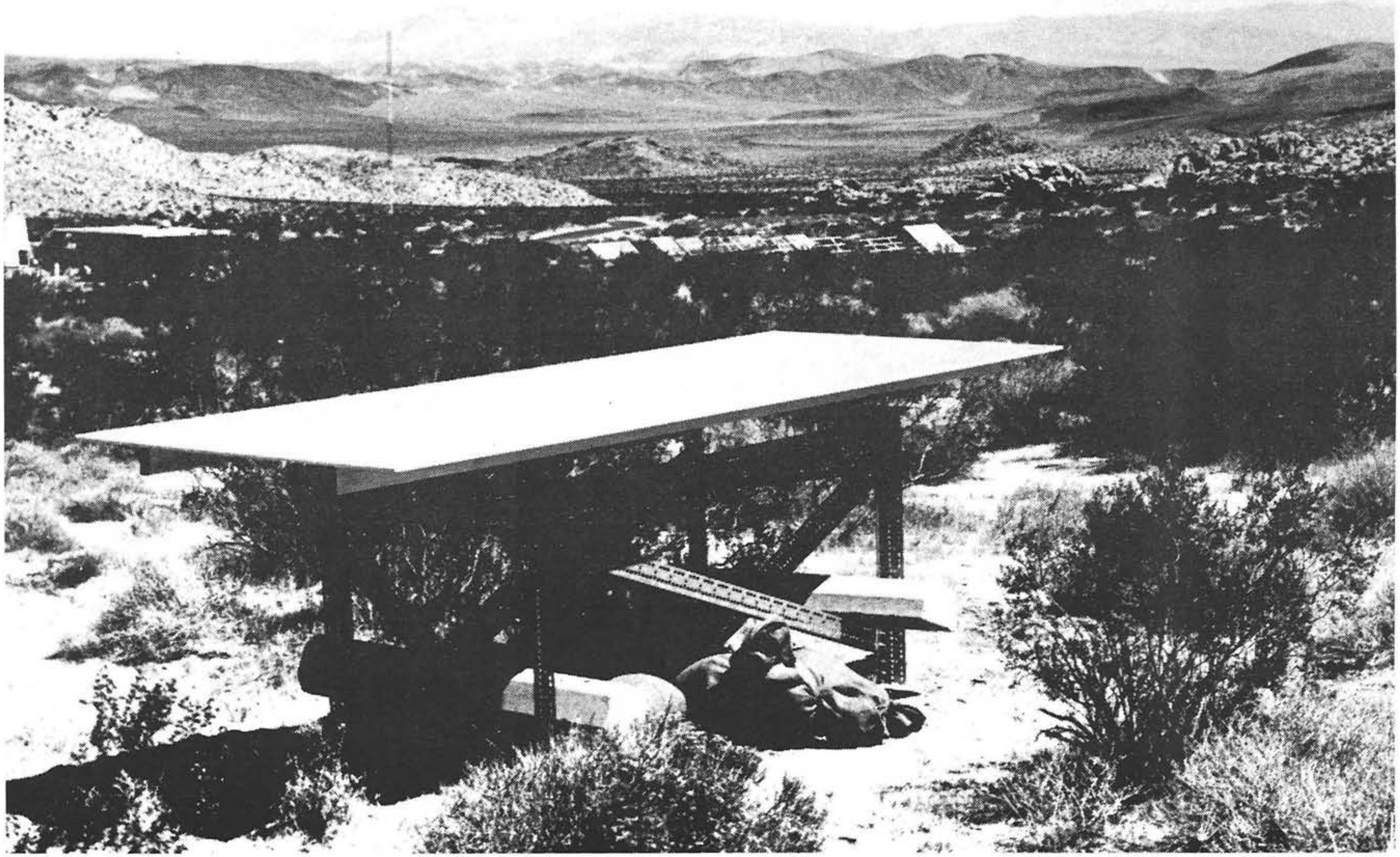


Figure B1-4. Desert Exposure Test Setup

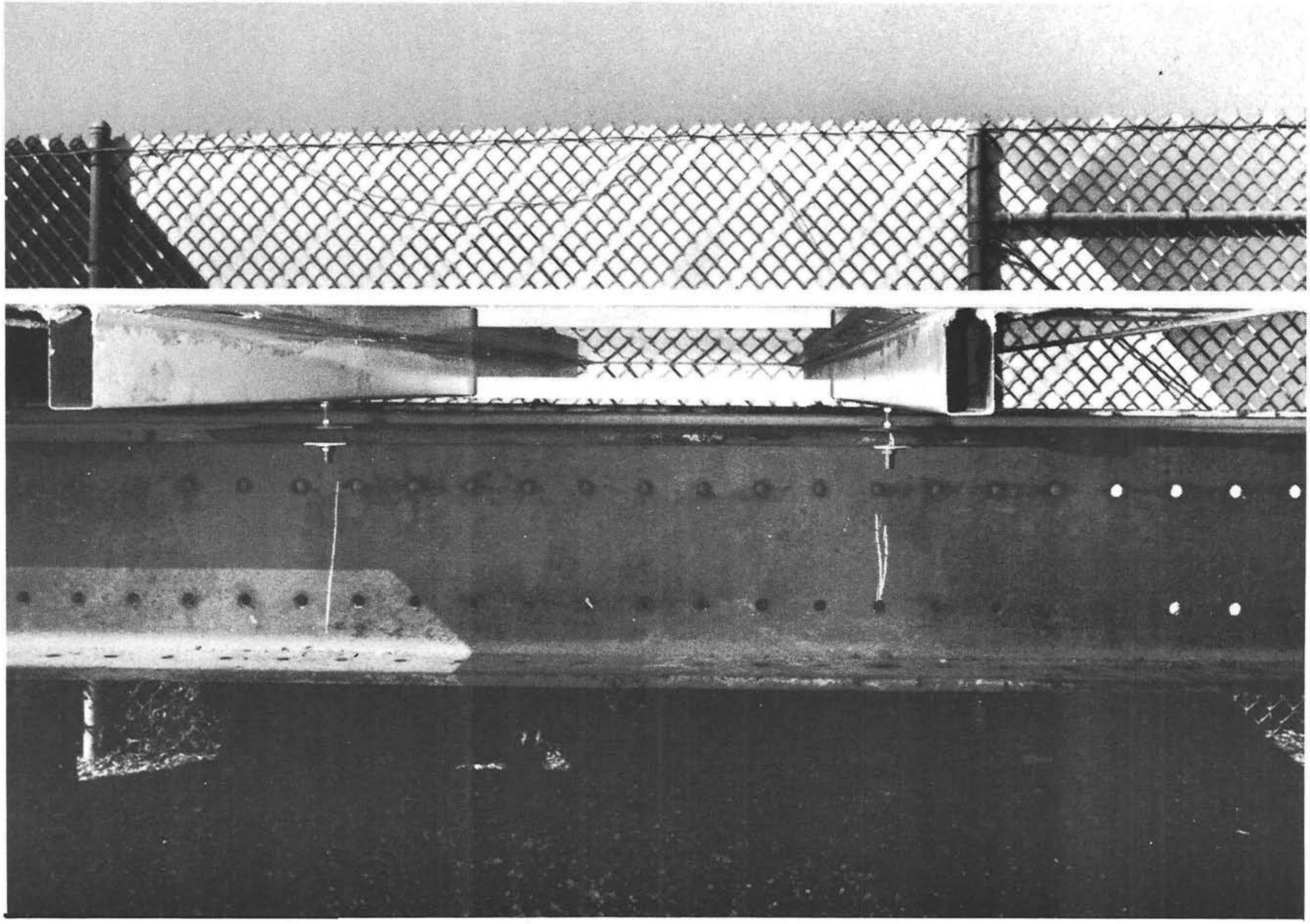


Figure B1-5. Marine Exposure Test Setup

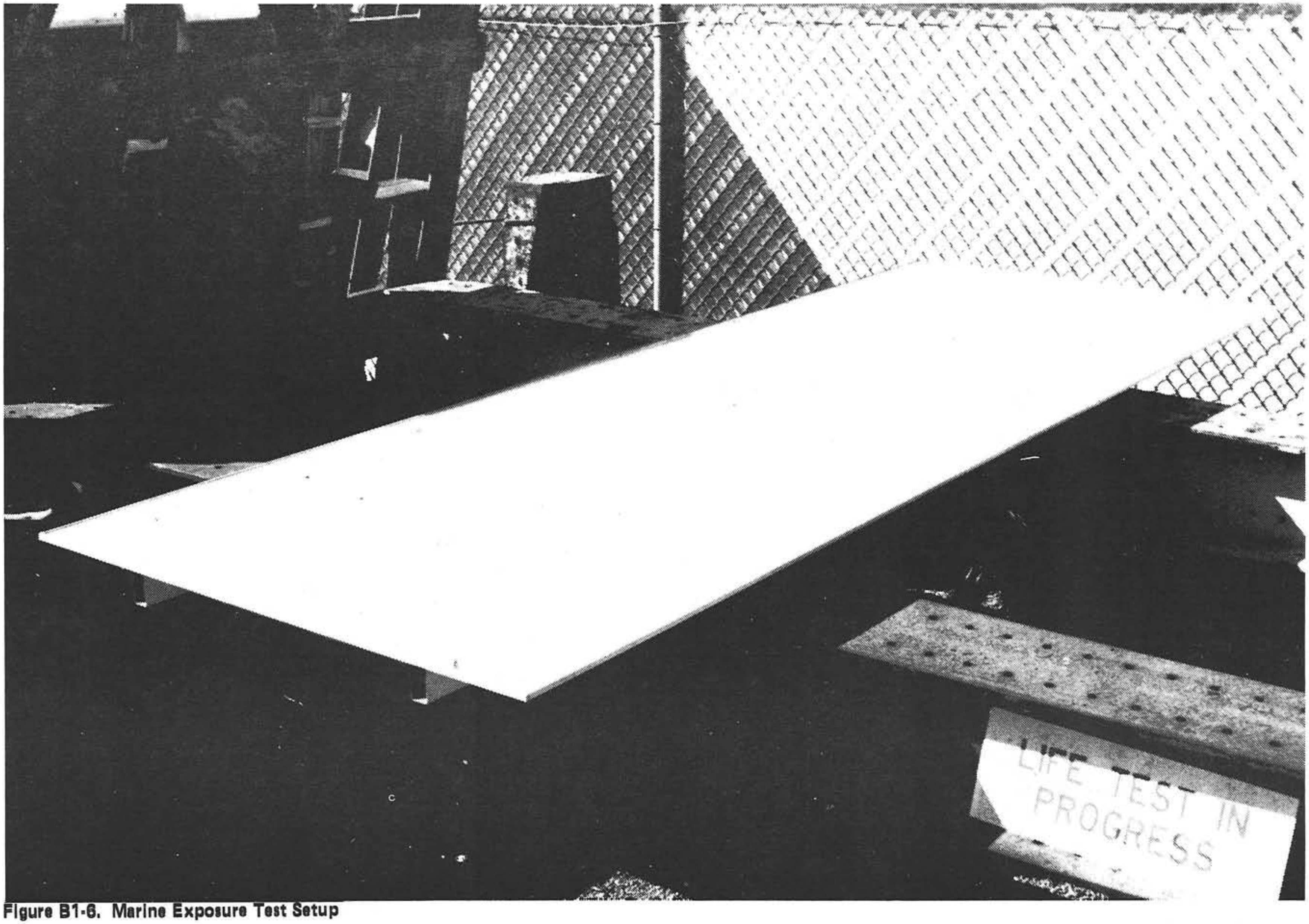
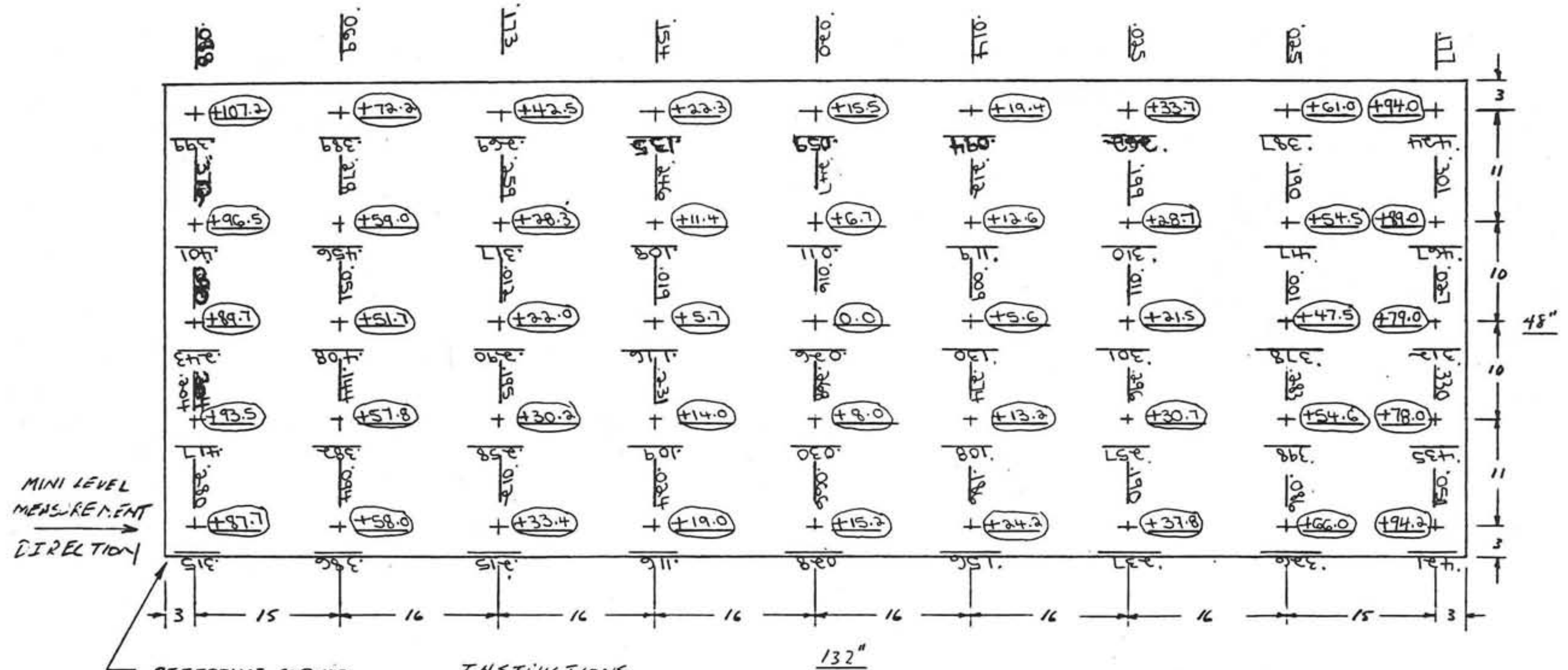


Figure B1-6. Marine Exposure Test Setup

FORM DATE 4/11/80
J. J. Dietrich

2ND GENERATION MIRROR MODULE MEASUREMENTS

DATE 6/24/0
MIRROR/PANEL SN 07
TEMPERATURE 70°



REFERENCE CORNER

MINI LEVEL MEASUREMENT DIRECTION

INSTRUCTIONS

1. LEVEL PANEL OVER FOUR SUPPORT POINTS - FLAT WITHIN .003"
2. MEASURE SLOPES IN BOTH DIRECTIONS AT GRID POINTS
3. MEASURE HEIGHT AT EACH GRID POINT - MARKED ○
4. RECORD DATA
5. RECORD PANEL ORIENTATION

BY [illegible]

Rev A 1T54042 A.3

Figure B1-7. Temperature Cycle Test

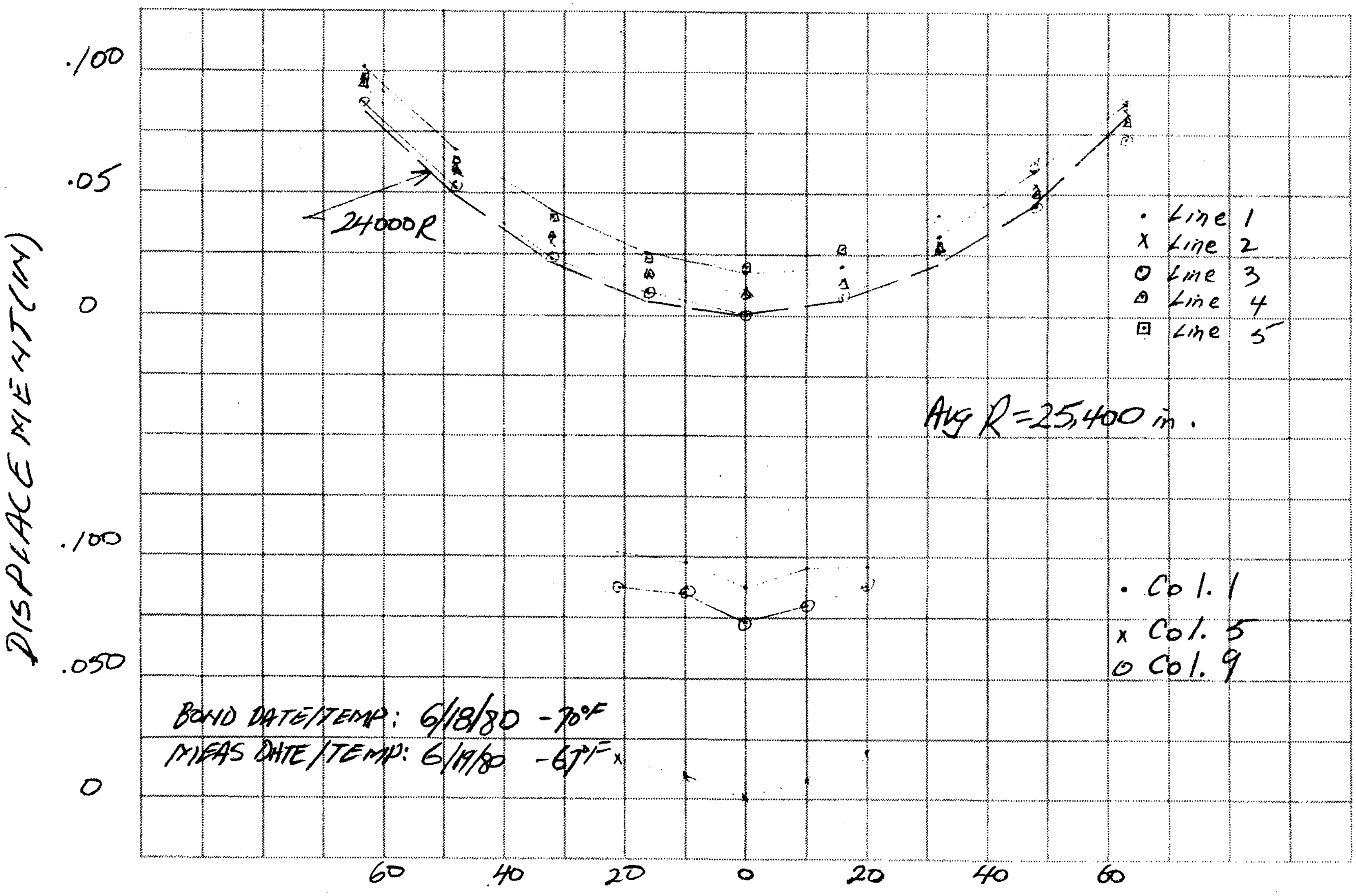


Figure B1-8. Mirror Module Contour SN07

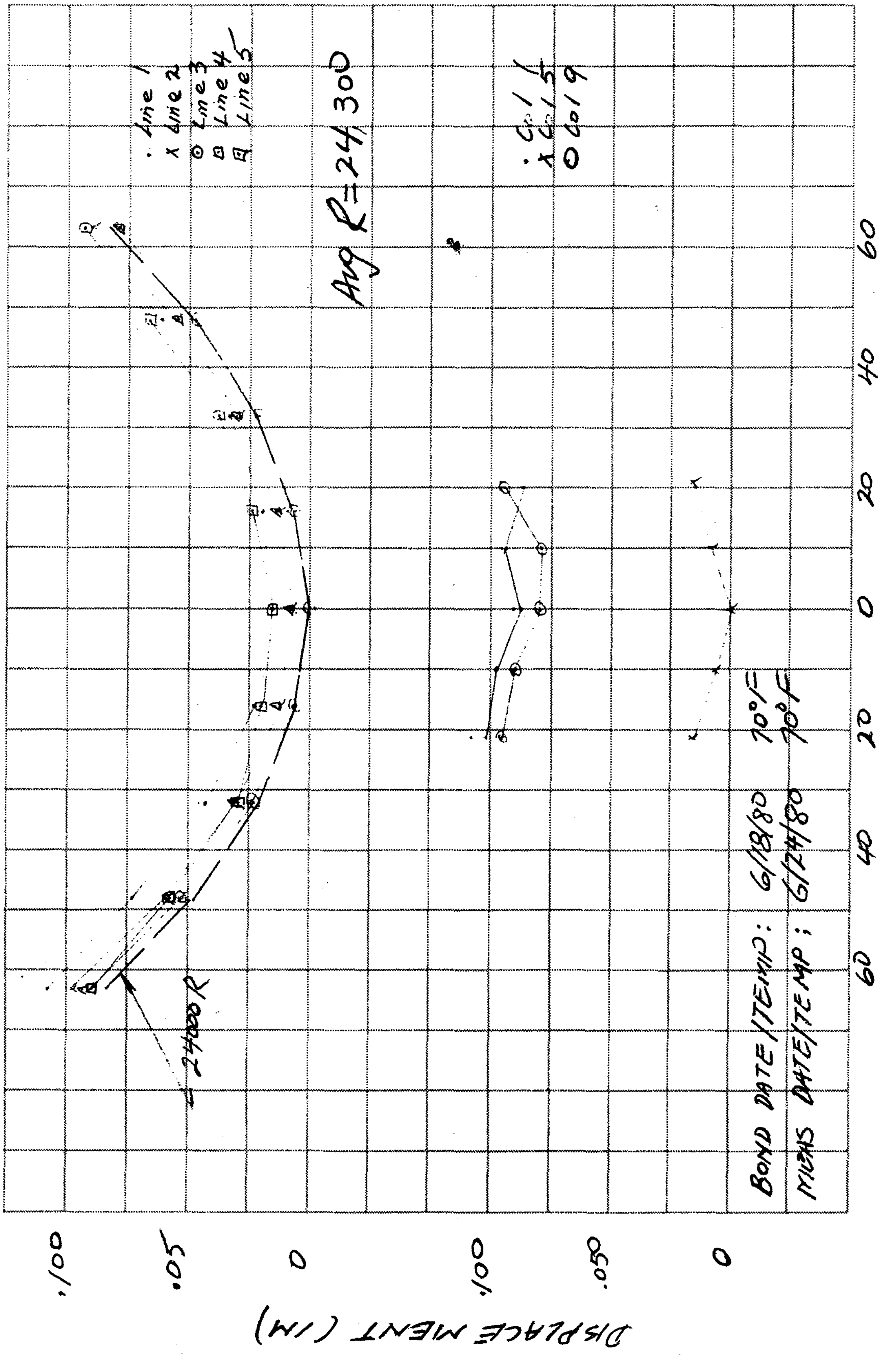


Figure B1-9. Mirror Module Contour SN07 After 6 Days

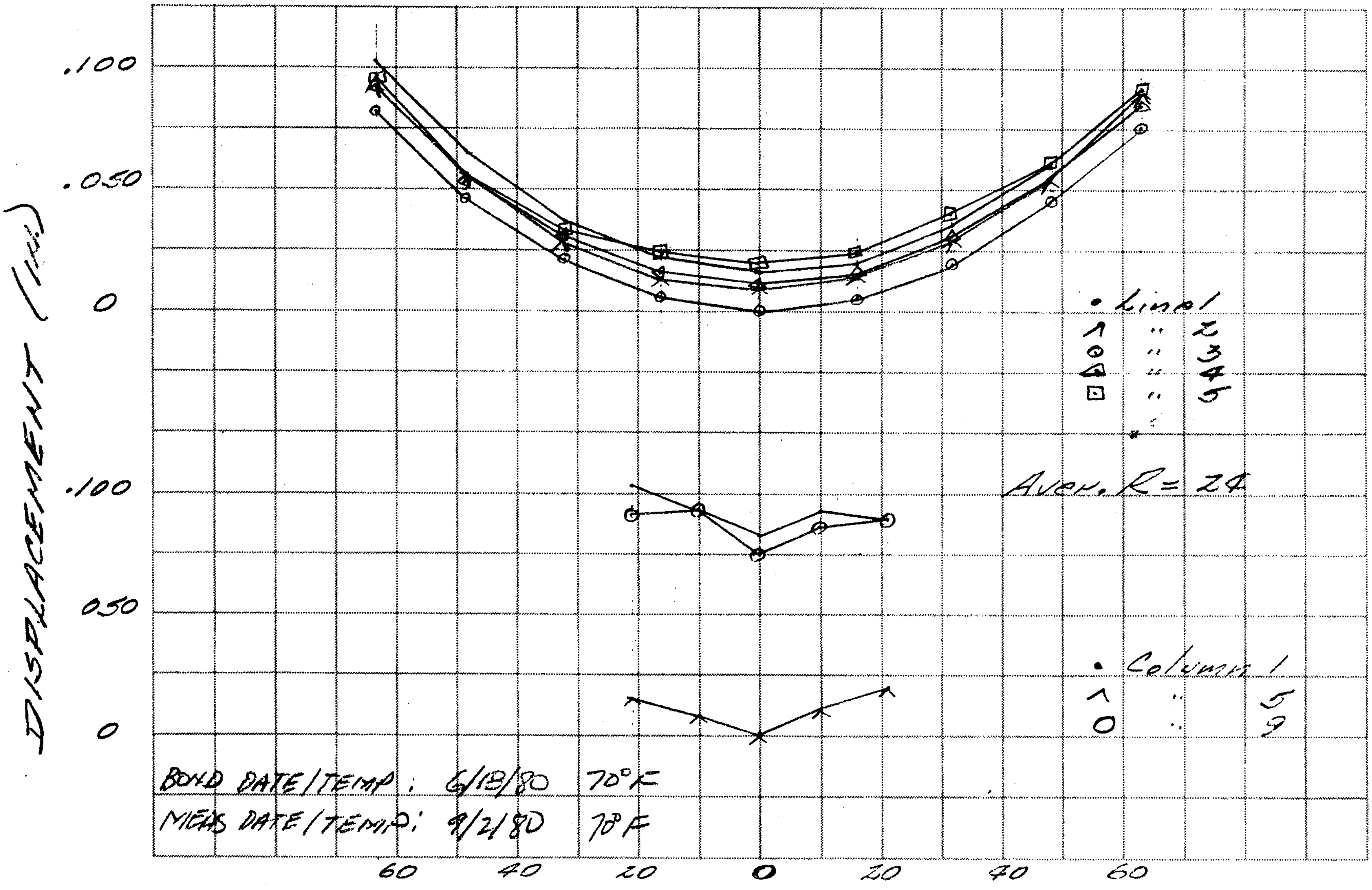


Figure B1-10. Mirror Module Contour SN07 After 80 Thermal Cycles

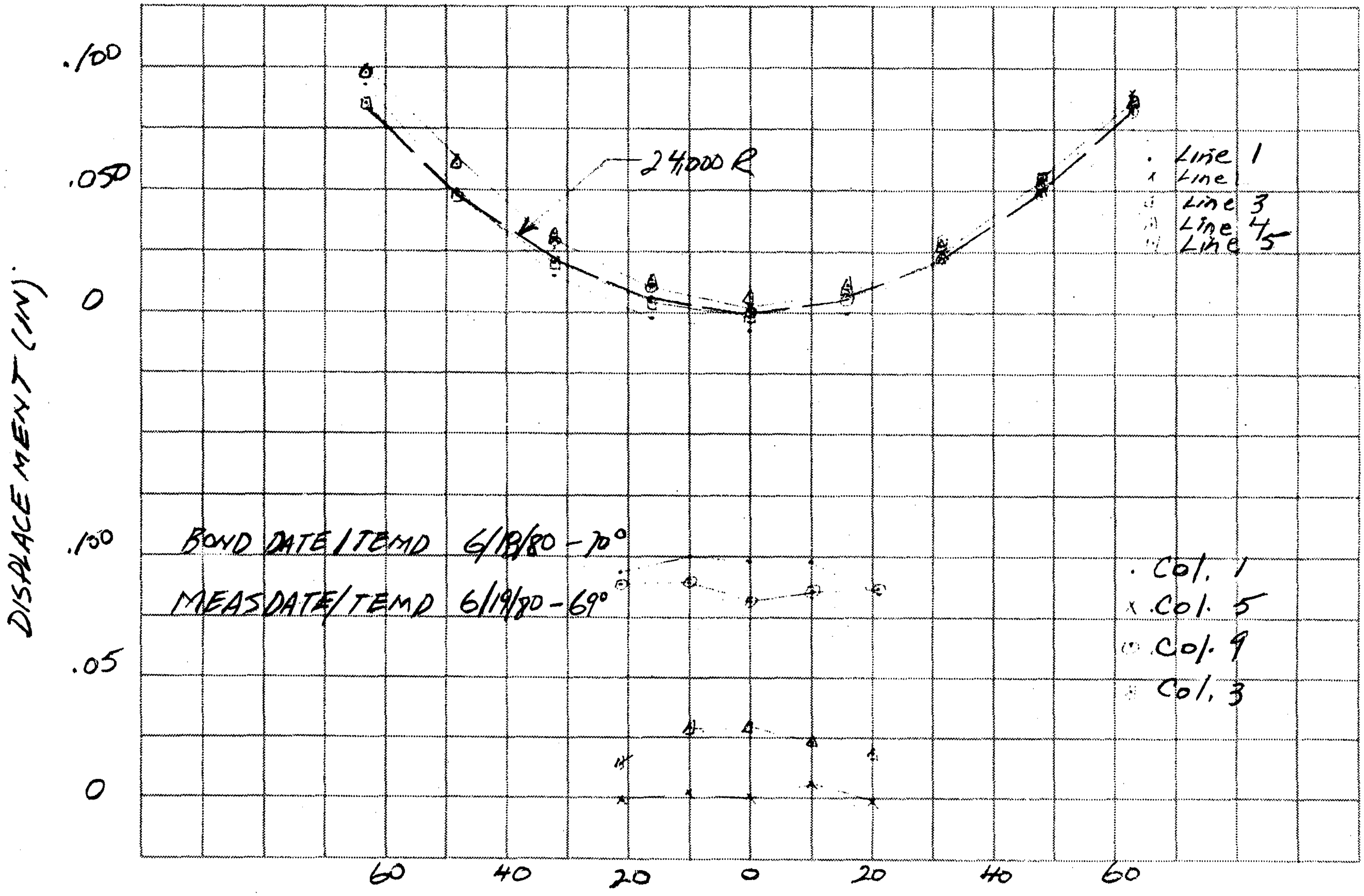


Figure B1-11. Mirror Module Contour SN08, Original Measurements

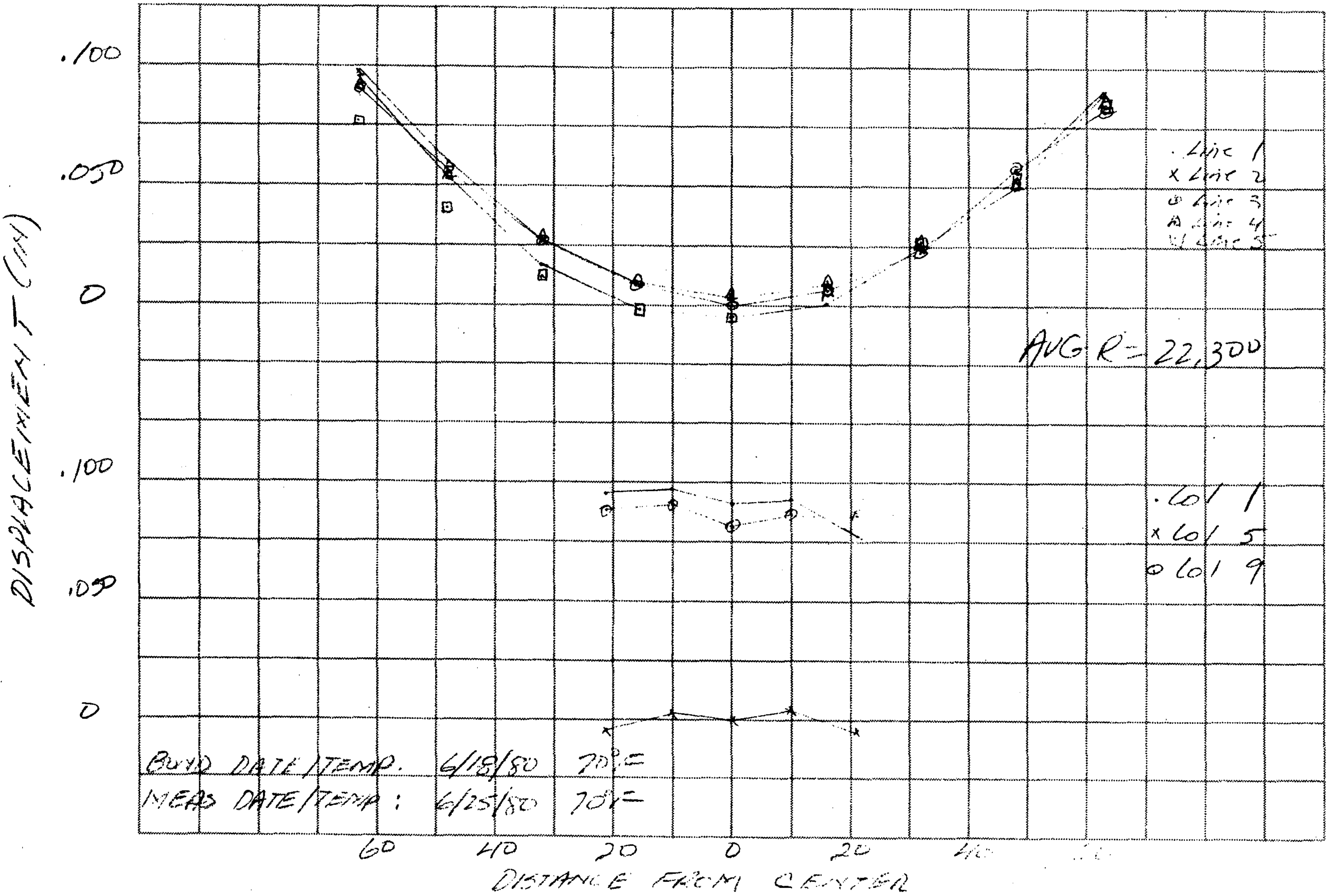


Figure B1-12. Mirror Module Contour SN08, Start of Test

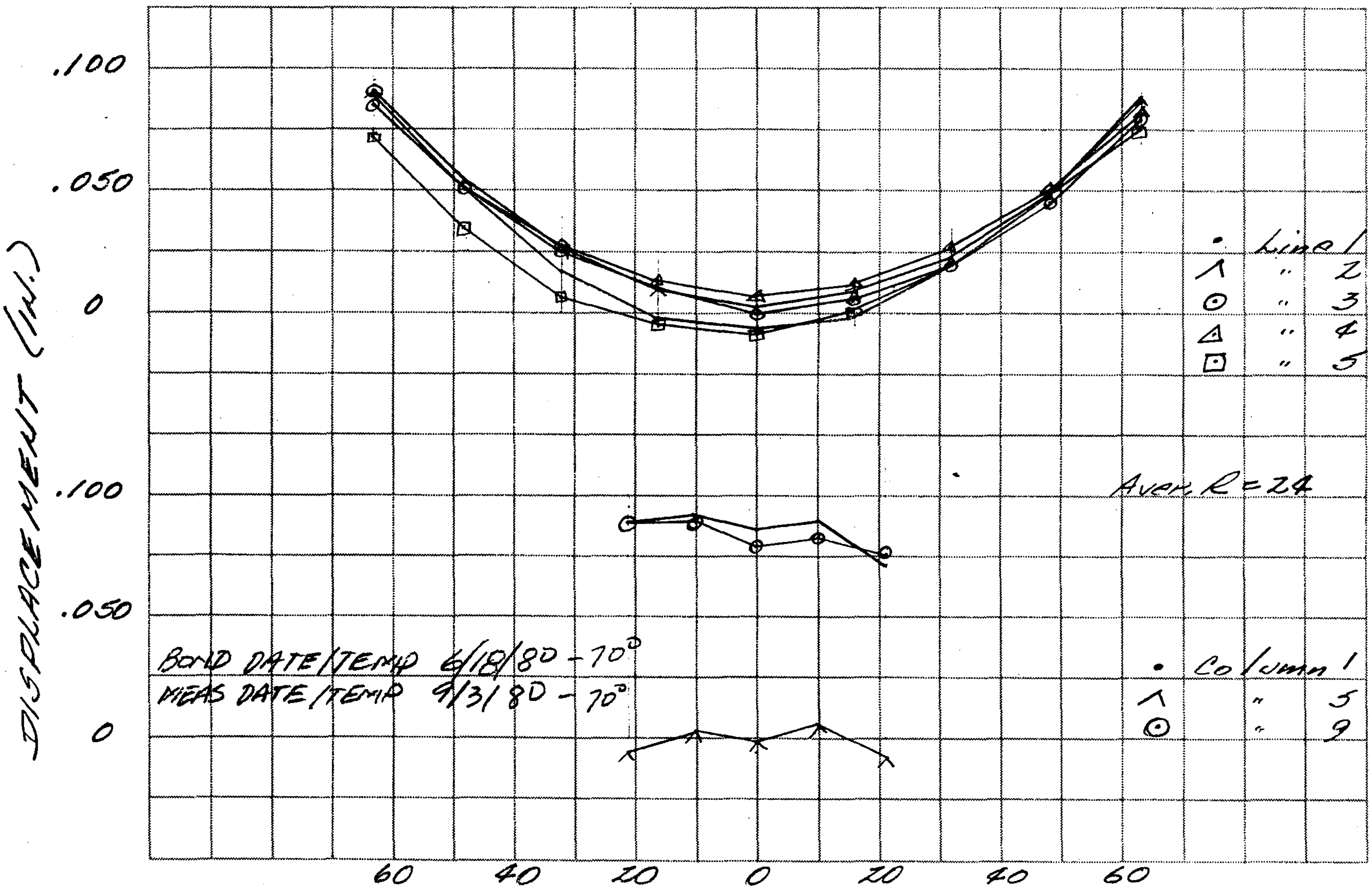


Figure B1-13. Mirror Module Contour SN08, Completion of Test

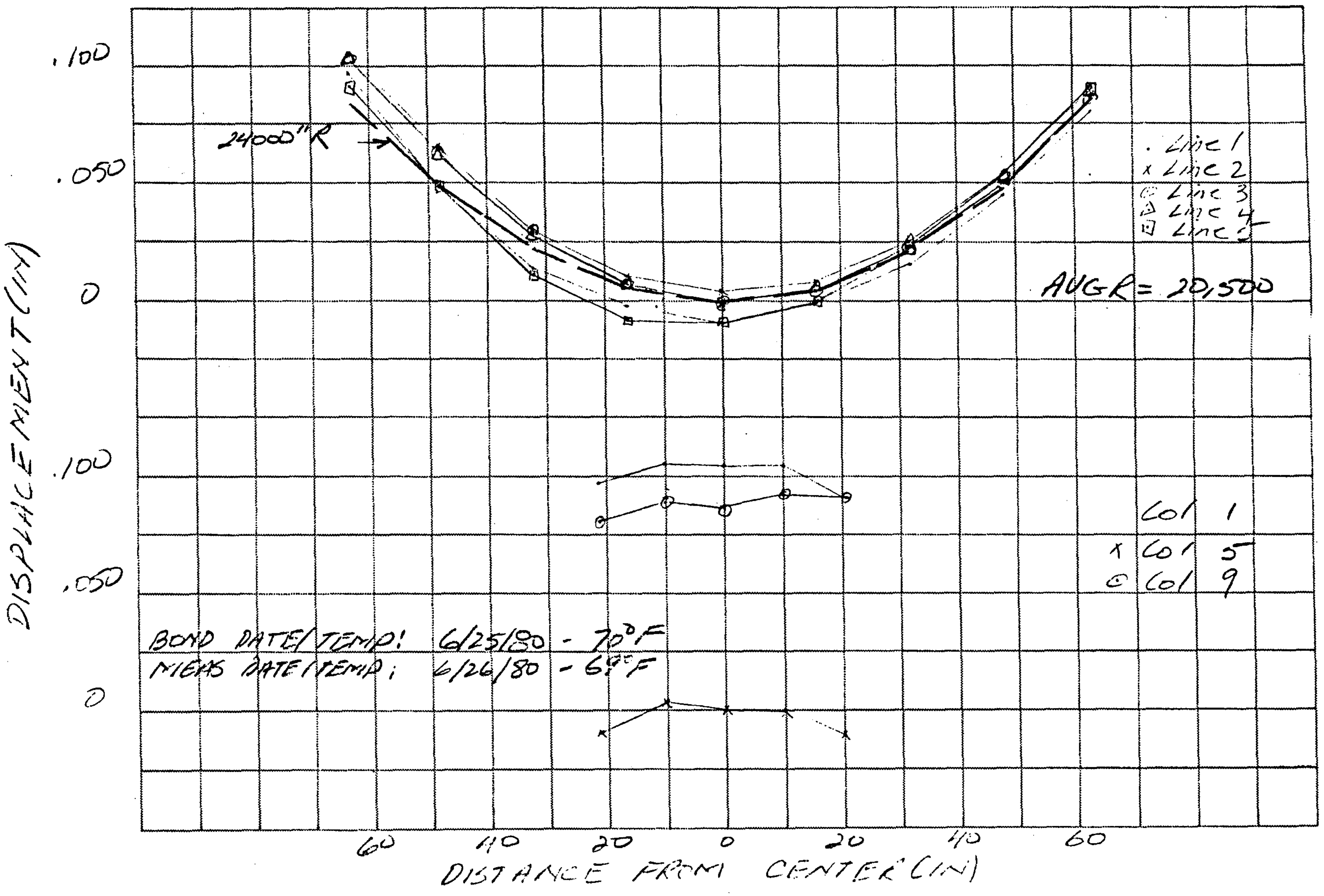


Figure B1-14. Mirror Module Contour SN09, 24 Hours After Bonding

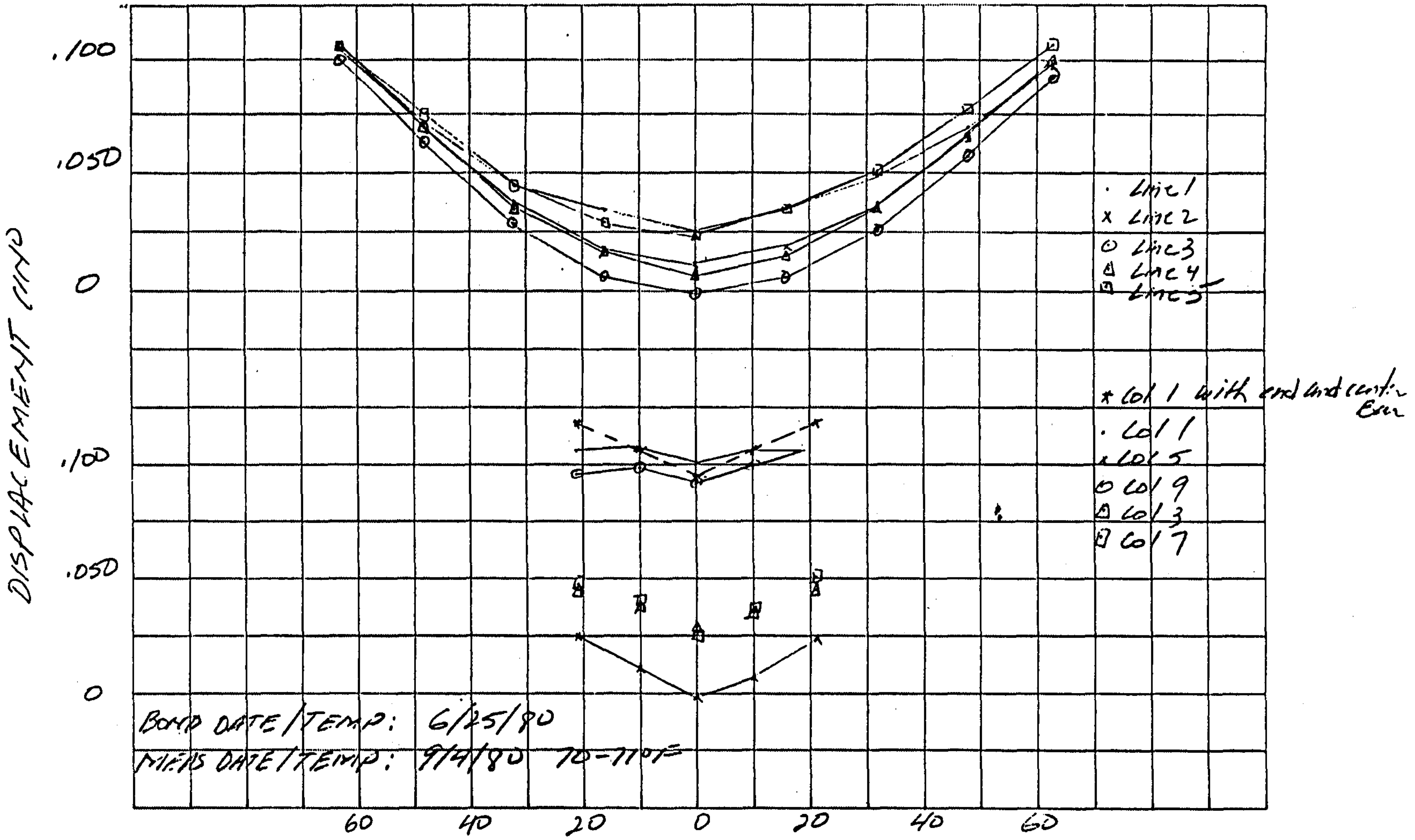


Figure B1-15. Mirror Module Contour SN09 With Center Bar

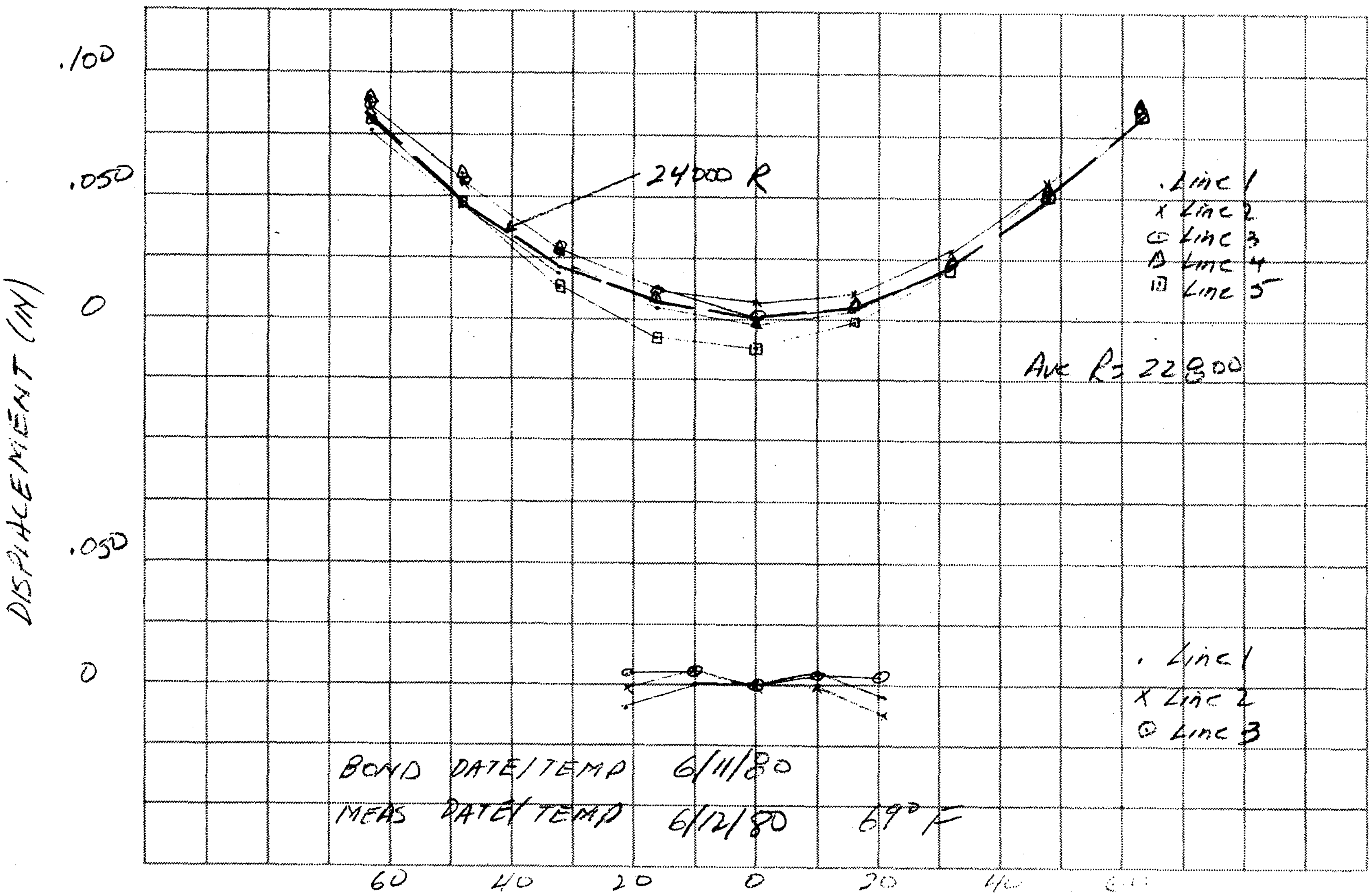
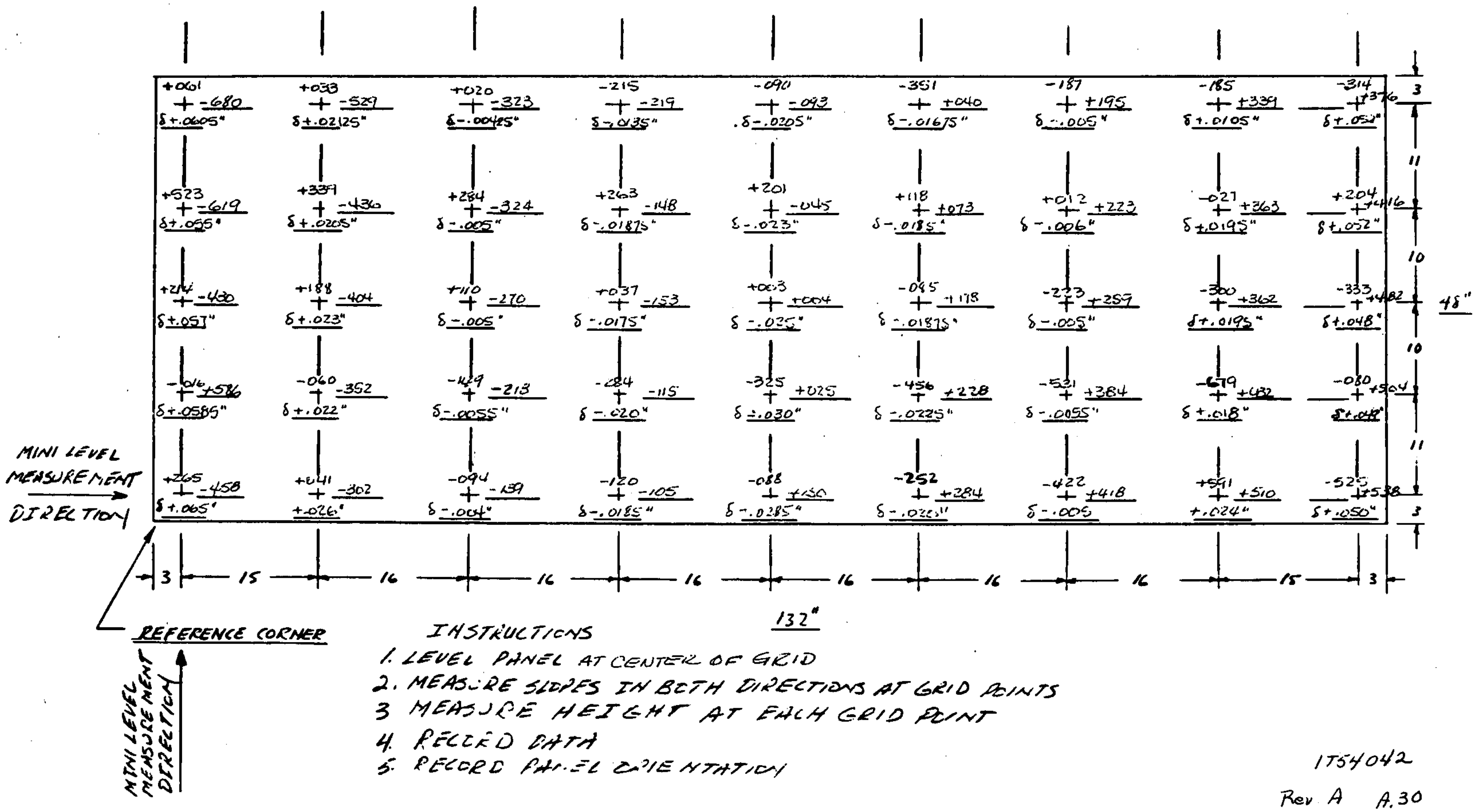


Figure B1-16. Panel Contour SN06, 24 Hours After Bonding

FORM DATE 4/11/80
J. Lichte

2ND GENERATION MIRROR MODULE MEASUREMENTS
MARINE EXPOSURE SPECIMEN.

DATE 11-05-80
MIRROR/PANEL SN 035
TEMPERATURE 63°F



+061 -680 δ+.0605"	+033 -529 δ+.02125"	+020 -323 δ-.00425"	-215 -219 δ-.0135"	-090 -093 δ-.0205"	-351 +040 δ-.01675"	-187 +195 δ-.005"	-185 +339 δ+.0105"	-314 +376 δ+.052"
+523 -619 δ+.055"	+339 -436 δ+.0205"	+284 -324 δ-.005"	+263 -148 δ-.01875"	+201 -045 δ-.023"	+118 +073 δ-.0185"	+012 +223 δ-.006"	-021 +363 δ+.0195"	+204 +416 δ+.052"
+214 -430 δ+.057"	+188 -404 δ+.023"	+110 -270 δ-.005"	+037 -153 δ-.0175"	+003 +004 δ-.035"	-045 +178 δ-.01875"	-223 +259 δ-.005"	-300 +362 δ+.0195"	-333 +482 δ+.048"
-016 +586 δ+.0585"	-060 -352 δ+.022"	-129 -213 δ-.0055"	-284 -115 δ-.020"	-325 +025 δ-.030"	-456 +228 δ-.0225"	-531 +384 δ-.0055"	-679 +432 δ+.018"	-080 +504 δ+.048"
+265 -458 δ+.065"	+041 -302 +.026"	-094 -139 δ-.004"	-120 -105 δ-.0185"	-088 +150 δ-.0285"	-252 +284 δ-.0205"	-422 +418 δ-.005	+591 +510 +.024"	-525 +538 δ+.050"

INSTRUCTIONS
1. LEVEL PANEL AT CENTER OF GRID
2. MEASURE SLOPES IN BOTH DIRECTIONS AT GRID POINTS
3 MEASURE HEIGHT AT EACH GRID POINT
4. RECORD DATA
5. RECORD PANEL ORIENTATION

1T54042
Rev A A.30

Figure B1-17. Marine Exposure Specimen

ICRM DATE 4/11/80

2ND GENERATION MIRROR MODULE MEASUREMENTS

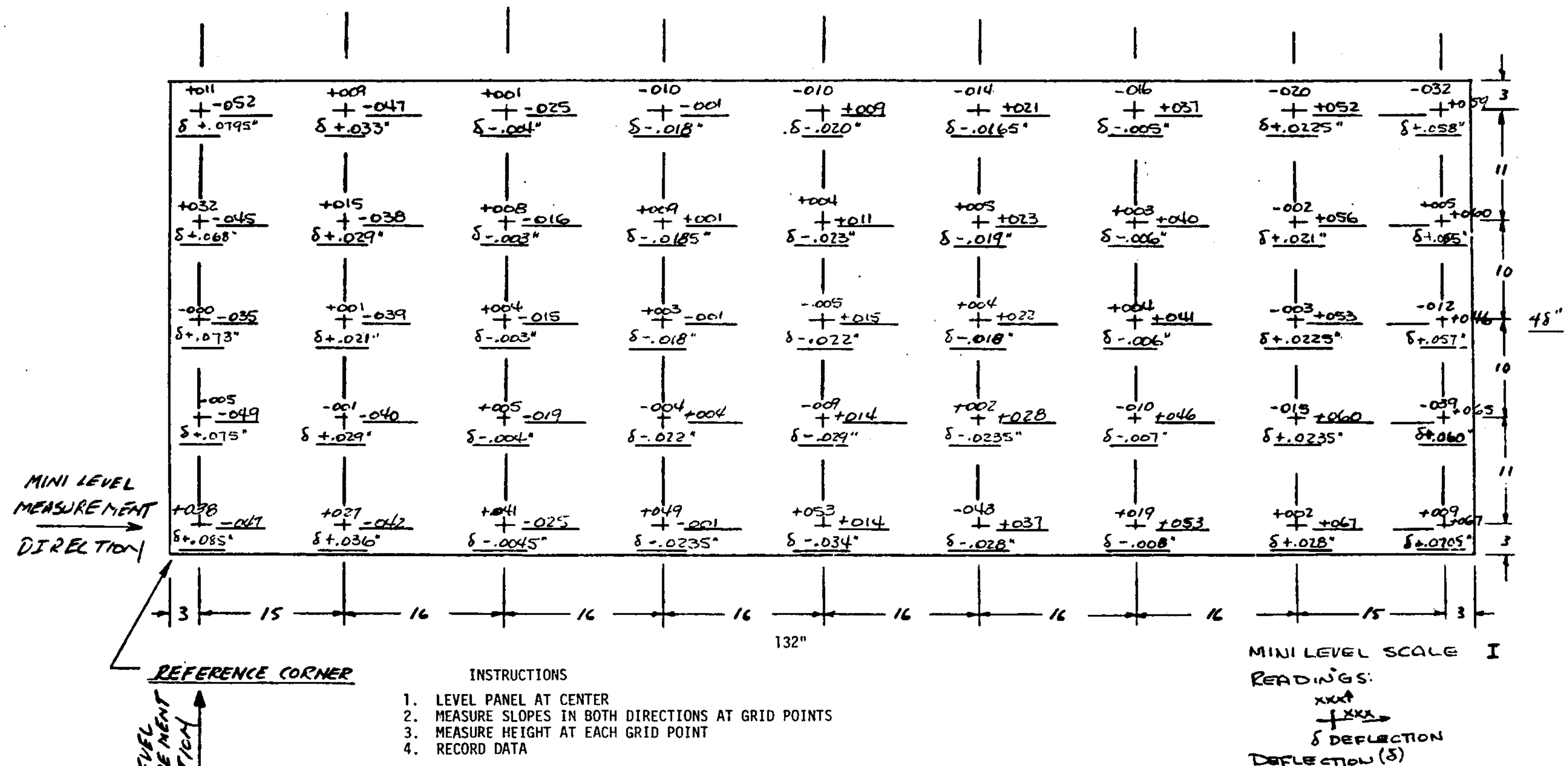
DESERT EXPOSURE SPECIMEN

INITIAL INPLACE MEASUREMENTS

DATE 8-29-80

MIRROR/PANEL SN 44

TEMPERATURE 80°F



+011 -052 δ +.0795"	+009 -047 δ +.033"	+001 -025 δ -.004"	-010 -001 δ -.018"	-010 +009 δ -.020"	-014 +021 δ -.0165"	-016 +037 δ -.005"	-020 +052 δ +.0225"	-032 +059 δ +.058"
+032 -045 δ +.068"	+015 -038 δ +.029"	+008 -016 δ -.003"	+009 +001 δ -.0185"	+004 +011 δ -.023"	+005 +023 δ -.019"	+003 +040 δ -.006"	-002 +056 δ +.021"	+005 +060 δ +.065"
-000 -035 δ +.073"	+001 -039 δ +.021"	+004 -015 δ -.003"	+003 -001 δ -.018"	-.005 +015 δ -.022"	+004 +022 δ -.018"	+004 +041 δ -.006"	-003 +053 δ +.0225"	-012 +046 δ +.057"
-005 -049 δ +.075"	-001 -040 δ +.029"	+005 -019 δ -.004"	-004 +004 δ -.022"	-009 +014 δ -.029"	+002 +028 δ -.0235"	-010 +046 δ -.007"	-015 +060 δ +.0235"	-039 +065 δ +.060"
+038 -047 δ +.085"	+027 -042 δ +.036"	+041 -025 δ -.0045"	+049 -001 δ -.0235"	+053 +014 δ -.034"	-048 +037 δ -.028"	+019 +053 δ -.008"	+002 +067 δ +.028"	+009 +067 δ +.0705"

INSTRUCTIONS

1. LEVEL PANEL AT CENTER
2. MEASURE SLOPES IN BOTH DIRECTIONS AT GRID POINTS
3. MEASURE HEIGHT AT EACH GRID POINT
4. RECORD DATA

MINI LEVEL SCALE I

READINGS:

xxx

xxx

δ DEFLECTION

DEFLECTION (δ)

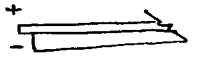


Figure B1-18. Desert Exposure Specimen - INITIAL INPLACE MEASUREMENTS

1T54042

Rev. A A.31

Figure B1-18. Desert Exposure Specimen — Initial Inplace Measurements

4.3 THERMAL DISTORTION TEST AND COLD WATER SHOCK TEST

Each of two specimens were stabilized at 32°F, 77°F, and 118°F where slope and deflection measurements were taken. The data taken during tests is shown in Figures B1-7 through B1-10 for SN07 and Figures B1-11 through B1-13 for SN08. After measurements were taken at 118°F, the specimens were stabilized at 122°F and five gallons of tap water at 65°F were poured over each specimen. No visual damage occurred.

4.4 THERMAL CYCLE TESTS

Since the test setup for the thermal distortion test required the ability to level the mirror module, therefore allowing only one mirror at a time in the temperature chamber, that setup was not used for this test.

The two test specimens were placed in the chamber and cycled as follows:

Temperature	Time
Ambient to -22°F	45 min
-22°F	30 min
-22°F to +122°F	90 min
+122°F	30 min
+122°F to ambient	45 min.

A typical recording of temperature versus time for the chamber air temperature is shown in Figure B1-19. After completion of 82 cycles, the chamber refrigeration system malfunctioned and the testing was terminated. No visual damage or deterioration could be found during inspections performed during and after exposure.

These panels were removed from the chamber after 82 cycles and sent to the production area for measurement. The data taken is shown in Figure B1-10 for SN07 and in Figure B1-13 for SN08.

The specimens, SN07 and SN08 along with SN09, were installed in the chamber and subjected to the same temperature cycle as previously except the high temperature was 140°F instead of 122°F. A total of 45 cycles were performed. No visual damage or deterioration could be found during inspections during and after exposure.

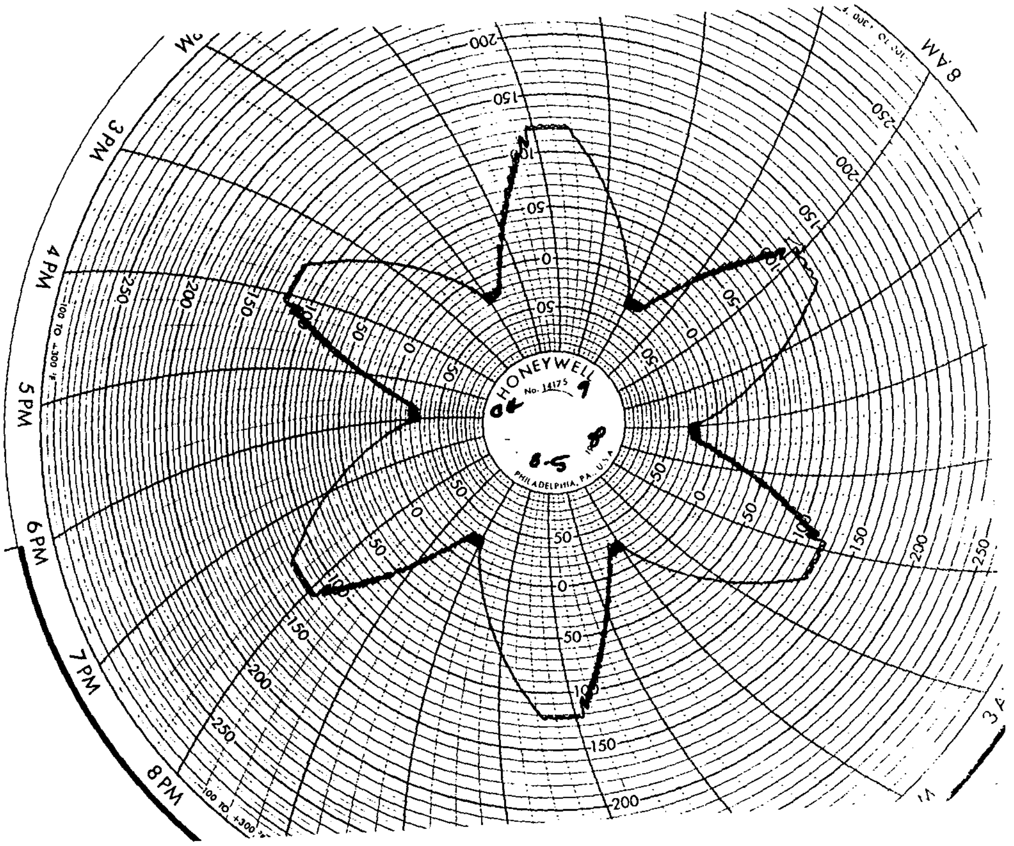


Figure B1-19. Thermal Cycle Test

Appendix B-2
WIRE RACE BEARING TEST

The wire race bearing (WRB) is used to support the azimuth drive assembly and react all loads from the heliostat mirror assembly. To do this, the bearing is designed to react maximum static loads as follows:

Moment - 401,000 in-lbs.
Radial - 9,400 lbs.
Thrust - 4,500 lbs.

The bearing is installed in the heliostat as shown in Figure B2-1. The other requirements for this bearing are that it have low compliance and a 30 year life. Compliance of 0.100 milli-radians at 52,000 in-lbs moment load was the target for the WRB. The daily bearing duty cycle consists of approximately 180° of rotation (0°-90°-0°) at loads up to 150,000 in-lbs.

The WRB is designed and built for MDAC-HB by McGill Bearing. A summary of the test program is as follows:

1. Assemble the test specimen and determine the optimum shimming method.
2. Determine torque required to breakout the bearing with an overturning load.
3. Measure load versus deflection with overturning moments up to 400,000 in-lbs.
4. Measure load versus deflection as above at intervals over 10,00 life cycles.

Test procedures and results are as follows.

1.0 ASSEMBLY PROCEDURE

The wire race bearing is not a close tolerance piece of hardware, but uses a shim to adjust the bearing preload. One purpose of this test was to develop a method for shimming the bearing. A preload of 2,100 lbs was selected as a starting point.

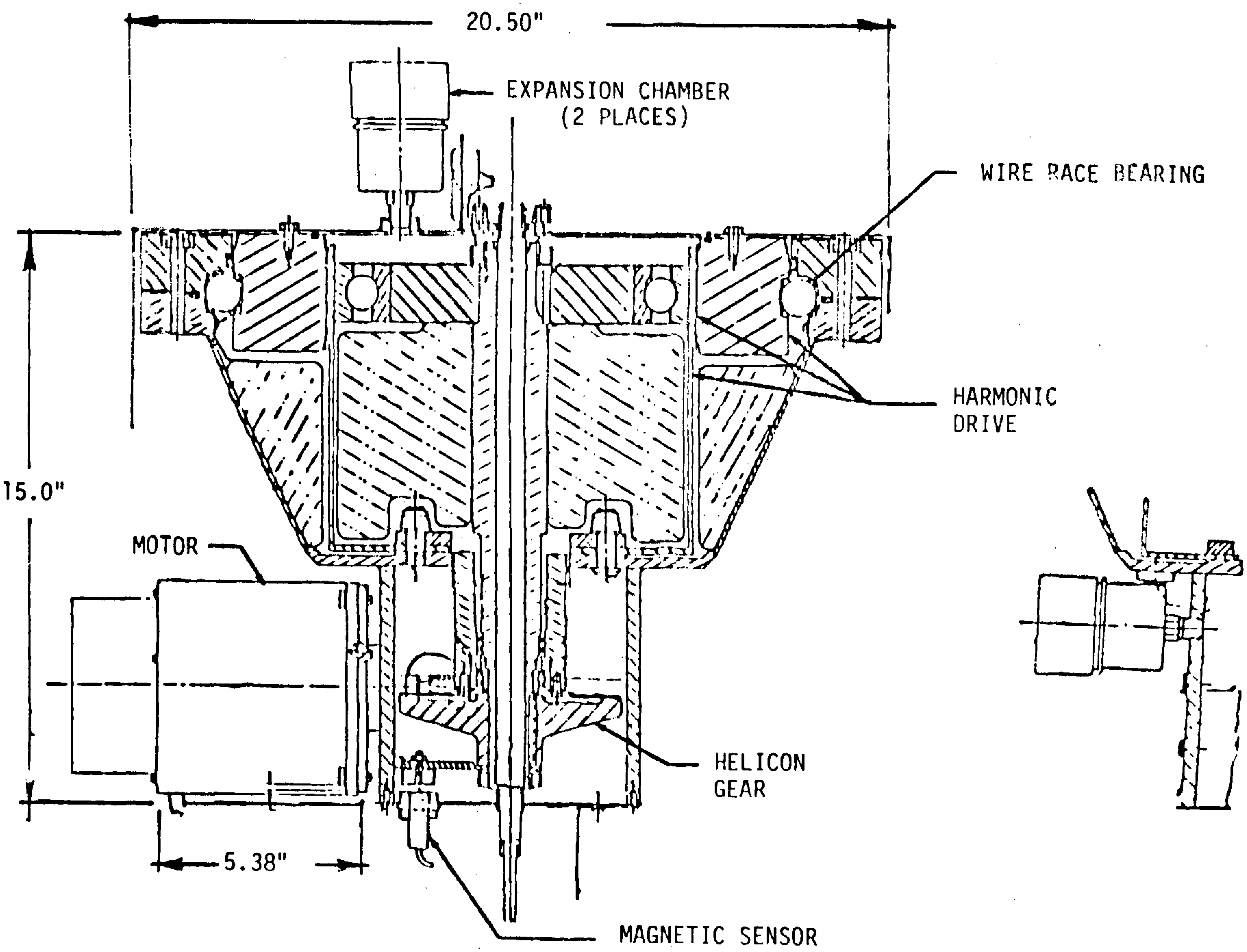


Figure B2-1. Azimuth Drive Cross Section

The test specimen was assembled per 1D22426 with the omission of both o-rings and the 1D22443-1 shim. No difficulties were noted. The wire races snapped into their housing, the circular spline was supported in the center of the drive housing, and the balls loaded in place. The 3/8-24 x 2" bolts which secure the 1D22489-1 retainer to the 1D22474 support were brought up snug and the clearance gap between these two pieces was maintained approximately constant around the periphery. Using a 90° and opposing torque pattern, these bolts were brought to 10 in-lb torque which relates to a 2,100 lb. compression load on the bearing.

At this condition, a feeler gage was used to measure the gap where the shim fits. The readings were taken 4 places, 90° apart and averaged 0.062 inches. In order to straddle the optimum shim size, 0.066 inches was selected as a starting shim size.

2.0 LOADING VERSUS DEFLECTION READINGS AND BREAKOUT TORQUE

The 1D22443-1 shim pack was trimmed to 0.066" and installed. The specimen was mounted on top of the short pedestal, breakout torque was measured, and then hydraulic cylinders were connected to apply on overturning moment load to the specimen (See Figure B2-2). Dial indicators were positioned as shown in Figure B2-3 and load versus deflection readings were taken up to 400,000 in-lbs moment load. These data are documented in Figure B2-4.

Following the load deflection readings, it was noted that breakout torque was reduced. Breakout torque was measured against overturning moment from 0 to 121,000 in-lbs at 20,000 in-lb intervals. Torque to breakout the specimen ranged from a low of 10 ft. lbs. at zero moment to 20 ft. lbs. at 121,000 in-lbs moment. This indicated the anti-friction capabilities of the bearing were acceptable.

The shim pack was then trimmed to 0.064, 0.062 and 0.060 inches and load versus deflection data recorded at each interval.

This testing indicated that 0.062" of shim gave the best results in a tradeoff of compliance and breakout torque. The specimen was reshimmed to 0.062" and the test repeated. Results are presented in Figure B2-5.

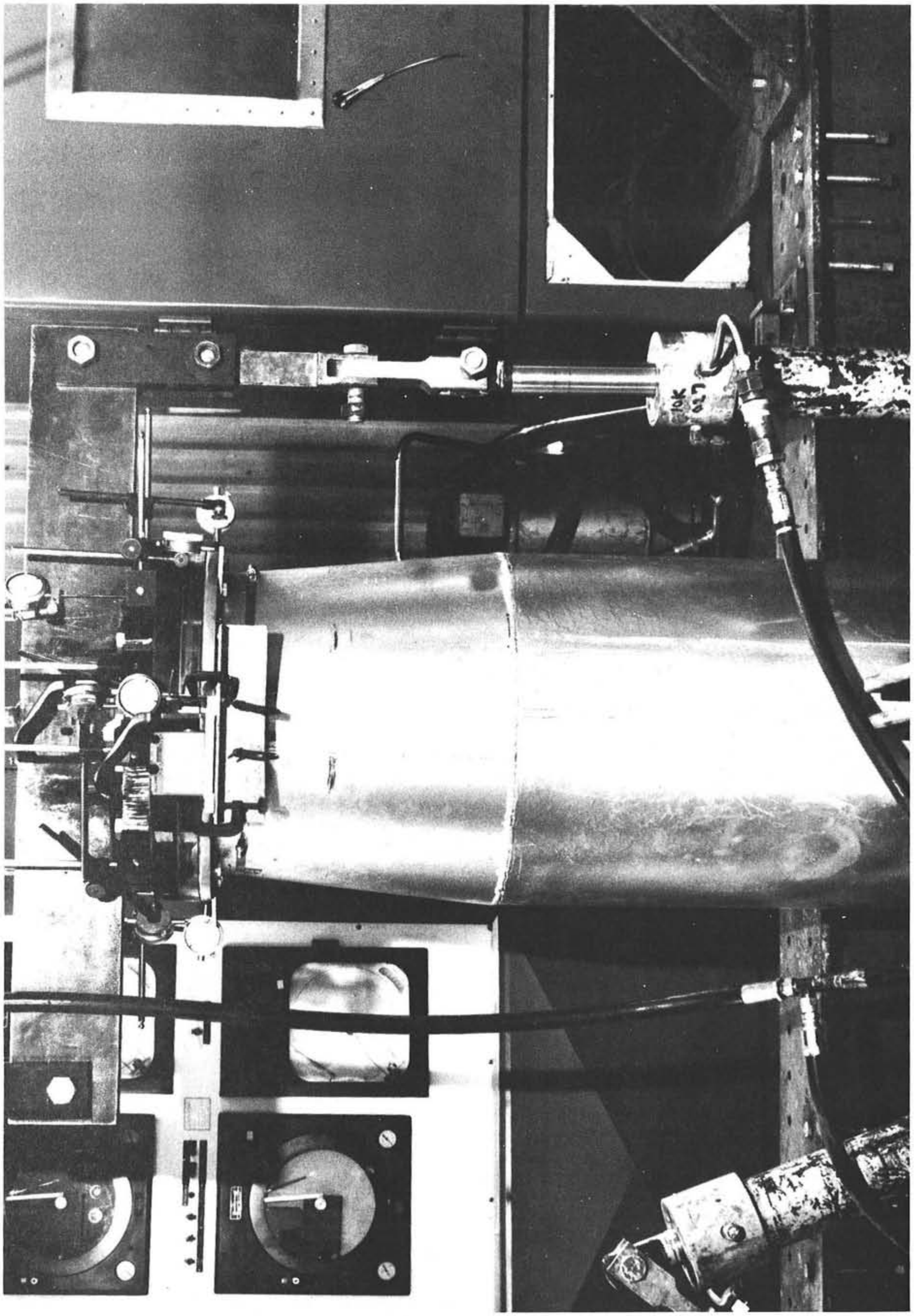


Figure B2-2. Bearing Test

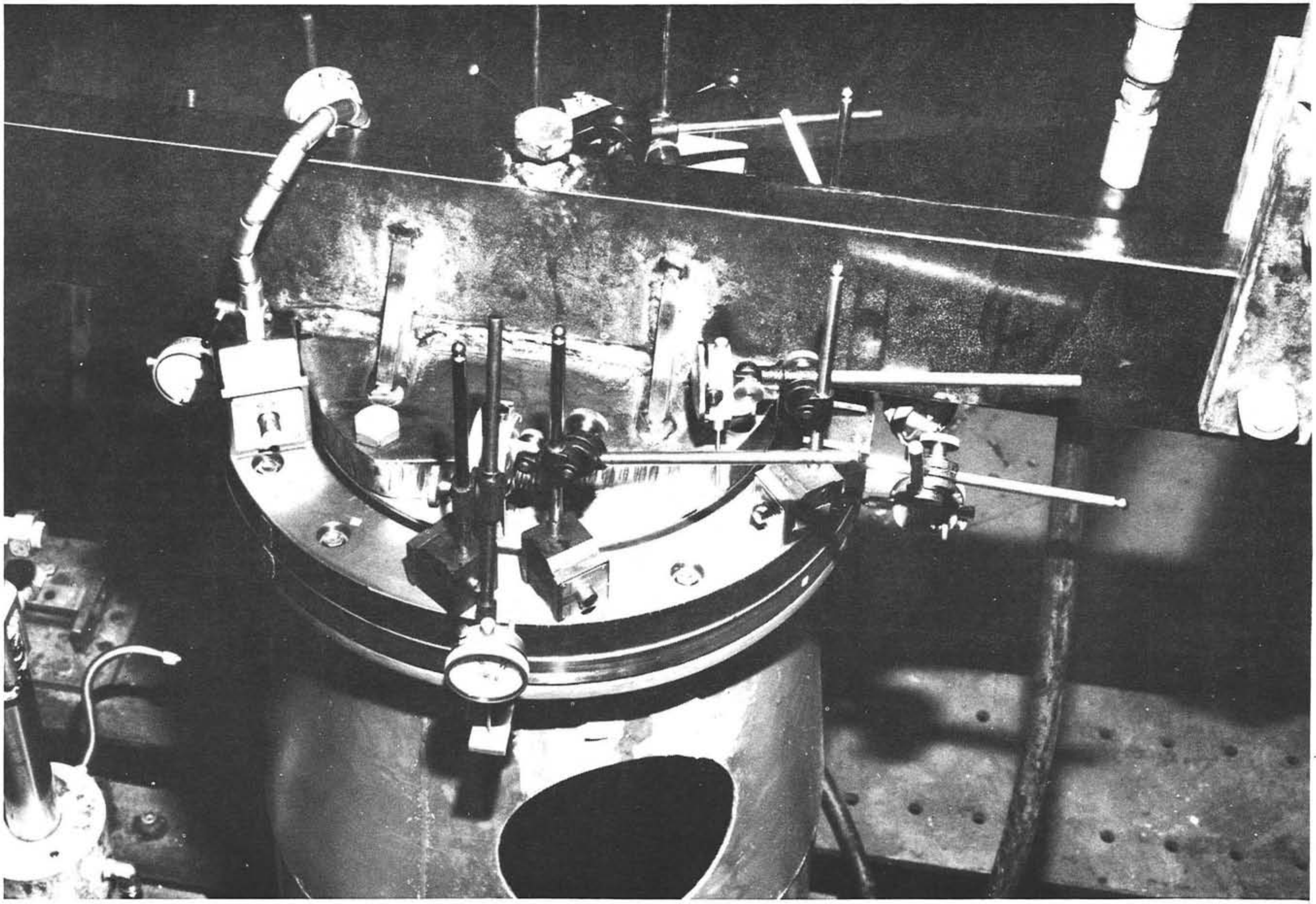


Figure B2-3. LoAD Deflection Setup

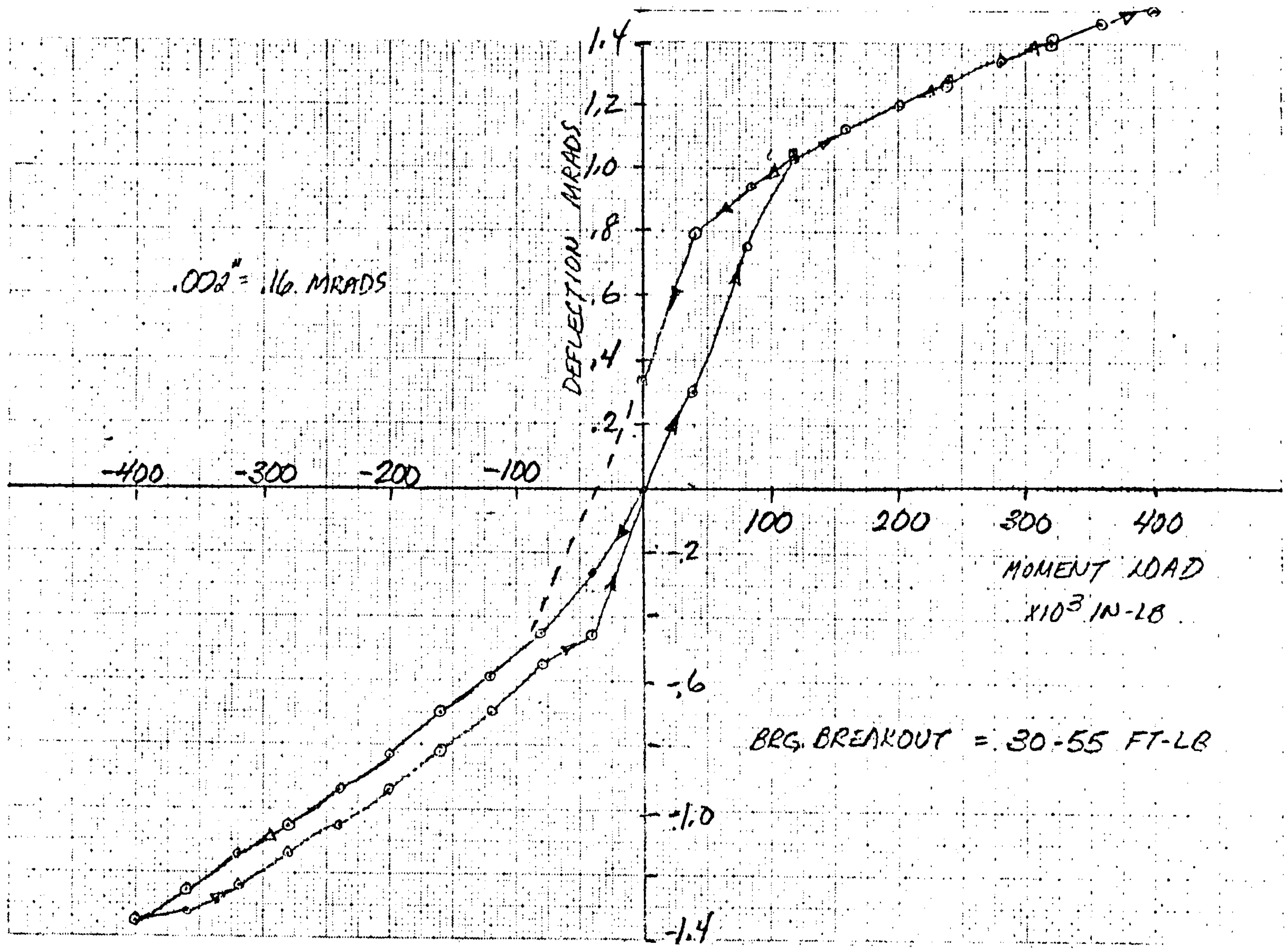


Figure B2-4. Wire Race Bearing Load Versus Deflection (0.066-In. Shim)

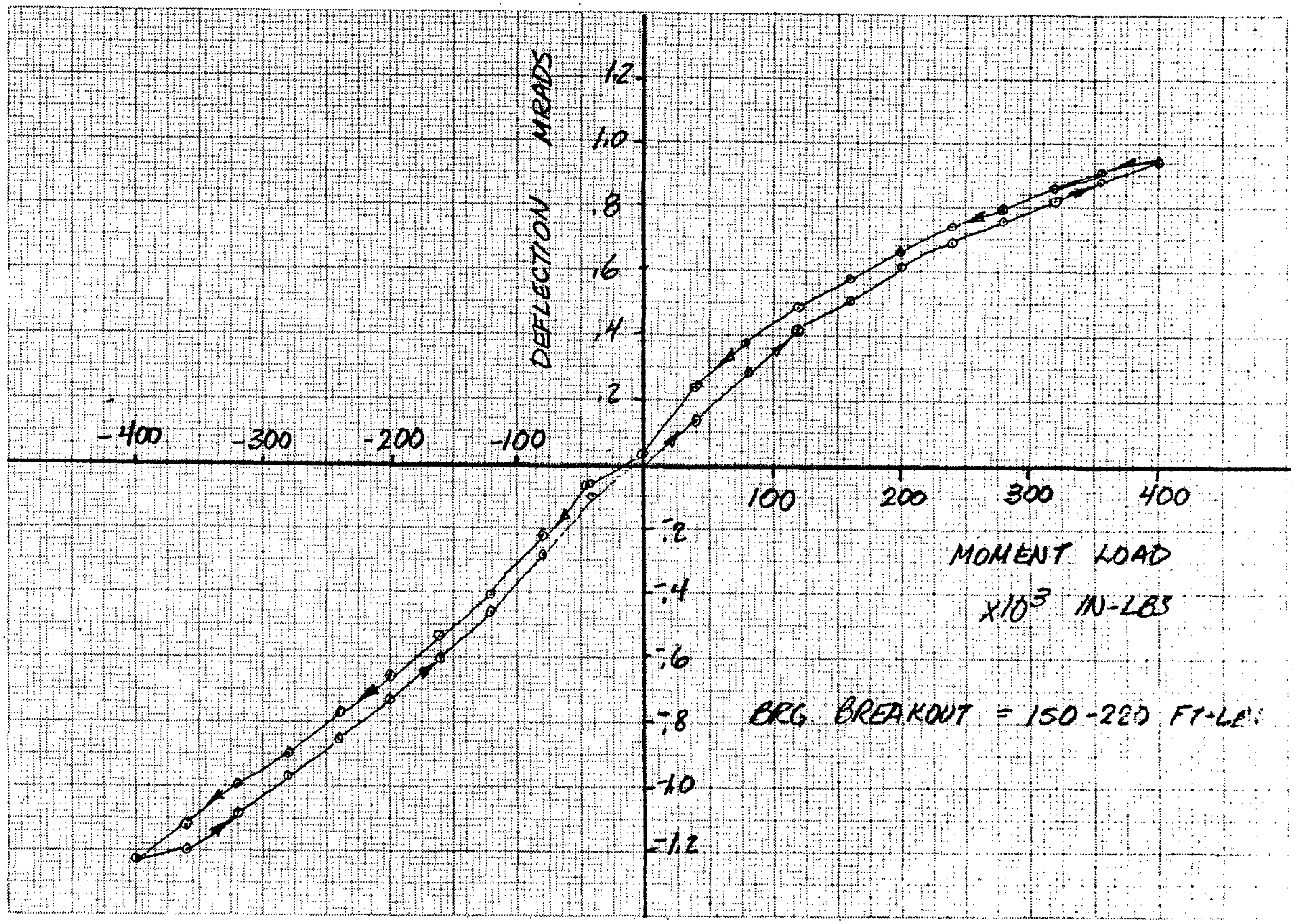


Figure B2-5. Wire Race Bearing Load Versus Deflection Following Disassembly and Reassembly (Reshimmed to 0.062-In.)

Shim Size WRB Nominal (In.)	Deflection (mrads) at 50K in-lbs		Breakout Torque (ft-lbs.)	
	-50K	+50K	Minimum	Maximum
+.004	-.2	+.4	30	55
+.002	*	+.32	60	110
Net	-.22	+.20	90	150
-.002	-.16	+.12	220	350
Net	-.10	+.18	150	220

---

*Data Unavailable

The final shimming requirements established are to apply 10-15 in-lbs bolt torque and measure the gap. The shim should be trimmed to a net condition +0/-.002. For these conditions:

1. Data shows 0.2 mrad nominal deflection at 50,000 in-lb.
2. Breakout torque required (no seal) is 2,640 in-lbs (maximum) or 2.6% of available capacity.
3. Breakout torque is not constant from one buildup to another but never exceeds the 2.6% maximum.

This indicates that the no-load hysteresis in the bearing increased by approximately 0.16 milliradians. This is not excessive and can be accommodated by the available budget.

After testing the bearing was disassembled for inspection with no anomalous conditions noted.

On disassembly, the wire races showed no wear or brinelling. Metal flakes were noted behind the wire races on the 1D22489 retainer and 1D22474 support, indicating that the races were scuffing these housings under load. The ball bearings were marred from contact loads (ball-to-ball), but the depth of the marks was extremely light.

4.0 LIFE TEST

The purpose of the life test was to determine if the WRB could perform adequately over its projected 30 year life. The test fixture allowed cycling the bearing with a hydraulic cyclinder while under a dead weight moment load. The test setup is shown in Figure B2-6.

The specimen was built up with the 2-459V747-75 dynamic seal and the same bearing hardware according to the method developed in previous testing. The unit was filled with Mobilgear 626 oil for bearing lubrication to a depth to cover the lower half of the WRB.

Breakout torque readings of 100-150 ft. lbs. were recorded which were minimal as this included the dynamic seal friction. Load versus deflection readings were recorded and are presented in Figure B2-7. These are the baseline data from which other data was compared during the life testing.

The 3,800 lb. dead weight load was fitted to the specimen at a 41" moment arm (156,000 in-lb) and a hydraulic cylinder with position feedback used to drive the specimen through a 90° arc. The lab computer was used to drive the actuator and count cycles. A cycle consisted of 0°-90°-0°. At intervals of 1,000, 2,500, 5,000 and 10,000 total cycles, load versus deflection data were recorded to give an indication of wear occurring on the bearing. Wear shows up as hysteresis around the zero load point. The data at the conclusion of the test is provided in Figure B2-8.

One requirement for the heliostat application is compliance at 50,000 in-lb load. Loads on the heliostat bearing will be in one direction and the chance of a load reversal is very remote. However, to get an understanding of bearing wear, total bearing deflection at ±50,000 in-lb load was plotted versus number of cycles (see Figure B2-9).

CONCLUSIONS

This test activity is complete, and based on the results, the following conclusions are offered:

1. The wire race bearing, when properly shimmed, has a breakout torque which will be acceptable for the heliostat application.
2. The bearing load/deflection characteristics are acceptable and will be within the budget available.

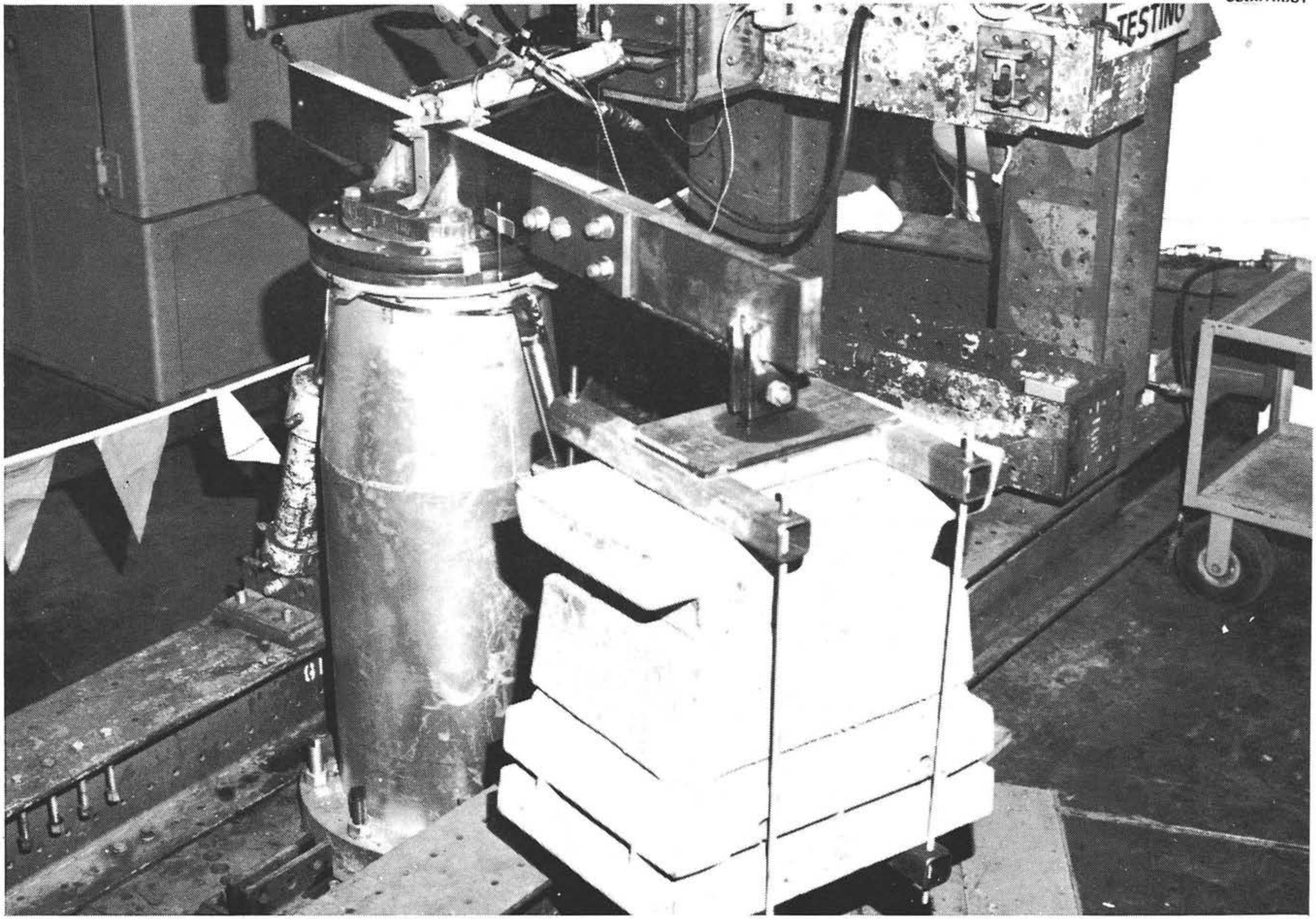


Figure B2-6. WRB Life Test Setup

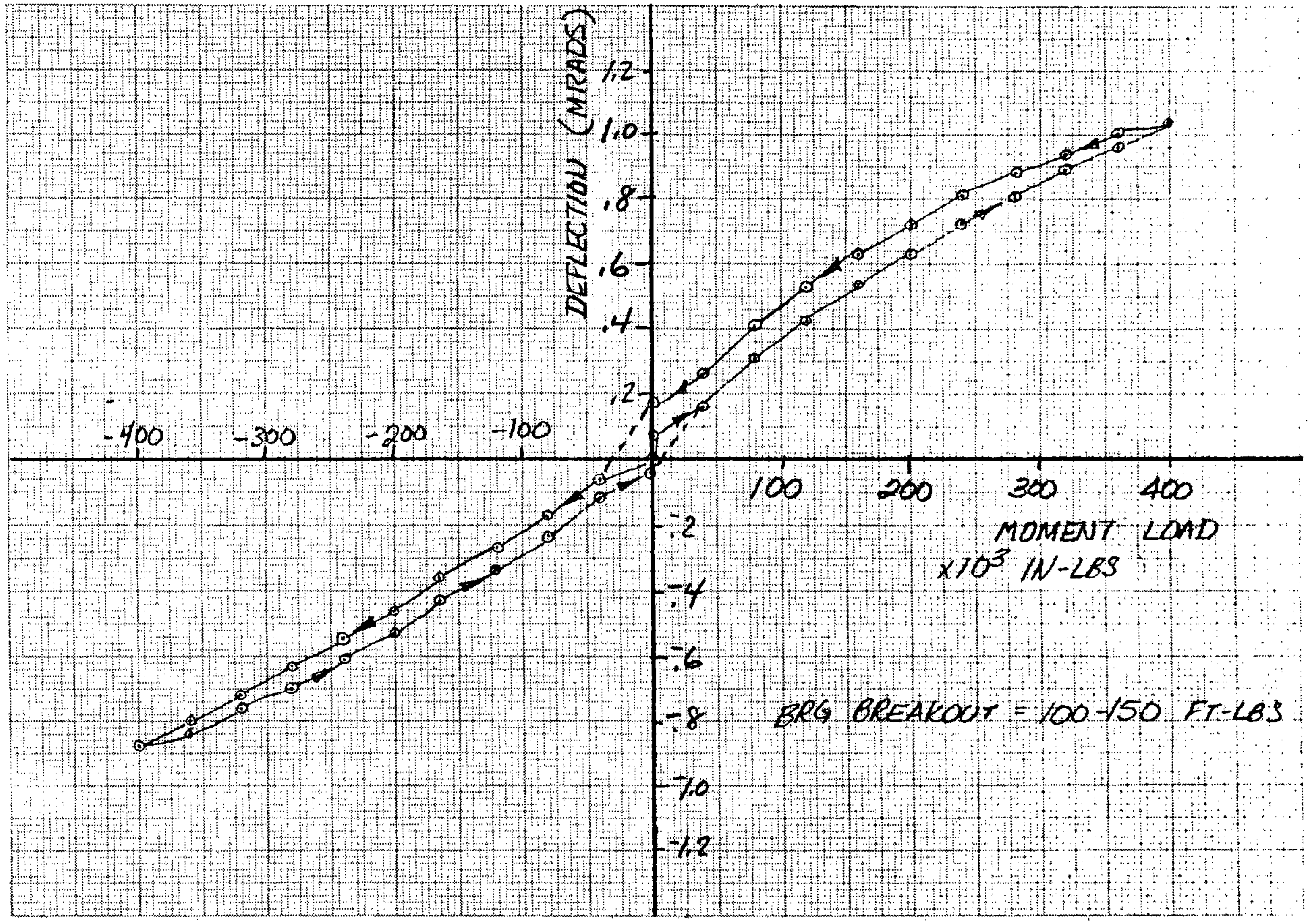


Figure B2-7. Wire Race Bearing Load Versus Deflection Run IV WRB Life Test — Baseline (0.060-In Shim)

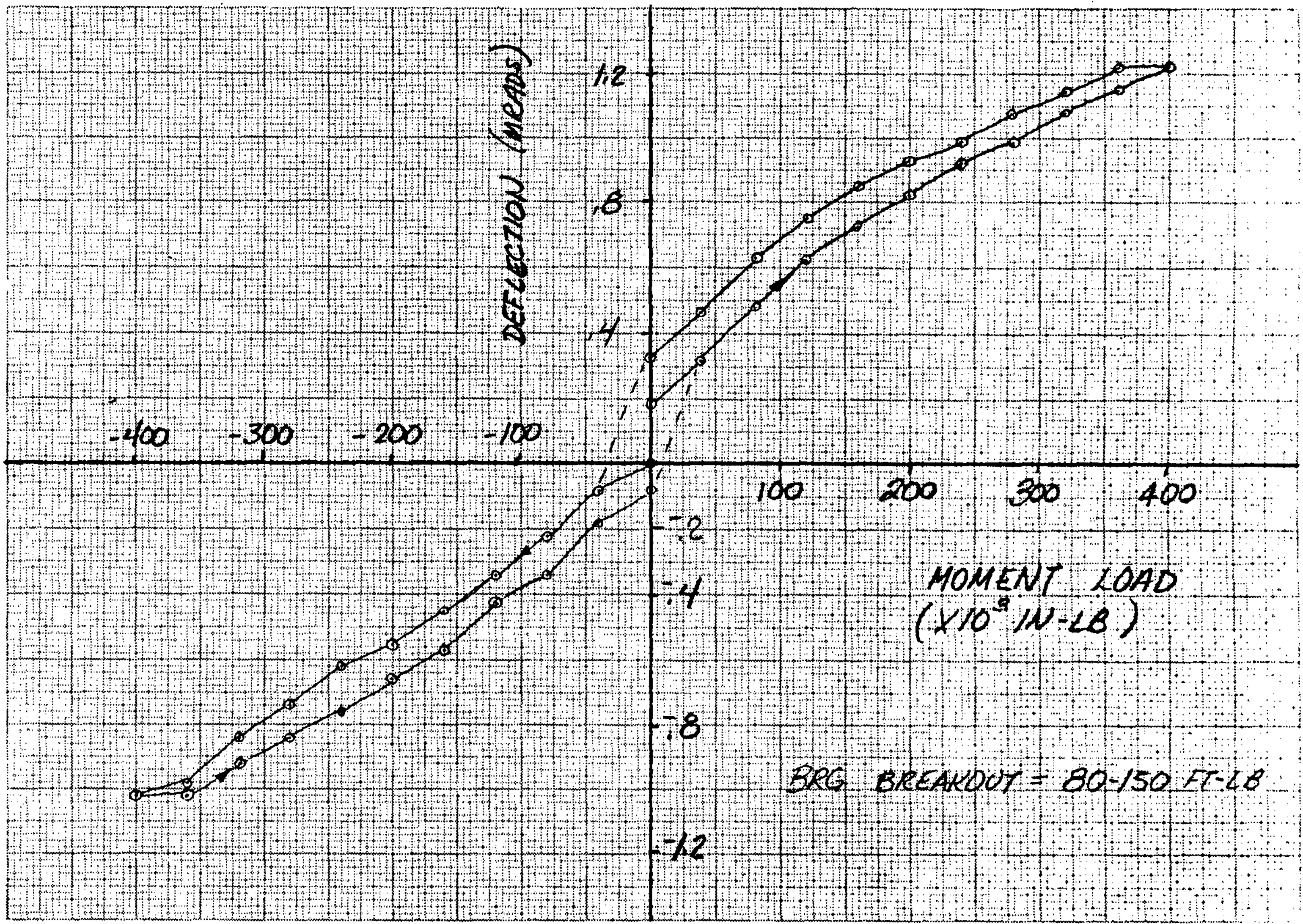


Figure B2-8. Wire Race Bearing Load Versus Deflection WRB Life Test – After 10,000 Cycles (0.060-In. Shim)

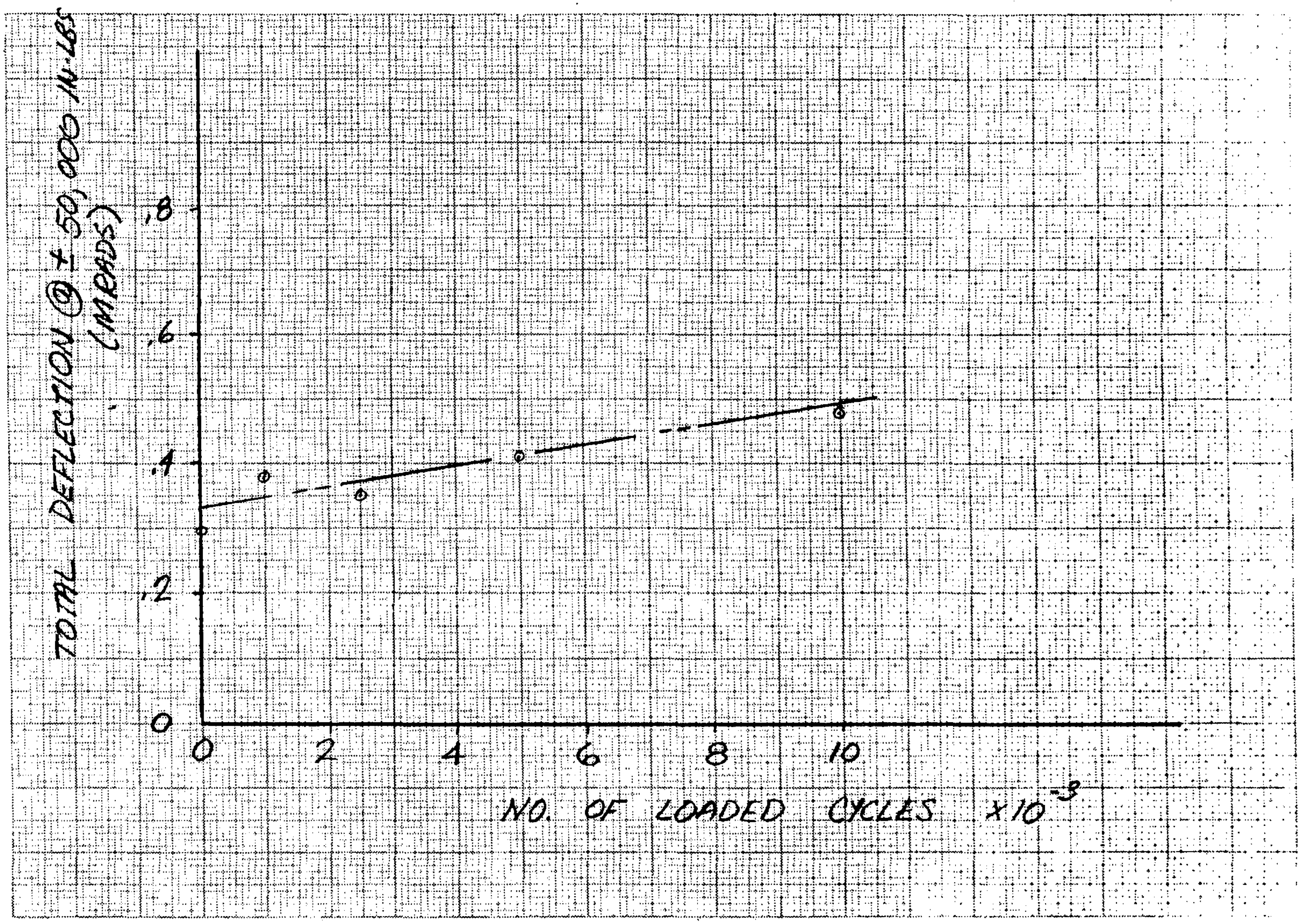


Figure B2-9. WRB Life Test — BRG Deflection Versus No. of Cycles

3. The wear marks noted on the bearing balls are normal and do not indicate a problem.

4. The metal flakes noted behind the wire races are normal. Some chafing between the races and their interfacing parts occurs during normal operation.

5. The WRB will perform adequately over the 30 year life span of the heliostat, based on accelerated life testing.

6. WRB compliance and hysteresis are sensitive to foreign (soft) materials in the load path.

The wire race bearing design is recommended for use on the Second Generation Heliostat. The WRB enjoys a cost advantage over the conventional large diameter ball bearing, and it will perform to meet all requirements on the heliostat. This type of bearing is easily installed; there are no close tolerance machining operations or press fits associated with the installation.

Appendix B-3

SHORT-DIRECTION STABILIZING BAR FOR SECOND GENERATION MIRROR MODULES

The Second Generation mirror modules exhibited consistent curvature in the long direction but had variable flatness in the short direction. This is shown in Figures B3-1 and B3-2 which are the contour plots of SN06 and SN07. Note the consistency in the long direction but the short direction contours are quite variable between columns and between the two panels. Even though this variability in the short direction was a concern from the start, its effects on beam quality for the heliostat were still unknown.

After the Second Generation heliostat was installed and aligned at Huntington Beach in July, 1980, beam quality assessment began. When it was determined that short direction out of flatness was the cause of the poor heliostat image, a design change to the mirror module was proposed and evaluated. The change involved two items: 1) a return to 4 point support for the mirror modules and 2) the addition of a member or members connecting the bottom of each hat section to stabilize cross direction flatness. Figures B3-3 through B3-6 show the dramatic improvements in image quality for a single mirror module. Figure B3-3 shows SN09 as installed and aligned on the heliostat with 3 point support. Figure B3-4 shows the same mirror module with a 4 point support. Figure B3-5 shows SN09 with a single center stabilizing bar, and Figure B3-6 shows SN09 with two stabilizing bars, one at the center and one at the end. Figures B3-7 and B3-8 show the SN015 without and with a stabilizing bar respectively.

Based on the results of this evaluation a single stabilizing bar in the center of each mirror module was chosen as the design fix. A sketch of the fix is shown in Figure B3-9. This fix was the "E" drawing change and was implemented on all Second Generation mirror modules.

CR15

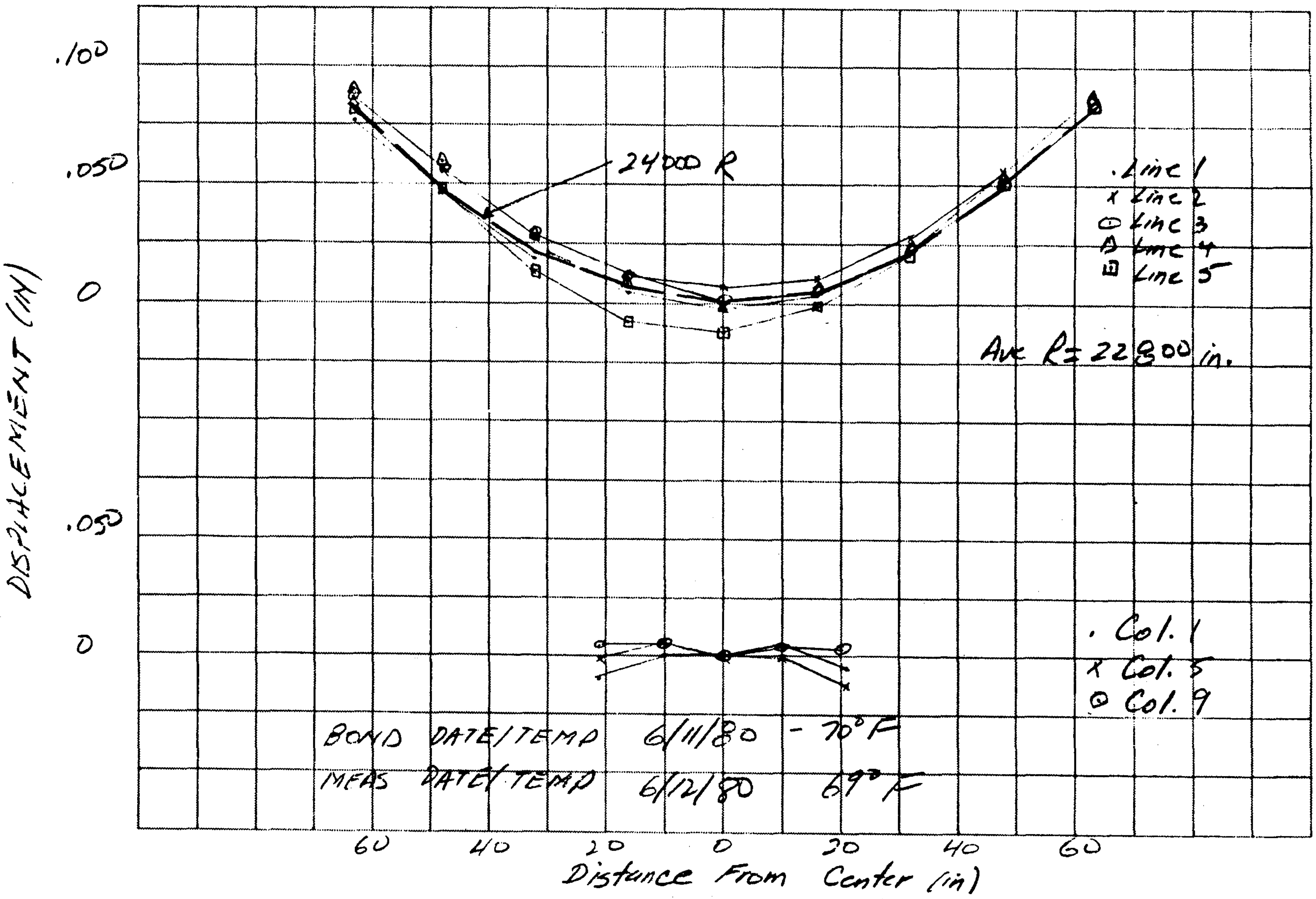


Figure B3-1. Panel Contour SN06, 24 Hours After Bonding

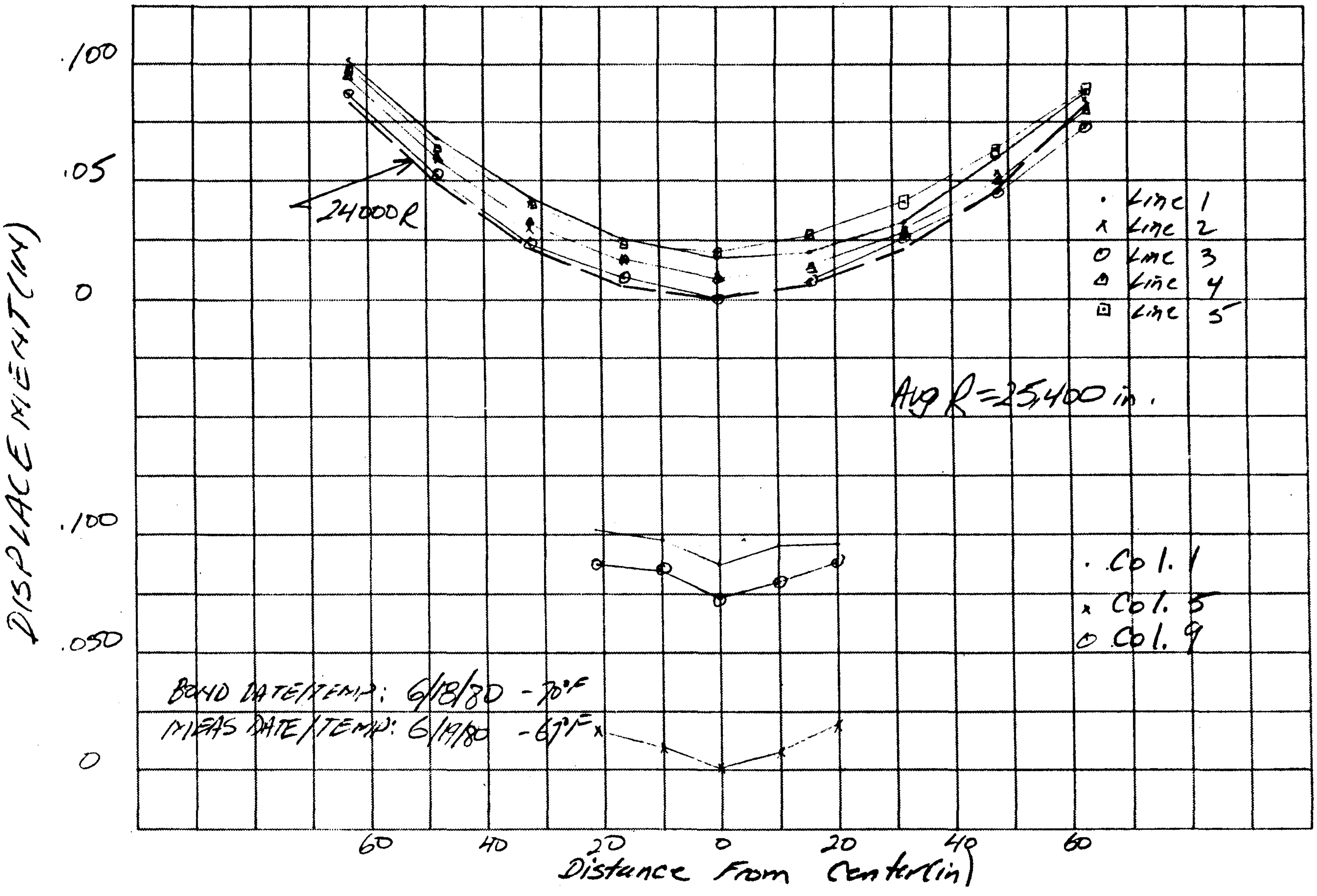


Figure B3-2. Mirror Module Contour SN07

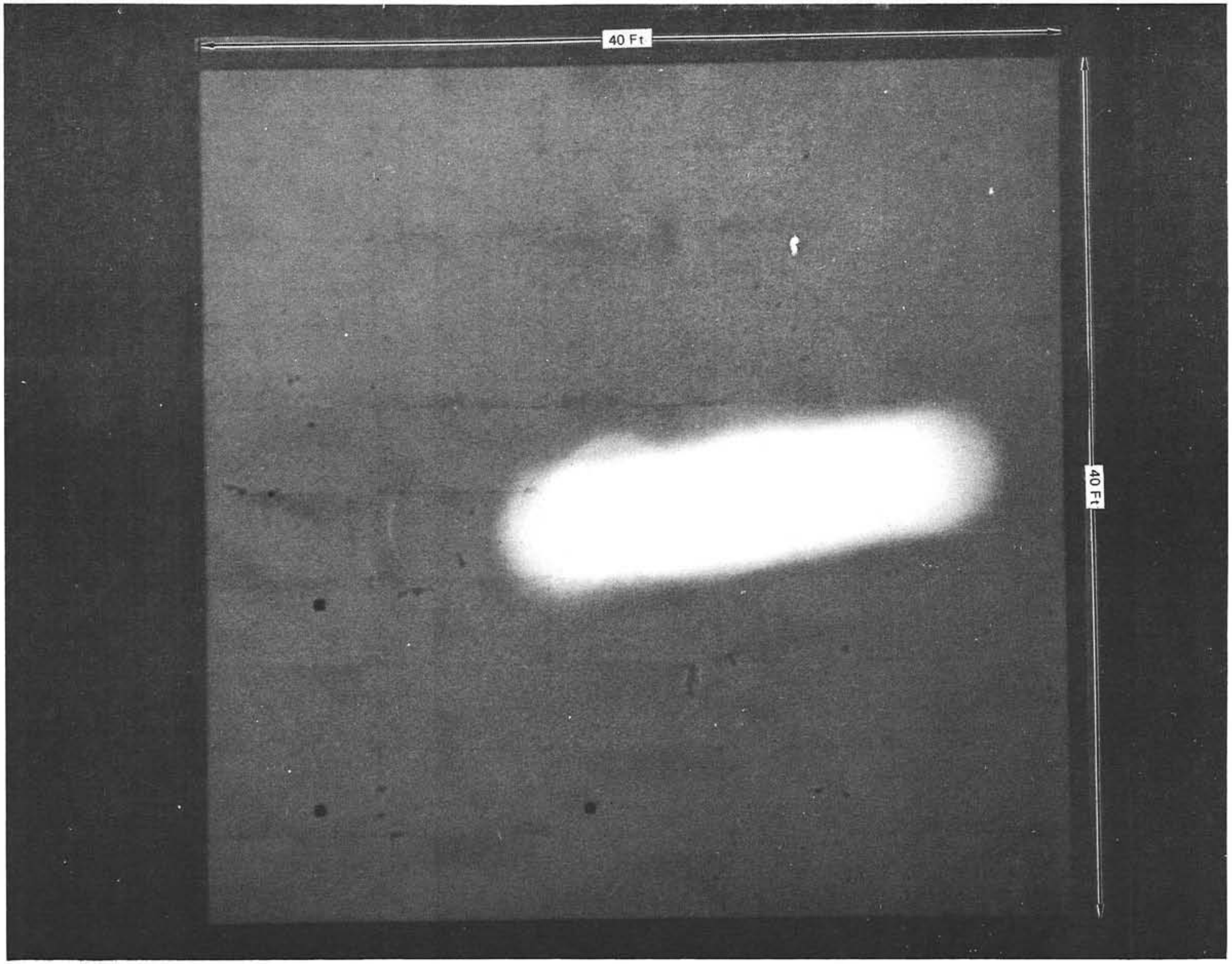


Figure B3-3. Three Point Support With No Correction

DATE: 8-26-80 TIME: 11:47 A.M.
TEMP: 80°F EST. DISTANCE: 650 FT.
PANEL S/N: 09 – 3 pt. PANEL NO: 7
HELIOSTAT: NO. 1 – LOWER WING

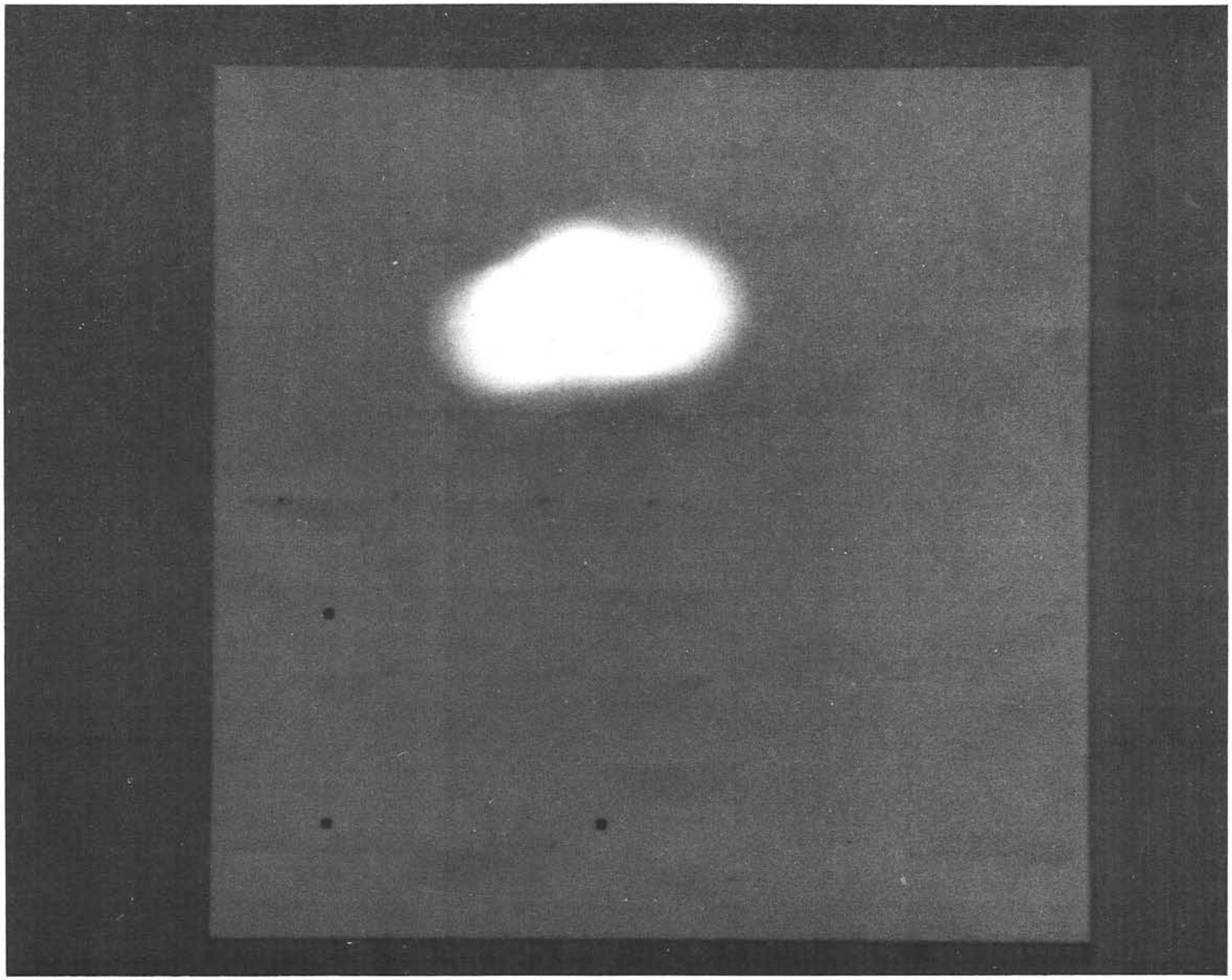


Figure B3-4. Four Point Support With No Correction

DATE: 8-29-80 TIME: 2:27 P.M.
TEMP: 80°F EST. DISTANCE: 650 FT.
PANEL S/N: 09 WITH NO CORRECTION – 4 pt.
PANEL NO: 7
HELIOSTAT: NO. 1 – LOWER WING

CR15
SSC081292

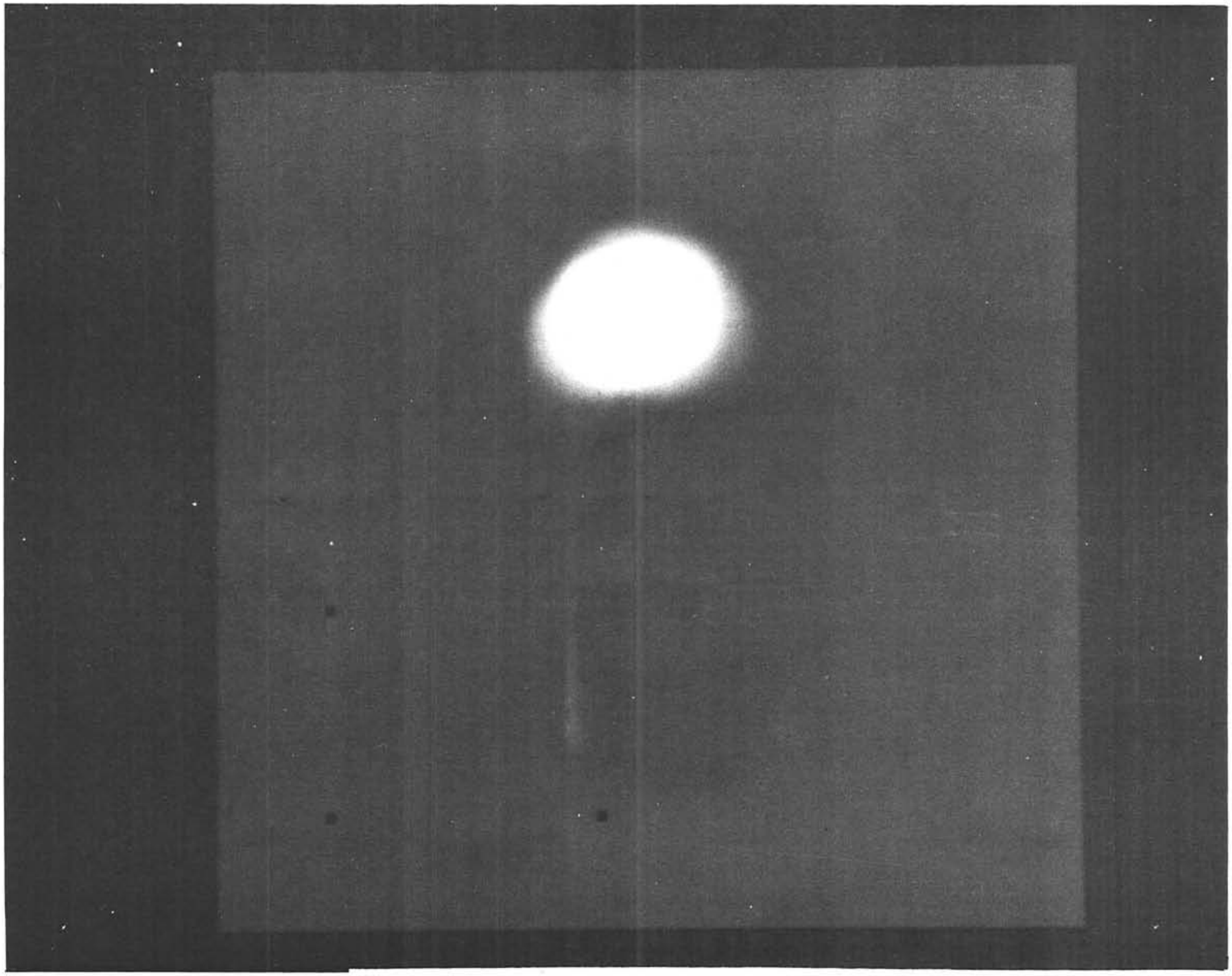


Figure B3-5. Four Point Support With Center Bar

DATE: 8-29-80 TIME: 2:25 P.M.
TEMP: 80°F EST. DISTANCE: 650 FT.
PANEL S/N: 09 WITH CENTER BAR
PANEL NO: 7
HELIOSTAT: NO. 1 – LOWER WING

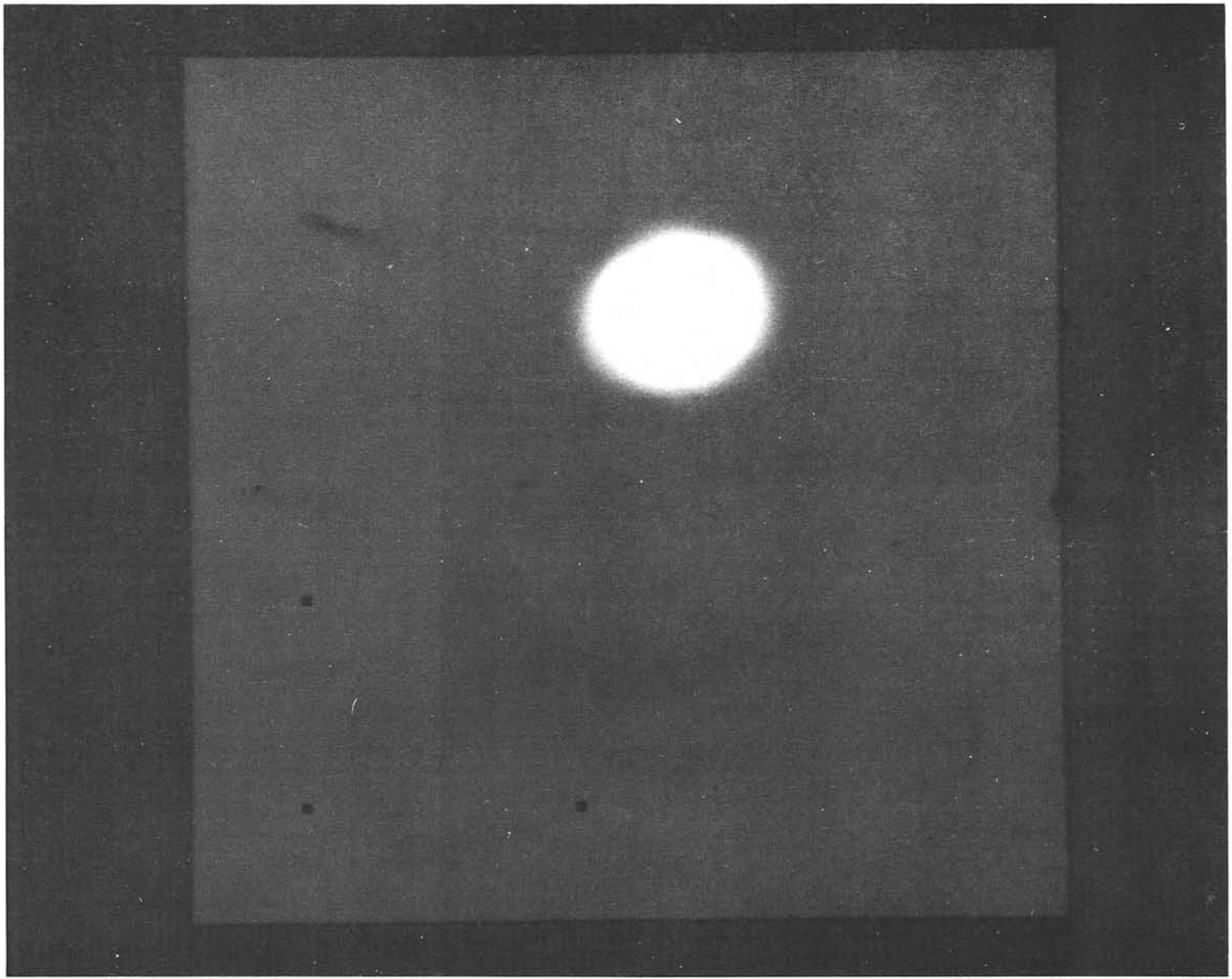


Figure B3-6. Four Point Support With Center And End Bar

DATE: 8-29-80 TIME: 2:24 P.M.
TEMP: 80°F EST. DISTANCE: 650 FT.
PANEL S/N: 09 WITH CENTER & END BAR
PANEL NO: 7
HELIOSTAT: NO. 1 – LOWER WING

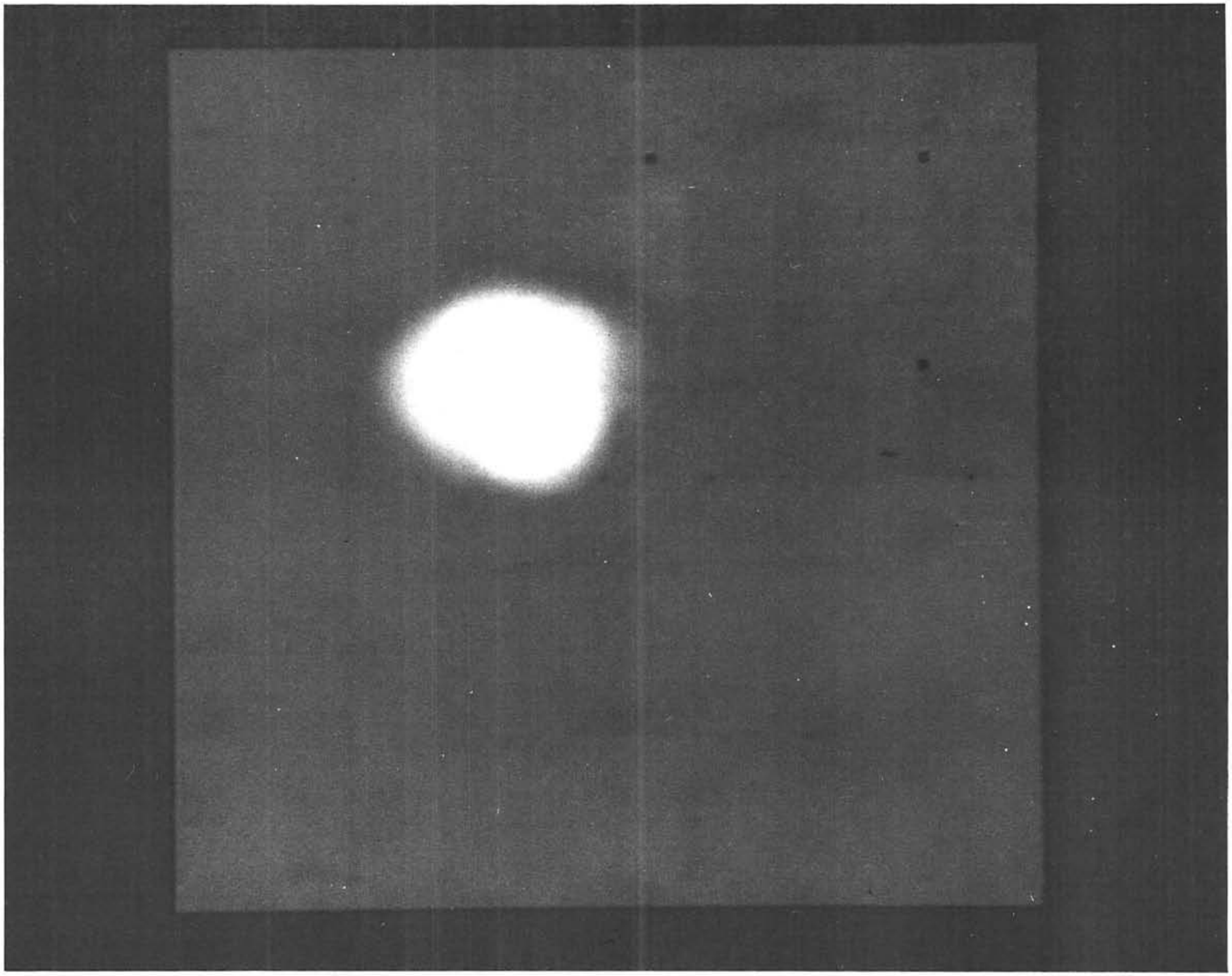


Figure B3-7. As Built—No Correction

DATE: 8-29-80 TIME: 2:29 P.M.
TEMP: 80°F EST. DISTANCE: 650 FT.
PANEL S/N: 15 WITH NO BAR
PANEL NO: 6
HELIOSTAT: NO. 1 – LOWER WING

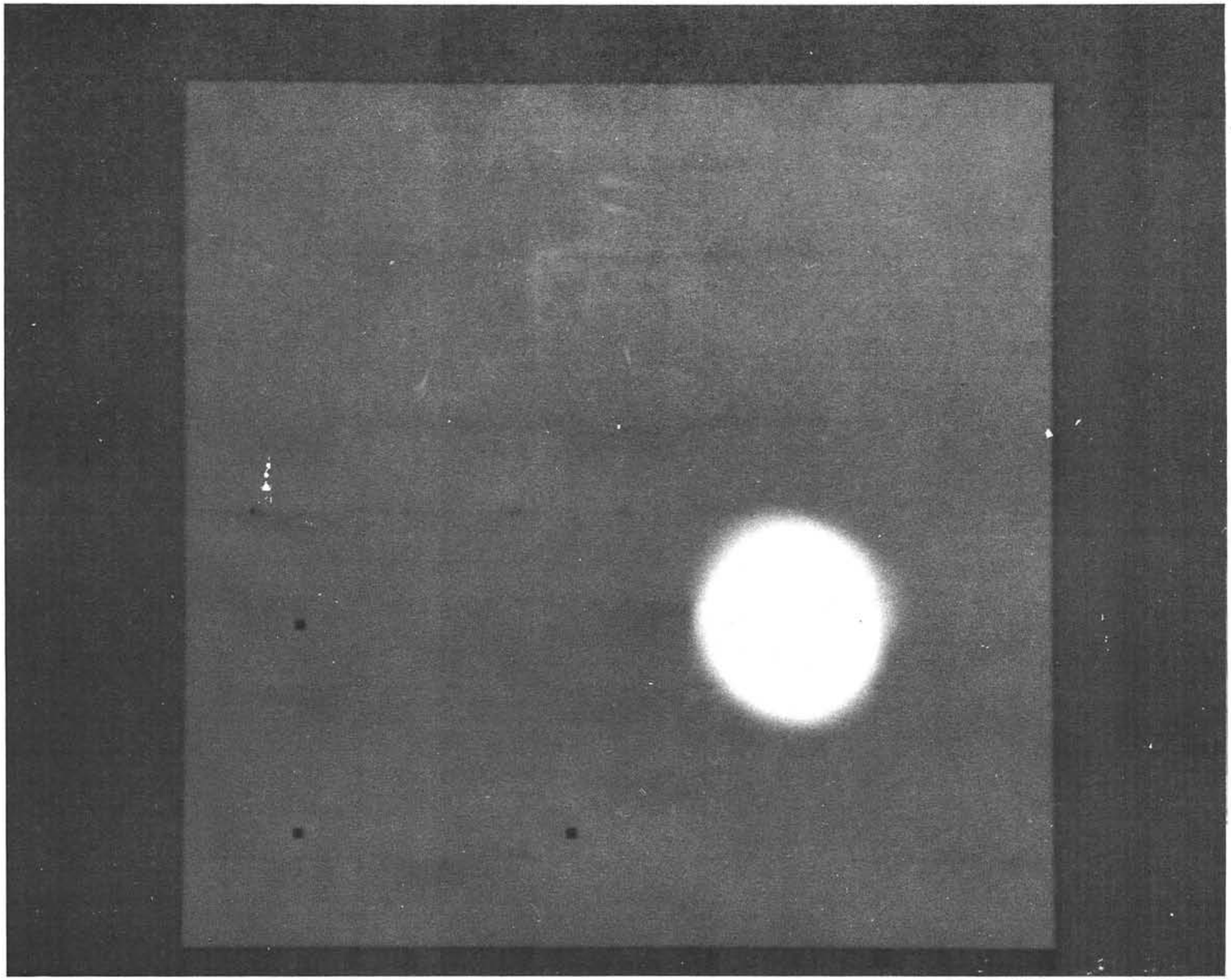


Figure B3-8. Center Bar Clamped

DATE: 8-29-80 TIME: 2:28 P.M.
TEMP: 80°F EST. DISTANCE: 650 FT.
PANEL S/N: 15 WITH CENTER BAR (CLAMPED)
PANEL NO: 6
HELIOSTAT: NO. 1 — LOWER WING

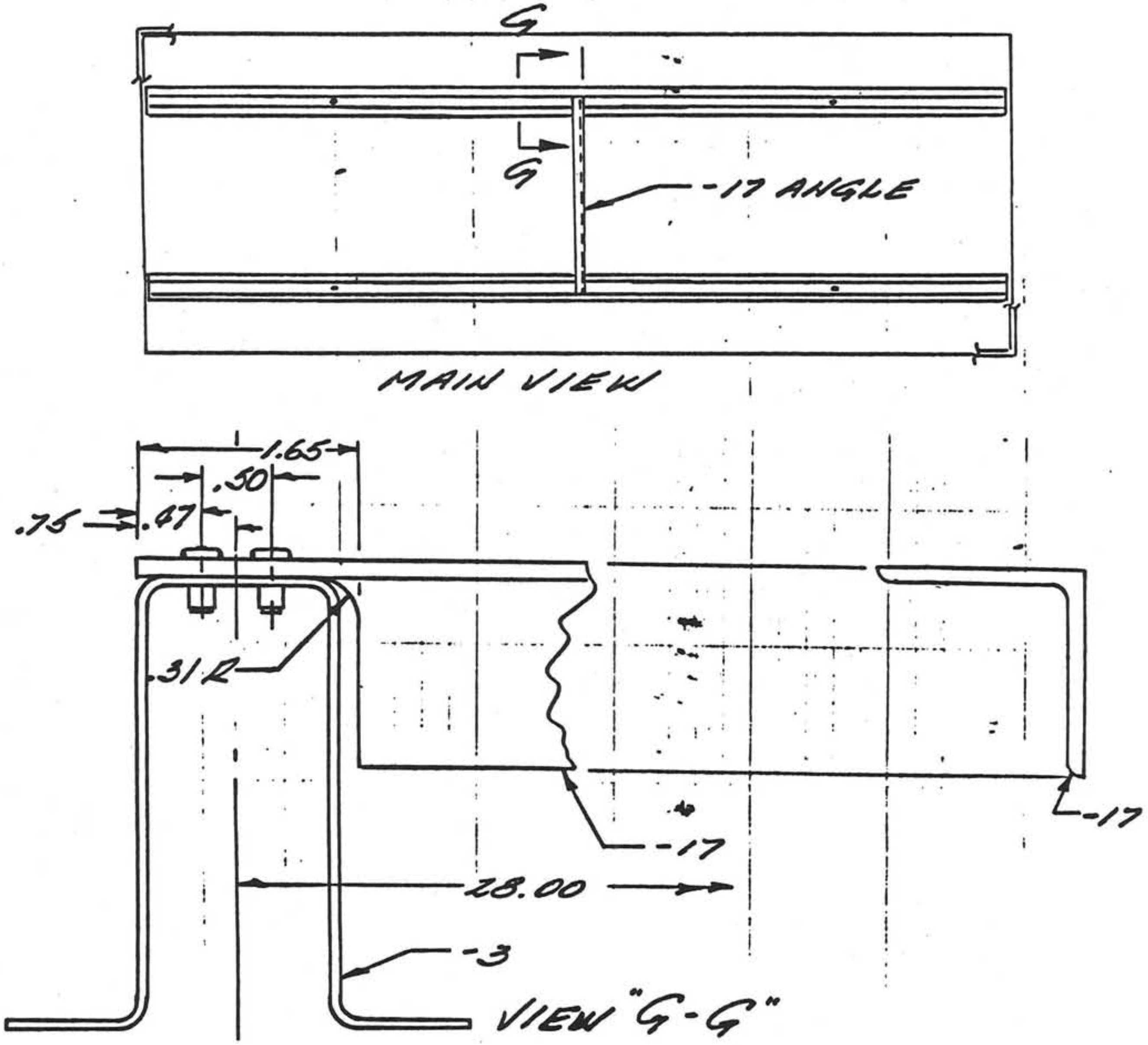


Figure B3-9. Sketch of Center Mirror Module Stabilizing Bar

Appendix B-4
HELIOSTAT MIRROR MODULE MAXIMUM TEMPERATURE PREDICTION

SUMMARY

Tests were conducted on the Second Generation mirror modules to gather data to use in predicting the maximum mirror module temperatures. Figure B4-1 shows a layout of the test setup used by Gray Butte, California in gathering the data. Table B4-1 shows the maximum mirror module temperature predictions based on a 122°F day with a solar flux of 308 BTU/hr ft^2 as measured on site.

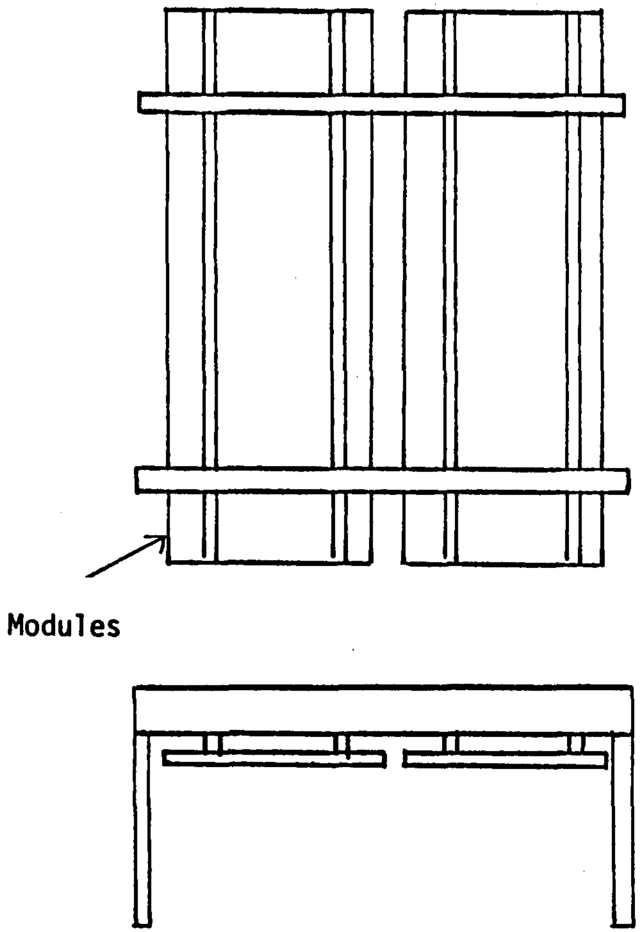
TEST PLAN

In conducting the tests, two mirror modules were used. One mirror module had the backside painted white, the other module was left unpainted. On 24 September 1980 preliminary tests to obtain initial data were conducted with mirrors laying on top of the frame. Temperature data was taken first with the backside of the modules facing up. After the maximum backside temperatures were recorded, the modules were turned over so that the mirrors were facing up. No data was taken for one hour after the modules were turned over to allow them to reach their new equilibrium temperatures. The mass of data used for the analysis was all obtained after September 24 with the modules bolted under the frame with their backsides facing up.

Data was also taken from one unpainted Second Generation mirror module hanging vertically with the mirror facing the sun. The solar heat flux of 308 BTU/hr ft^2 (972 w/m^2) was measured near noon using a pyrheliometer. A summary and sampling of the data obtained in provided in Figures B4-2 through B4-9.

METHOD OF ANALYSIS

The maximum temperature of the mirror modules due to solar radiation on their back sides was determined as follows. Plots of Δt (module temperature-air temperature) versus wind speed were made. One such plot is shown in



The modules are shown bolted to the bottom of the frame with the mirror side down. This is how all tests except for the September 24, 1980 tests were conducted. For the September 24, 1980 tests, the modules were laying on top of the frame.

Figure B4-1. Mirror Module Test Layout

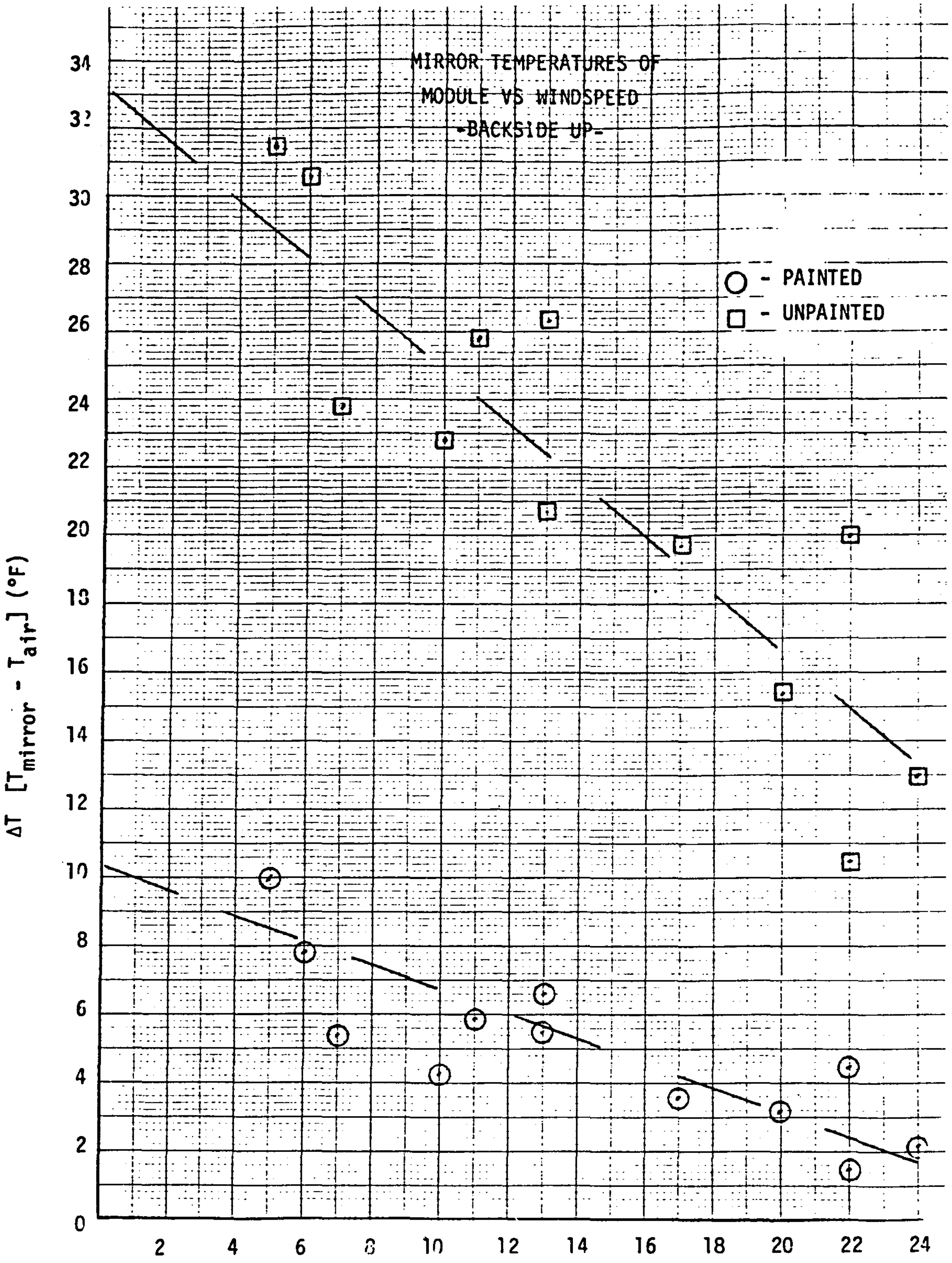


Figure B4-2. Temperature Difference Versus Wind Velocity

Date: Sept 24, 1980

Mirror Type: Double Glass - Back Unpainted

Comments: Backside up

Q_{solar} : 975 watts/m^2

Time	WIND SPEED ~ MPH	T_{air} ~ °F	Thermocouple Temperatures, Degrees F								
			#1	#2 *	#3 *	#4	#5	#6	#7	#8 *	#9
12:31	5	89.0	120.9	121.6	114.4	107.1	105.7	106.1	107.1	101.3	119.8
12:41	5	89.0	119.6	120.5	115.1	107.6	106.0	106.8	108.0	103.9	120.5
12:51		88.5	120.9	121.1	113.4	107.5	105.8	106.2	106.9	101.9	119.7
13:01		91.5	125.9	126.3	116.2	110.0	107.5	108.0	109.4	102.0	122.8
13:14		92.2	120.3	121.3	115.1	108.3	107.2	108.5	110.6	105.3	121.2
13:32	12	92.7	117.4	118.8	113.1	106.4	105.8	107.1	109.4	103.1	117.9

* Thermocouples are on the backside of the mirror

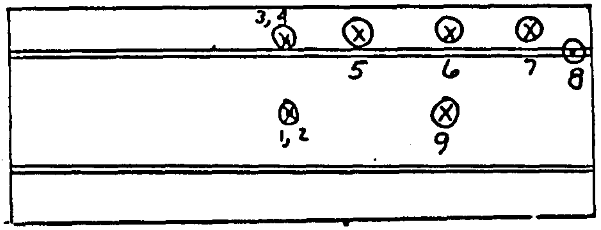


Figure B4-3. Back Unpainted, Back Side Up

Date: Sept. 24, 1980

Mirror Type: Double Glass - Painted Back

Comments: Backside up

Q solar = 975 watts/m^2

Time	WIND SPEED ∿ MPH	T_{air} ∿ °F	Thermocouple Temperatures, Degrees F								
			#1	#2 *	#3 *	#4	#5	#6	#7	#8 *	#9
12:31	5	89.0	104.9	105.7	107.7	104.5	105.1	103.9	106.7	101.5	102.9
12:41	5	89.0	103.5	104.9	106.9	103.7	103.8	103.4	106.7	103.8	102.7
12:51		88.5	105.1	106.2	106.7	104.2	104.1	103.6	106.7	103.0	103.1
13:01		91.5	107.3	108.2	108.2	105.6	105.2	104.5	108.2	100.6	104.4
13:14		92.2	103.9	105.6	106.2	103.6	104.1	103.7	107.1	104.6	103.5
13:32	12	92.7	102.3	104.2	104.5	101.3	102.4	102.9	105.0	101.9	103.0

* Thermocouples are on the backside of the mirror

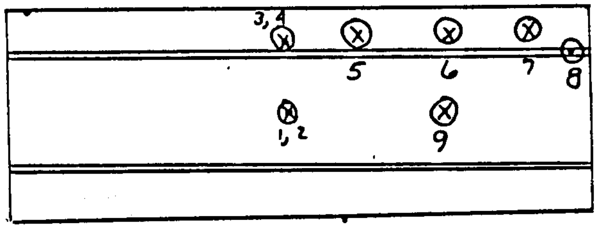


Figure B4-4. Back Painted, Back Side Up

CR15

Date: Sept 24, 1980

Mirror Type: Double Glass - Unpainted

Comments: Hangs vertically with the mirror facing the sun; $Q_{solar} = 975$ watts/m^2

Time	WIND SPEED ~ MPH	T_{air} ~ °F	Thermocouple Temperatures, Degrees F								
			#1	#2 *	#3	#4	#5	#6	#7	#8	#9
12:31	5	89.0	97.1	96.2							
12:41	5	89.0	99.6	96.9							
12:51		88.5	99.1	96.6							
13:01		91.5	102.0	99.2							
13:14		92.2	103.1	100.2							
13:32	12	92.7	102.2	99.5							
14:10		92.5	103.2	100.3							
14:20		93.8	103.0	100.2							
14:30		93.7	101.8	99.1							
14:40		90.7	102.4	99.9							
14:46		90.7	102.5	100.0							

* Thermocouples are on the backside of the mirror

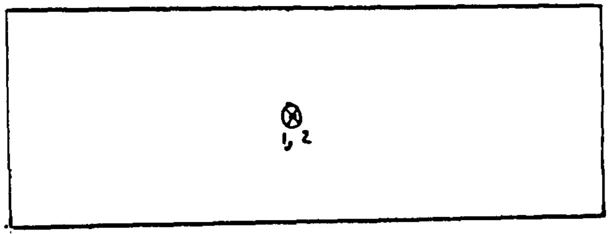


Figure B4-5. Vertical, Mirror to Sun

Date: Sept 27, 1980
Mirror Type: Double Glass - Unpainted
Comments: Mirror side up
Qsolar = 975 wa [illegible]

Time	WIND SPEED ∿ MPH	T_{air} ∿ °F	Thermocouple Temperatures, Degrees F								
			#1	#2 *	#3 *	#4	#5	#6	#7	#8 *	#9
14:10		92.5	100.4	99.9	97.8	99.9	99.3	100.0	99.0	105.4	103.4
14:20		93.8	99.9	99.4	97.6	99.9	98.7	99.5	98.4	105.4	102.9
14:30		93.7	99.6	98.9	97.3	99.9	98.4	98.9	98.0	104.6	102.4
14:40		90.7	100.4	100.0	98.0	100.6	98.7	99.5	98.4	106.4	103.1
14:46		90.7	101.1	100.8	98.9	101.1	99.3	101.1	99.3	107.8	103.9

* Thermocouples are on the backside of the mirror

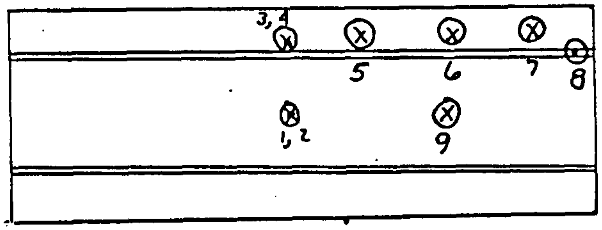


Figure B4-6. Mirror Side Up — Unpainted

Date: Sept 29, 1980
Mirror Type: Double Glass - Painted
Comments: mirror side up
Q_{solar} = 975 watts/m^2

Time	WIND SPEED ~ MPH	T_{air} ~ °F	Thermocouple Temperatures, Degrees F								
			#1	#2 *	#3 *	#4	#5	#6	#7	#8 *	#9
14:10		92.5	95.3	94.6	96.4	97.1	96.2	95.5	97.9	105.8	94.8
14:20		93.8	95.1	94.6	96.2	96.9	95.8	95.3	97.5	106.2	95.0
14:30		93.7	95.0	94.4	96.1	96.9	95.7	95.2	97.4	105.6	94.7
14:40		90.7	95.5	95.0	96.7	97.6	96.1	95.4	97.8	107.7	95.1
14:46		90.7	96.4	96.0	97.9	98.5	97.0	96.3	98.9	109.8	96.0

* Thermocouples are on the backside of the mirror

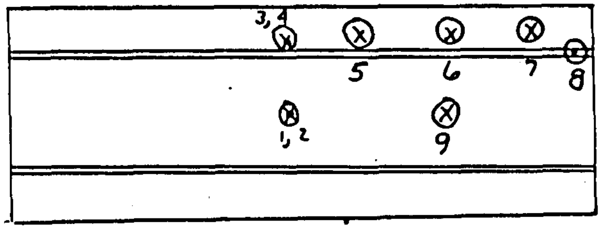


Figure B4-7. Back Painted, Mirror Up

Date:
Mirror Type: Double Glass - Unpainted
Comments: backside up

Time	WIND SPEED ~ MPH	T_{air} ~ °F	Thermocouple Temperatures, Degrees F								
			#1	#2 *	#3 *	#4	#5	#6	#7	#8 *	#9
10:05	6	84.8	100.7	101.0	107.4	97.2	96.5	89.8	97.7	97.3	87.2
10:35		98.1	111.3	111.6	114.1	102.4	101.8	95.8	103.7	100.5	91.4
11:05	6	90.5	115.6	116.2	116.2	105.6	104.9	99.0	107.1	105.3	94.4
11:35		93.1	121.9	118.9	122.9	108.9	108.2	103.3	111.0	108.2	98.2
12:05	12	92.8	126.3	127.2	119.0	110.8	109.0	105.9	112.7	108.8	101.1
12:35		94.3	127.2	127.2	116.9	110.4	108.7	106.2	112.7	107.4	101.8
13:05	12	94.1	125.2	125.4	115.6	109.8	108.9	106.3	113.1	107.4	102.0
13:35		96.2	126.9	127.3	114.3	109.4	108.2	106.6	112.9	107.8	103.3
14:05	14	96.6	123.4	123.8	110.5	107.3	106.2	104.9	110.8	106.3	102.5
14:35		98.9	121.9	123.2	108.1	105.2	104.1	104.5	109.1	107.3	103.3
15:05	14	95.6	119.4	119.3	100.7	102.9	101.6	103.2	107.2	105.3	103.2
15:35		98.5	115.8	116.5	98.8	101.4	99.9	102.6	105.5	106.0	103.4

* Thermocouples are on the backside of the mirror

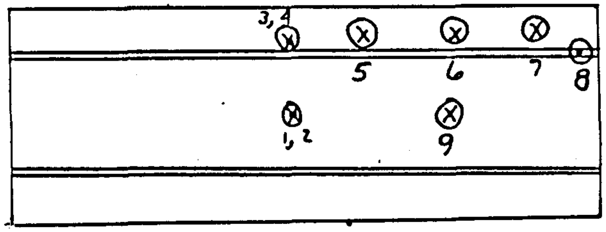


Figure B4-8. Unpainted, Back Side Up

Date: Sept 29, 1980

Mirror Type: Double Glass - Painted

Comments: backside up

Time	WIND SPEED ~ MPH	T_{air} ~ °F	Thermocouple Temperatures, Degrees F								
			#1	#2 *	#3 *	#4	#5	#6	#7	#8 *	#9
10:05	6	84.8	86.1	85.9	100.1	95.3	94.5	87.6	96.5	95.9	82.7
10:35		98.1	92.1	93.6	104.7	98.9	98.1	92.2	101.2	99.3	86.6
11:05	6	90.5	95.9	97.8	106.0	101.2	100.2	94.4	103.9	102.7	89.7
11:35		93.1	101.0	102.9	109.5	105.0	103.6	99.1	108.4	106.7	94.0
12:05	12	92.8	105.4	107.9	111.2	107.1	105.6	102.8	111.4	109.2	97.7
12:35		94.3	101.8	109.6	110.9	107.7	106.2	104.3	112.7	108.7	100.0
13:05	12	94.1	106.5	108.3	108.9	106.3	105.3	103.3	111.5	107.1	99.6
13:35		96.2	109.0	110.8	108.7	106.5	105.1	104.6	112.4	108.5	101.5
14:05	14	96.6	107.4	108.9	105.7	104.3	103.0	102.8	109.6	106.5	101.1
14:35		98.9	106.6	108.3	103.8	102.5	101.2	102.7	107.8	106.9	101.3
15:05	14	95.6	105.7	106.7	98.5	99.7	98.5	101.0	104.7	105.4	101.0
15:35		98.5	103.6	104.7	96.8	98.3	97.3	100.6	103.0	105.2	100.6

* Thermocouples are on the backside of the mirror

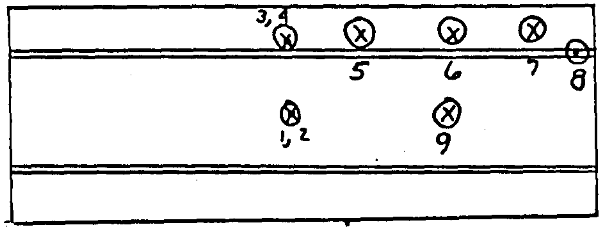


Figure B4-9. Painted, Back Side Up

Table B4-1. Module Maximum Temperature Predictions

	Maximum Temperature, Degrees F							
	Backside Up				Mirror Side Up		Mirror Side Up With Backlighting	
	Mirror		Back					
Mirror Module	T	"Theoretical"	T	"Theoretical"	Mirror	Back	Mirror	Back
Lam. Unpainted	155	154.5	157	156.5	131	130.5	155.5	157.5
Lam. Unpainted	132	133	134	136	131	130.5	137.5	138.5

Air Temperature = 122°F

Wind Speed = 0 MPH

Solar Energy Flux = 308 Btu/hr-ft^2

(See Table B4-2 for complete listing of assumptions used in calculations)

Figure B4-2. These plots were then extrapolated to obtain a zero windspeed Δt, which added to the ambient air temperature gives the desired maximum temperature of the module. However, these temperatures are valid for the modules only in the position in which they were exposed. An analytical model is required for temperature determinations when the modules are oriented mirror side to the sun and in the case of back lighting.

The model was developed by using the temperatures obtained from the modules in the test configuration to determine unknown parameters of the modules.

Concentrating on the sunward side of a mirror module, the system can be described by:

$$q = h_c \; (T_M - T_{air}) + \frac{K \; (T_M - T_B)}{D} \tag{1}$$

$q = \alpha_s \, q_{sol} = \alpha_s$ 308 BTU/ft^2-hr = absorbed heat flux

α_s = Solar absorptivity of module side facing sun

T_M = Temperature of module side facing sun

T_B = Temperature of module side away from sun

h_c = Convective heat transfer coefficient

K = Effective thermal conductivity

D = Thickness of mirror module

Values of T_M and T_B are extrapolated from the plots of ΔT versus wind speed. Both h_c and K remain to be determined however, since no accurate value of the effective thermal conductivity is available.

Using the same termperatures in the equation shown below as in eq. (1), and using available values for all other variables, h_c and K can be determined through the simultaneous solution of both equations.

$$\alpha_{s.f.} q_{sol} + \alpha_{s.b.} (.85) \, q_{sol} = h_c \; (T_b + T_M - 2T_{air}) - \alpha\varepsilon \left[(T_b + 460)^4 - (T_{air} + 460)^4 \right] \tag{2}$$

$\alpha_{s.f}$ = Solar absorptivity of module front surface

$\alpha_{s.b}$ = Solar absorptivity of module back surface (when applicable)

T_b = Temperature of back of module

T_m = Temperature of mirror side of module

α = 1.714×10^{-4} BTU/hr-ft^2-°R^4 (Stefan-Boltzmann constant)

ε = Thermal emissivity of back module

The values of all the parameters for one mirror module design in the test configuration were then known. These values were later used in applicable cases to determine the value of other variables. Table B4-2 shows the final values of all the parameters used in this analysis, which values were derived, the basis of their derivation and at what point in the series of calculations they were derived.

Table B4-2. Values Used in Calculation of Module Maximum Temperatures

Order of Analysis	Mirror Module	Front		Back				
		α_s	ε	α_s	ε	h_c	K	Δ X
1	Laminated Glass Painted	0.15	0.93	0.33	0.95	3.43*	0.68*	3 in.
2	Laminated Glass Unpainted	0.15	0.93	0.94*	0.95	3.43**	0.68**	3 in.

Solar radiation = 308 BTU/hr-ft^2

Ground temperature = 122°F

Air temperature = 122°F

*Values derived from calculations
**Derived value retained from previous calculation

All other values are data

After developing a model of the modules based on their backside-up orientation extrapolated to a zero-wind-speed condition, this model is used to predict maximum module temperatures for the other cases. The match obtained between the model and the test data, and the predicted maximum module temperatures for the various module conditions are shown in Table B4-1.

DATA OBSERVATIONS

The following observations were made while examining the test data:

1. Some locations on the backs of the mirror modules were hotter than the mirror when the mirrors were face up. The higher backside temperature is probably due to reradiation or sun reflecting off the ground and hitting the bottom side of the module which has a high solar absorptivity ($\alpha_s = 0.90$), as compared to the mirror ($\alpha_s = 0.15$).

2. Thermocouple Nos. 6 and 9 on the laminated glass modules show significantly lower temperatures than the other thermocouples when the backside of the modules are facing the sun. This is seen in all the data except for 24 September 1980. These lower temperatures are caused when the mirror modules were mounted under the frame and were caused by the frame blocking the sun from the module in the area of the frame. On September 24, 1980 the modules were on top of the frame so there was no blockage.

3. When the modules were mounted under the frames the modules painted white had their highest temperatures in the area of the frame. This is because the frames weren't painted white so they reached a higher temperature than the white modules. This isn't shown in the September 24, 1980 data because the modules were on top of the frames, thus blocking the sunlight from the frame.

Appendix B-5
DRIVE ASSEMBLY TEST

SUMMARY

This report documents design evaluation testing accomplished to investigate and validate performance of the Second Generation heliostat drive unit, MDAC P/N 1D22475-1. A test specimen, defined by 1D22436-1, was used for this purpose and a summary of testing accomplished is as follows.

A. Wire Race Bearing
   1. Load deflection testing.

B. Elevation Drive
   1. Start torque at maximum operating load.
   2. Efficiency.
   3. Hysteresis testing at no-load and maximum operating loads.
   4. Load deflection testing at maximum static loads.

C. Azimuth Drive
   1. Starting torque at maximum operating load.
   2. Efficiency.
   3. Hysteresis testing at no-load and maximum operating loads.
   4. Load deflection testing at maximum static loads.
   5. Reduction ratio.

During the latter part of the test effort, it was discovered that there was excessive input hysteresis (dead band) in the azimuth drive unit. The problem was traced to high friction in the wire race bearing and was fixed by reshimming the bearing.

The shimming procedure was revised to preclude this potential problem.

Following rework, the unit was retested for those parameters which were influenced by reshimming. A summary of the final test results, including the unit design requirements, is presented in Table B5-1.

Table B5-1. Second Generation Heliostat Drive Unit Requirements/Capabilities

	Azimuth		Elevation	
Parameter	Requirement	Capability	Requirement	Capability
Travel time	180° in 15 min	180° in 12.5 min	90° in 15 min	∿ 90° in 6.0 min
Survival load (face up at 90 mph)	99,500 in-lb	> 212,500 in-lb	27,300 lb	> 44,000 lb
Maximum static load (any orientation at 50 mph)	144,000 in-lb	> 212,500 in-lb	19,900 lb	> 18,600 lb
Maximum operational	80,900 in-lb	103,000 in-lb	10,816 lb	> 18,600 lb
Deflection at 27 mph	2.4 mrad at 41,900 in-lb	1.7 mrad at 42,000 in-lb	1.85 mrad at 52,900 in-lb and α = 20, 40°	1.6 mrad at 52,900 in-lb and α = 40°
Overturning moment (at the azimuth drive bearing centerline)	401,000 in-lb with 9,400 lb axial and 4,500 lb Radial	> 512,000 in-lb		
Emergency stow condition (50 mph wind)	Static capability		13,900 lb	> 15,000 lb

Final conclusions are that the unit performed satisfactorily, all design requirements were met,* and the structural integrity of the unit was proven. The drive unit is recommended for use on the Second Generation heliostat.

DISCUSSION

Testing of the drive unit was accomplished in the MDAC-HB Structures Laboratory. The test specimen was built up on a short test pedestal to the requirements of 1D22436. Testing was performed in three categories: (1) testing to verify proper shimming of the wire race bearing, (2) testing to evaluate the elevation drive, and (3) testing to evaluate the azimuth drive.

1.0 WIRE RACE BEARING EVALUATION

The wire race bearing was shimmed during assembly of the drive per the requirements of 1D22494. The procedure is to assemble the unit without O-rings or shims and torque the 3/8 inch bolts to 10 ± 1 in-lbs. The gap between the 1D22489-1 retainer and 1D22474-1 support is measured at four places 90 degrees apart and the shim sized to the average reading +0.000/-0.001.

The specimen was tested to determine compliance of the bearing at the maximum overturning moment of ± 401,000 in-lbs. The specimen was instrumented with dial indicators and measurements of load versus deflection were recorded. Various combinations of shim thickness and bolt torque were investigated until acceptable compliance was achieved.

With the shim thickness of 0.063 inch, data shown in Figure B5-1 were obtained. These data indicate a tight bearing with a compliance of only ± 0.5 mrads.

During testing to determine the load deflection characteristics of the wire race bearing, the test specimen was inadvertently overloaded in the elevation axis. This resulted in a load of approximately 44,000 lb tension applied to the jack. The jack design load is 28,100 lb tension which means

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*The 50 mph emergency stow requirement is accommodated by travel to the horizontal stow position with the elevation drive only, and loads in azimuth accommodation statically.

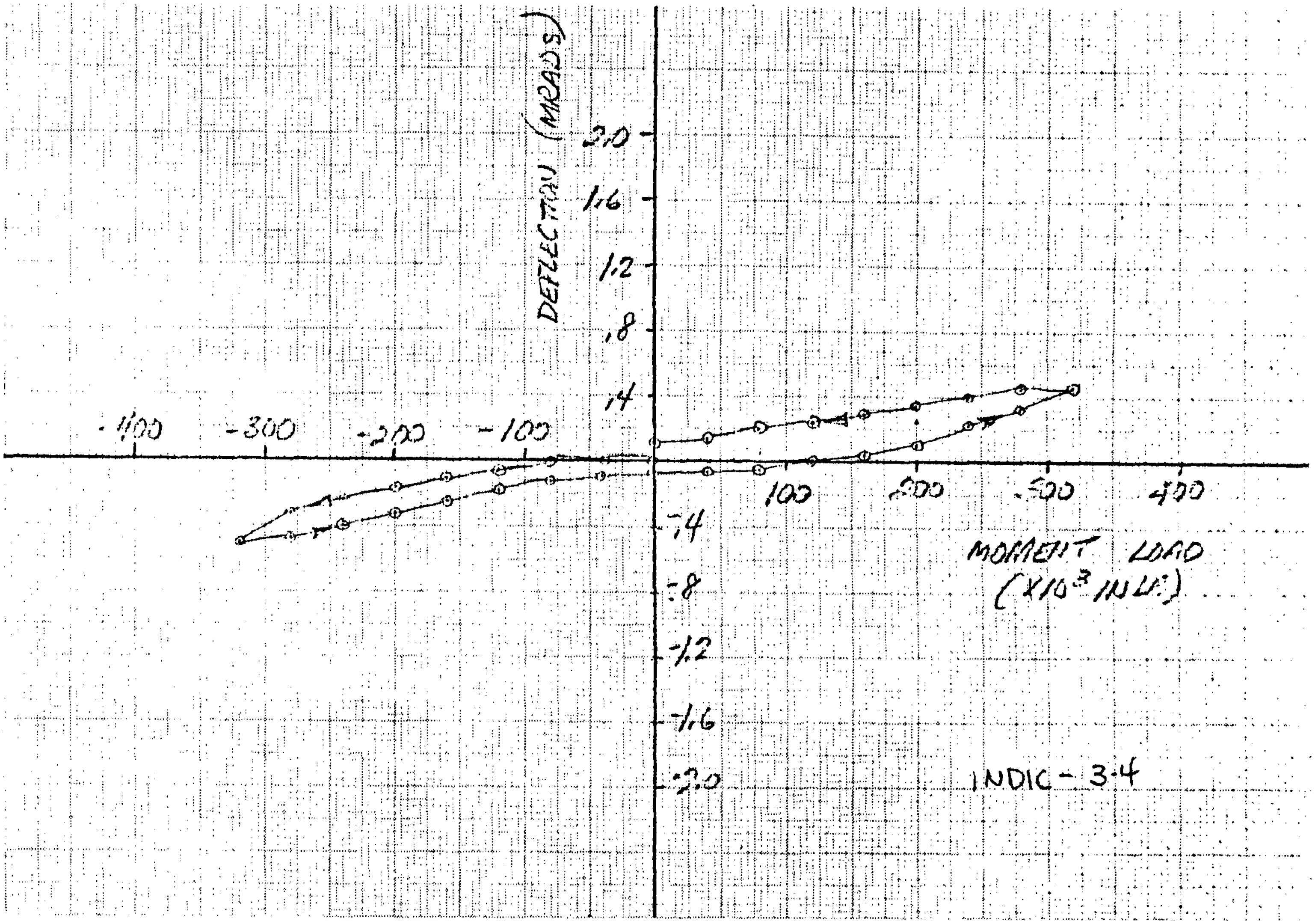

Figure B5-1. Load Versus Deflection, Elevation Plane (0.063-In. Shim) a 60 percent overload was applied. The specimen was not damaged as determined by visual inspection and dimensional checks of the jack and main beam structure following the incident. A load deflection test was run on the jack with the test specimen at the 40 degree attitude. The test results are shown in Figure B5-2. These data show a 0.011 inch backlash around the zero load point which is more than anticipated. The backlash in the ball nut, as measured at Duff-Norton was 0.003 to 0.005 and the backlash in the helicon gear set would be negligible at the output. Further investigation led to the conclusion that the jack was structurally sound and still operating properly. In operation in the heliostat the jack is always in tension and therefore the backlash does not affect pointing accuracy.

This overload condition also resulted in an overturning moment of 512,000 in-lb on the wire race bearing. Continued testing and later disassembly showed no damage to this hardware.

2.0 ELEVATION DRIVE TESTS

Elevation drive testing was accomplished to determine starting torques, efficiencies, maximum operating hysteresis, and maximum static hysteresis. All external loads were applied to the test specimen using hydraulic cylinders.

2.1 STARTING TORQUE

This test was run with the specimen at a 90 degree elevation angle (main beam vertical) and at 10,816 lb tension load applied to the jack (142,700 in-lb moment). This represents a worst case operational load for the elevation drive motor. A torque wrench was used to measure the torque required to breakout the motor with and against the load. Voltage was applied to the motor and increased until breakout occurred in both directions. In a second test the external hydraulic loads were removed for the specimen leaving a dead weight moment of 10,400 in-lbs (790 lbs on the jack). Breakout torque and voltage were measured at this condition. The results of these tests are as follows:

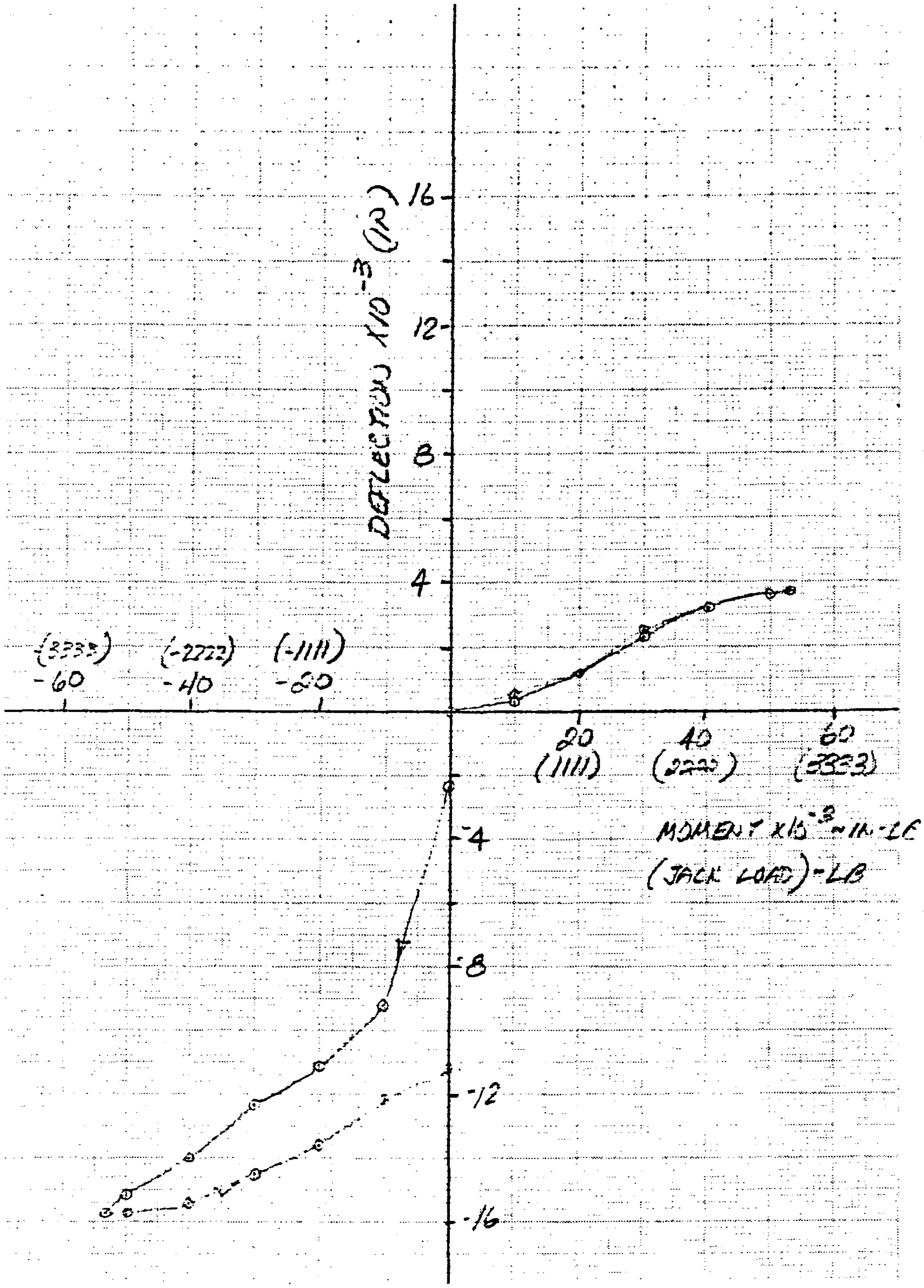

Figure B5-2. Elevation Drive Jack Deflection at 40°

Moment (in-lbs)	Jack Load (lbs)	Breakout Torque		Breakout Voltage	
		With	Against	With	Against
142,700	10,816 tension	8 in-lbs	23 in-lbs	156	158
10,400	790 tension	50 in-oz	60-70 in-oz	157	157

Design calculations predicted a worst case startup torque of 28.8 in-lbs would be required for the jack motor. This value was calculated using manufacturers worst case efficiencies for the ball nut, bearings, and helicon gear set. The 23 in-lb actual measured value is well within this maximum. The capacity to accommodate a nonoperational emergency stow load of 13,800 lbs is proven by extrapolation of the breakout torque and voltage requirements at 10,816 lbs against the motor capability determined in a previous test breakout torque is 32 in-lbs at 187V and 39 in-lbs at 208V.

2.2 EFFICIENCIES

The elevation drive was loaded to 180,000 in-lbs at 40 degrees, and 142,700 in-lbs at 90 degrees, and power applied to the motor for 20 seconds to measure efficiency. The counter on the motor was used to determine the distance traveled and a power meter in the voltage supply to the motor gave a direct readout of voltage, current, and power. The results are recorded in Table B5-2 and show an efficiency range of 15.3 percent and 18.4 percent for the two/rads respectively working against the load.

2.3 OPERATING LOAD HYSTERESIS

Load versus deflection measurements were taken on the specimen in the elevation plane at angles of 0 degrees, 40 degrees and 90 degrees. Hydraulic cylinders applied a moment of ± 53,000 in-lb (Figure B5-3) to simulate a 27 mph wind load, and deflection readings were taken at intervals using electronic levels (Figure B5-4).

Three minilevels (Wyler Co. Model #10H-150) were used. One mounted to the pedestal, one to the support structure, and one to the main beam. Data from these tests are presented in Figures B5-5, B5-6 and B5-7. The design these tests are presented in Figures B5-5, B5-6 and B5-7. The design requirement for the drive unit is 1.85 mrad average deflection at 40 degrees in a 27 mph wind. Test results at 40 degrees elevation angle show a deflection of 1.2 mrad for a moment load corresponding to 27 mph wind load.

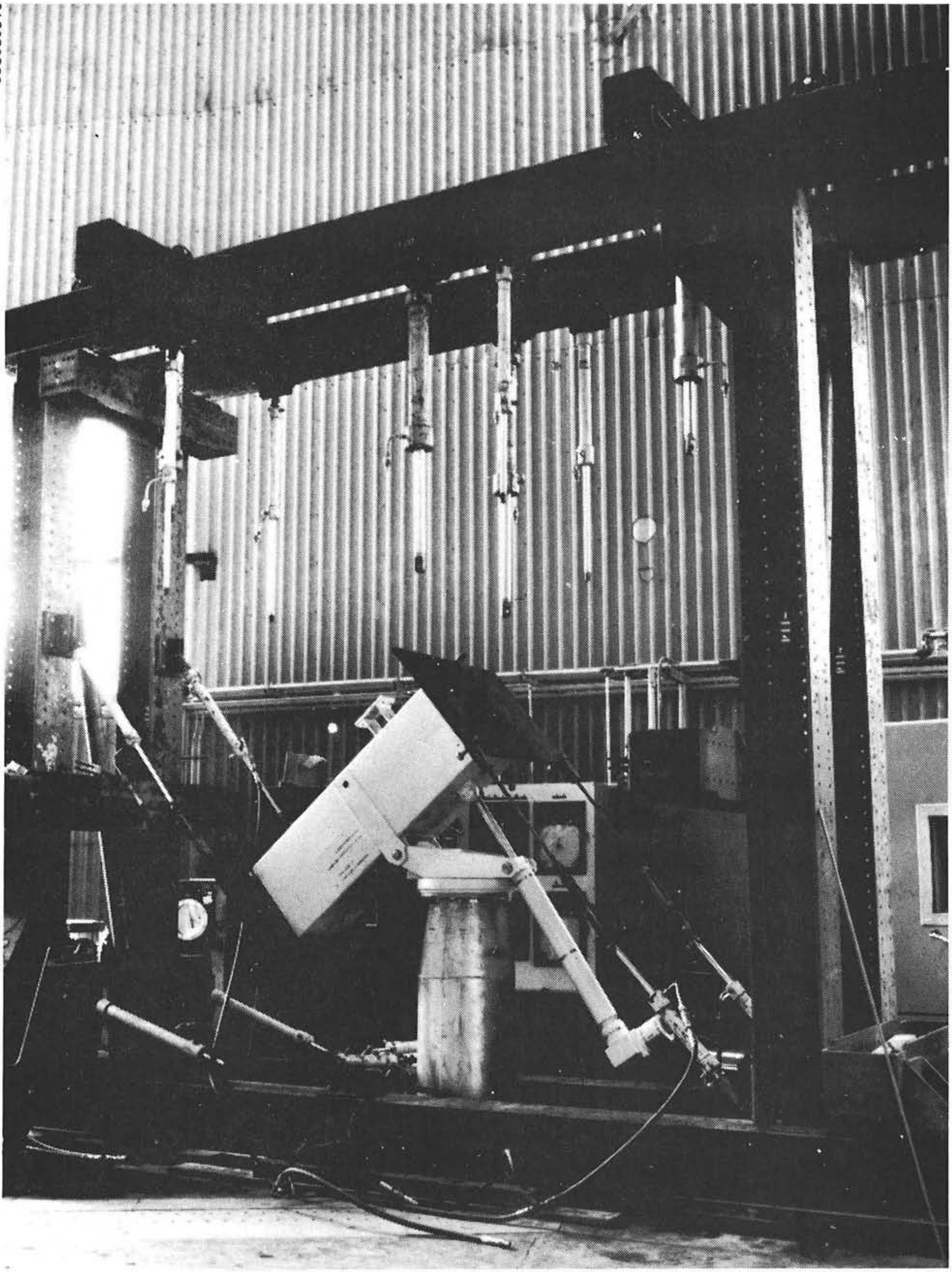

Figure B5-3. Elevation Drive Test Setup

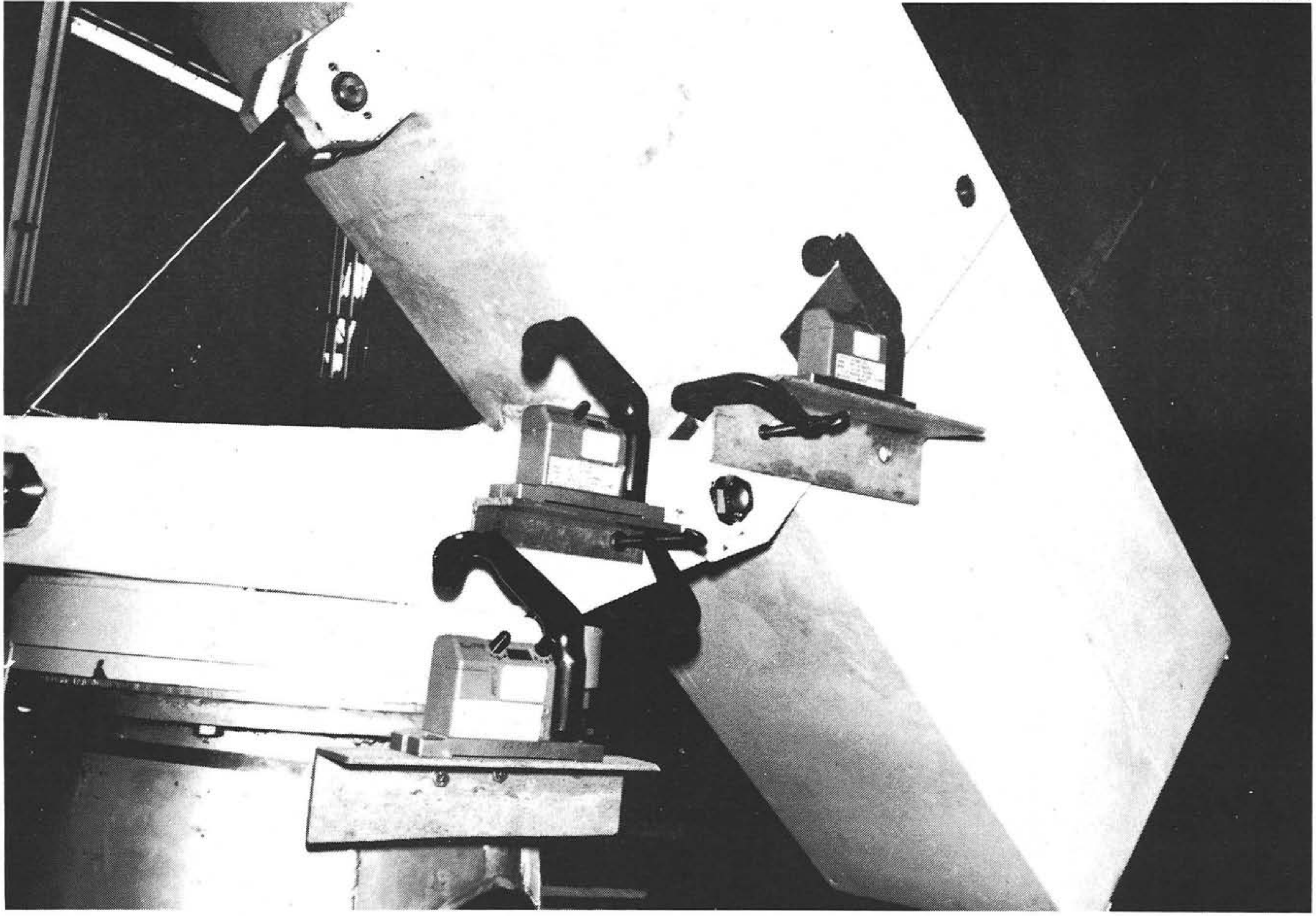

Figure B5-4. Minilevel Setup For Deflection Readings

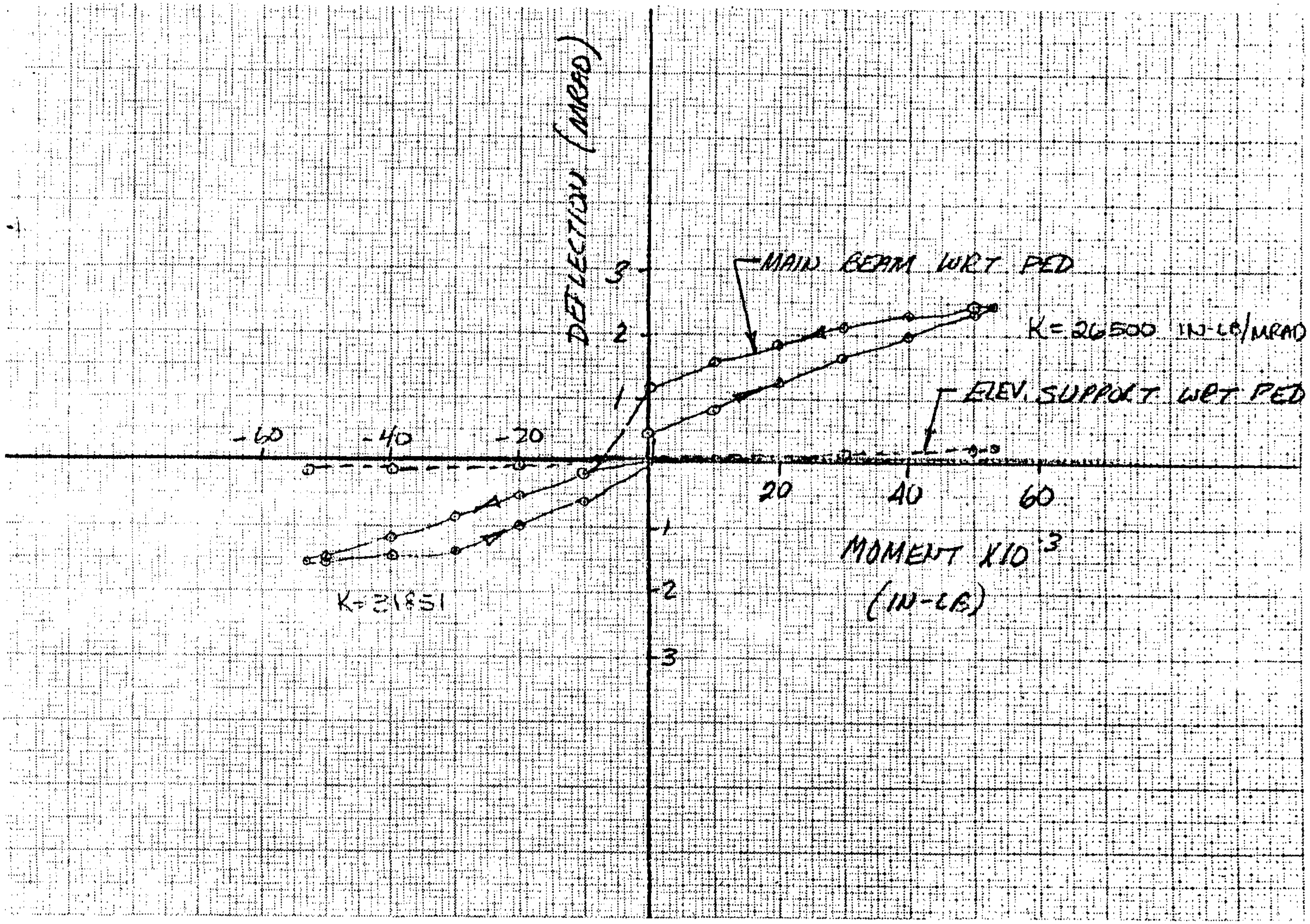

Figure B5-5. Elevation Drive Maximum Operating Hysteresis at 0° (0.063-In. Shim)

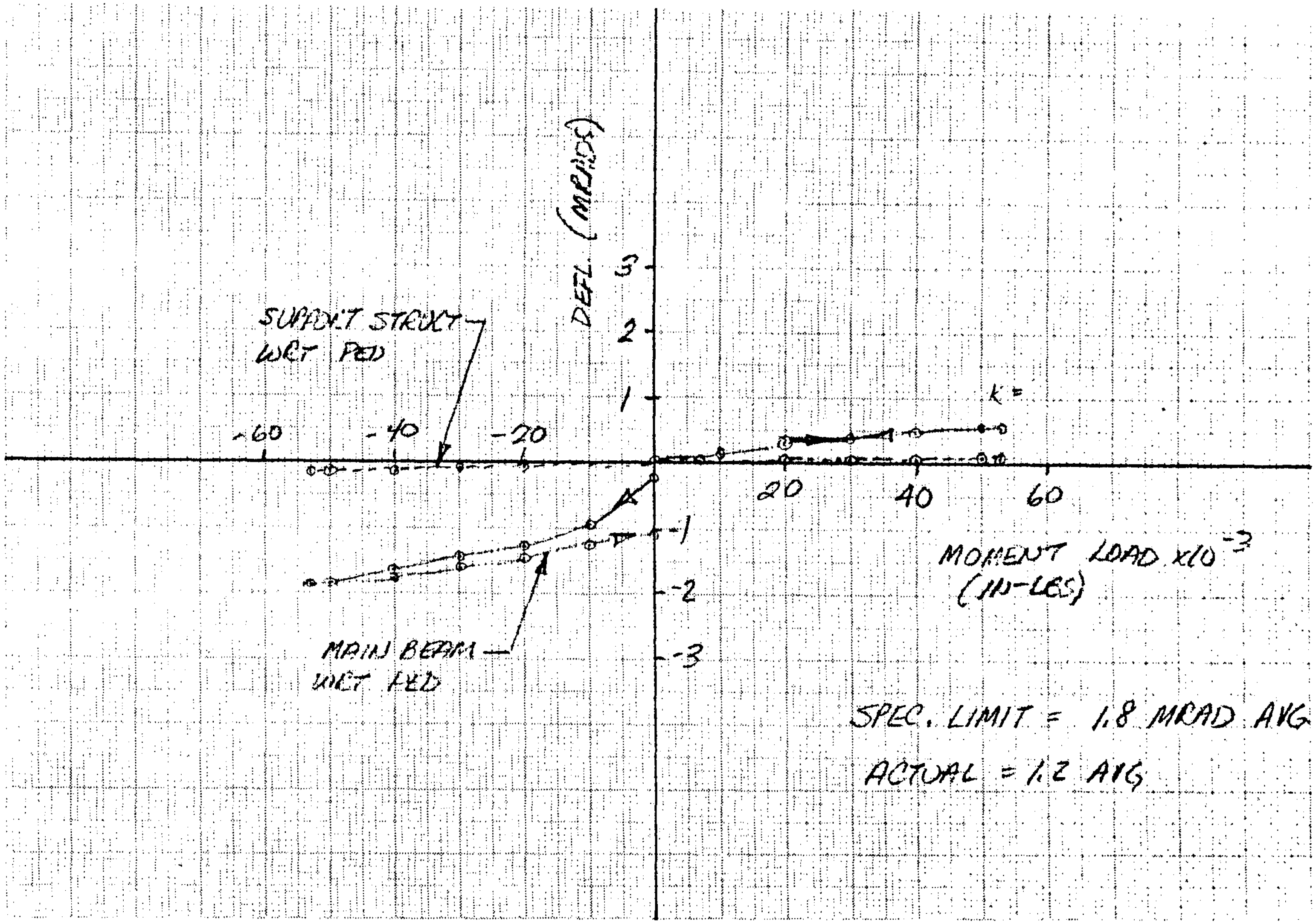

Figure B5-6. Elevation Drive Maximum Operating Hysteresis at 40° (0.063-In. Shim)

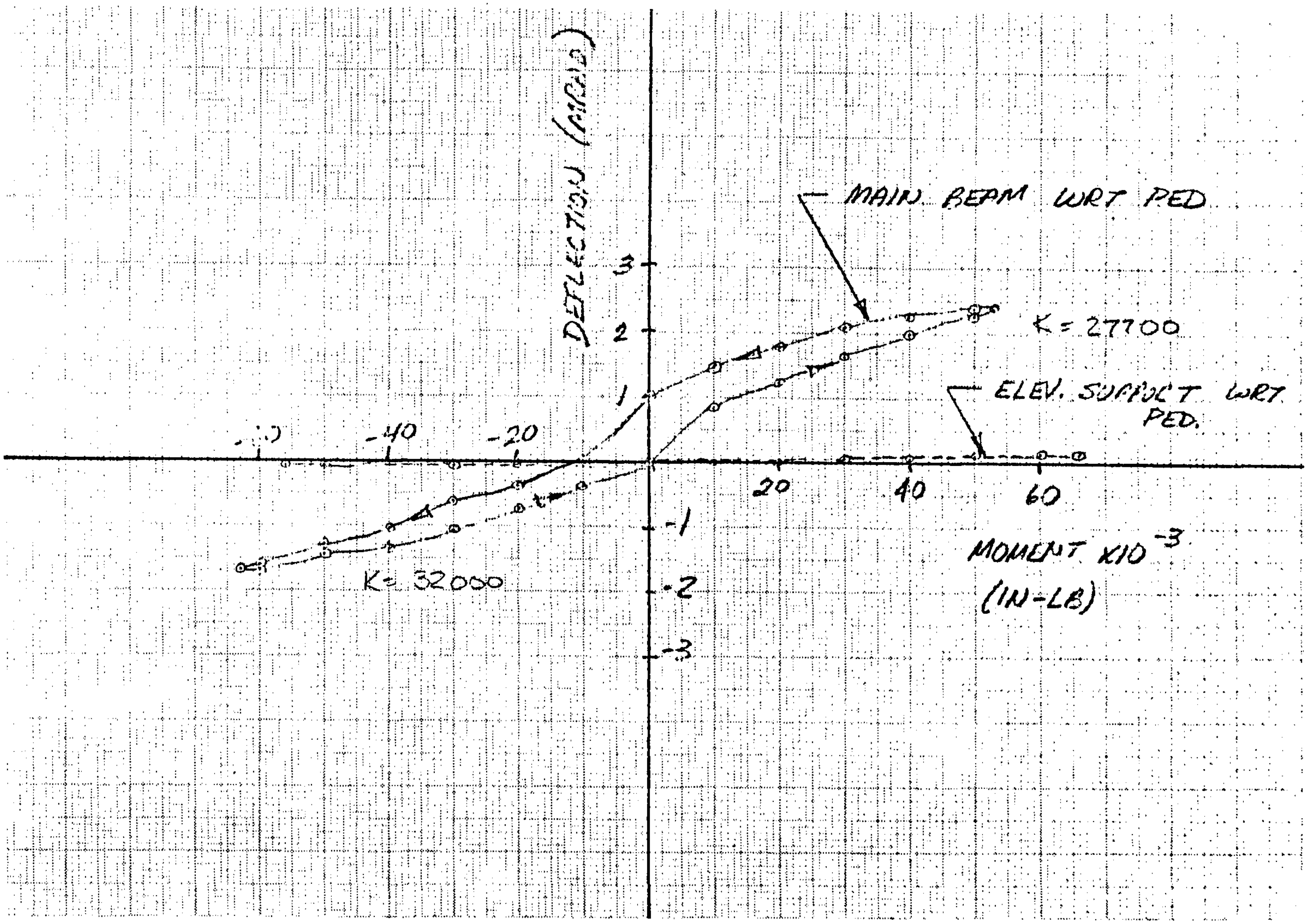

Figure B5-7. Elevation Drive Maximum Operating Hysteresis at 90° (0.063-In. Shim)

Table B5-2. Second Generation Heliostat Efficiencies

1T53864 Test Data
7-22 to 7-30-80

Moment Load (x1000 in-lb)	Motor Rotation WRT Load	Volts	Current Amps			Watts	Power In (ft-lb/sec)	Power Out (ft-lb/sec)	Efficiency (%)
			A	B	C				
AZIMUTH DRIVE									
80.9 CW	Against	212	1.1	1.1	1.15	280	206.5	28.6	13.8
80.9 CW	With	212	0.9	0.9	0.9	110	81.1	----	----
40 CW	Against	211	1.0	1.0	1.0	220	162.3	14.3	8.8
40 CW	With	212	0.9	0.9	0.9	100	73.8	----	----
80.9 CCW	Against	212	1.1	1.15	1.15	320	236	28.7	12.2
80.9 CCW	With	212	0.9	0.9	0.9	105	77.4	----	----
40 CCW	Against	212	0.95	1.0	1.0	220	162.3	14.3	8.8
40 CCW	With	212	0.9	0.9	0.9	100	73.8	----	----
ELEVATION DRIVE									
180 Tension	Against	212	1.6	1.5	1.39	420	310	56.9	18.4
at 40°	With	212	1.15	0.95	0.93	156	115	----	----
142.7 Tensn	Against	208	1.8	1.7	1.65	530	391	59.8	15.3
at 90°	With	208	1.15	0.9	0.9	130	96	----	----

Another test of elevation drive hysteresis and sensitivity was performed to quantify the unit performance. Input hysteresis was measured with the unit at 40 degrees elevation by manually advancing the drive motor and monitoring the change in elevation using the minilevel. Data was taken at every four motor turns. The test was conducted at no-load (specimen dead weight only) and at 53,000 in-lbs tension and compression load. Data is plotted in Figures B5-8 through B5-10. Two motor turns were the maximum hysteresis noted as a measure of input sensitivity.

The control system budget for elevation drive backlash was originally targeted at 0.14 mrads. At the optimum linkage gain, 0.14 mrads equates to 1.1 motor revolution at the optimum linkage gain. Further evaluation considering the total budget for beam pointing error (1.43 mrad rms) concluded that two motor turns backlash is acceptable.

2.4 MAXIMUM STATIC LOAD HYSTERESIS

Deflection testing in the elevation plane continued up to loads exceeding the maximum static requirements of the drive unit. With the unit at 0 degrees and 90 degrees elevation, loads of ± 230,000 in-lb were applied and deflection readings taken at intervals. These data are presented in Figures B5-11 and B5-12.

3.0 AZIMUTH DRIVE TESTS

Azimuth drive testing was accomplished to determine starting torque, efficiencies, maximum operating hysteresis and maximum static hysteresis. All external loads were applied with hydraulic cylinders and deflection readings about the azimuth axis obtained using a transit and target. Moment CW-CCW reference is looking down on the specimen.

3.1 STARTING TORQUE

Moments were applied to simulate the maximum operating load for the azimuth drive and a torque wrench used to measure the motor breakout torque. Voltage was applied to the motor and increased until breakout occurred. A summary is presented below.

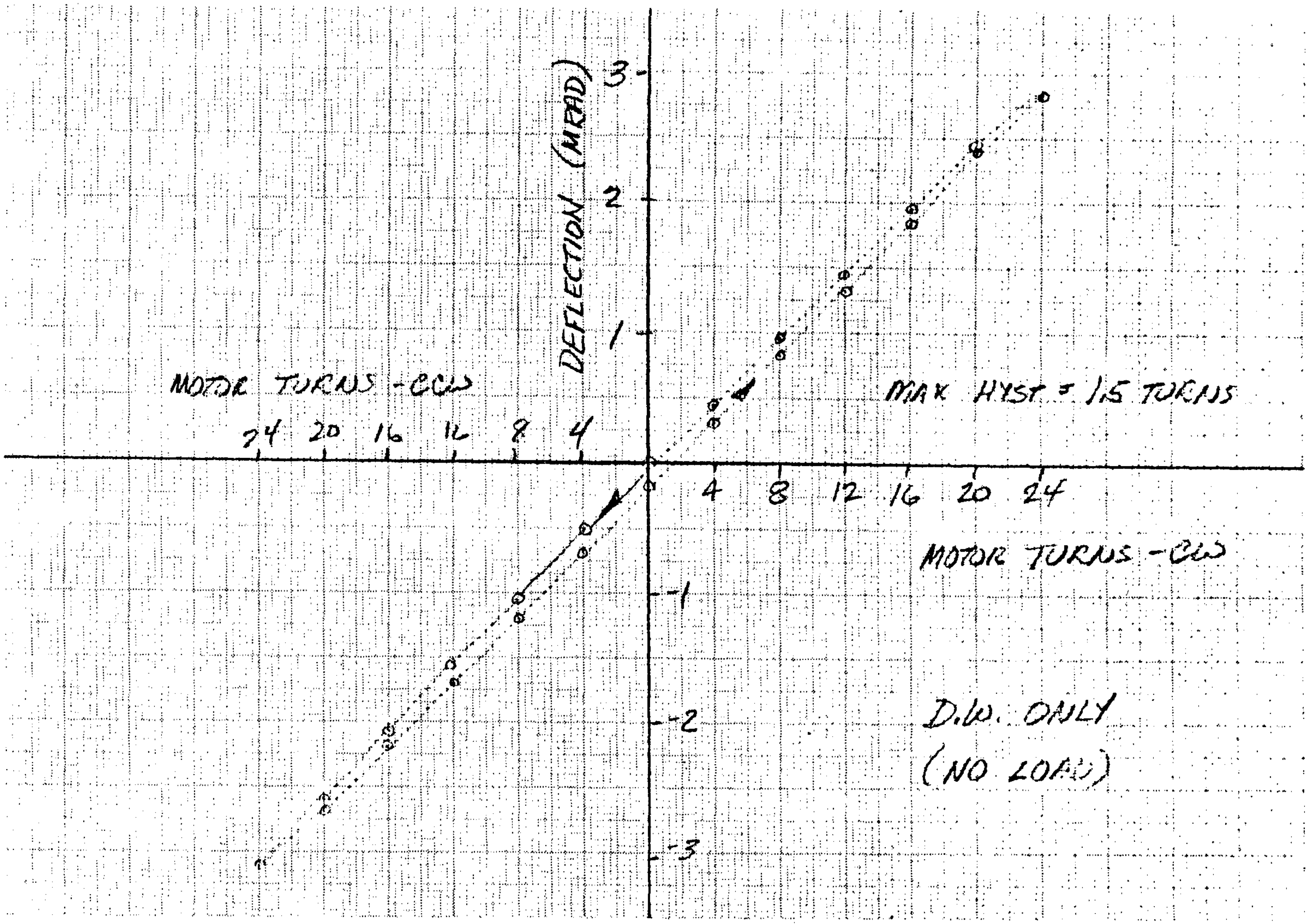

Figure B5-8. Elevation Drive Input Hysteresis (0.063-In. Shim)

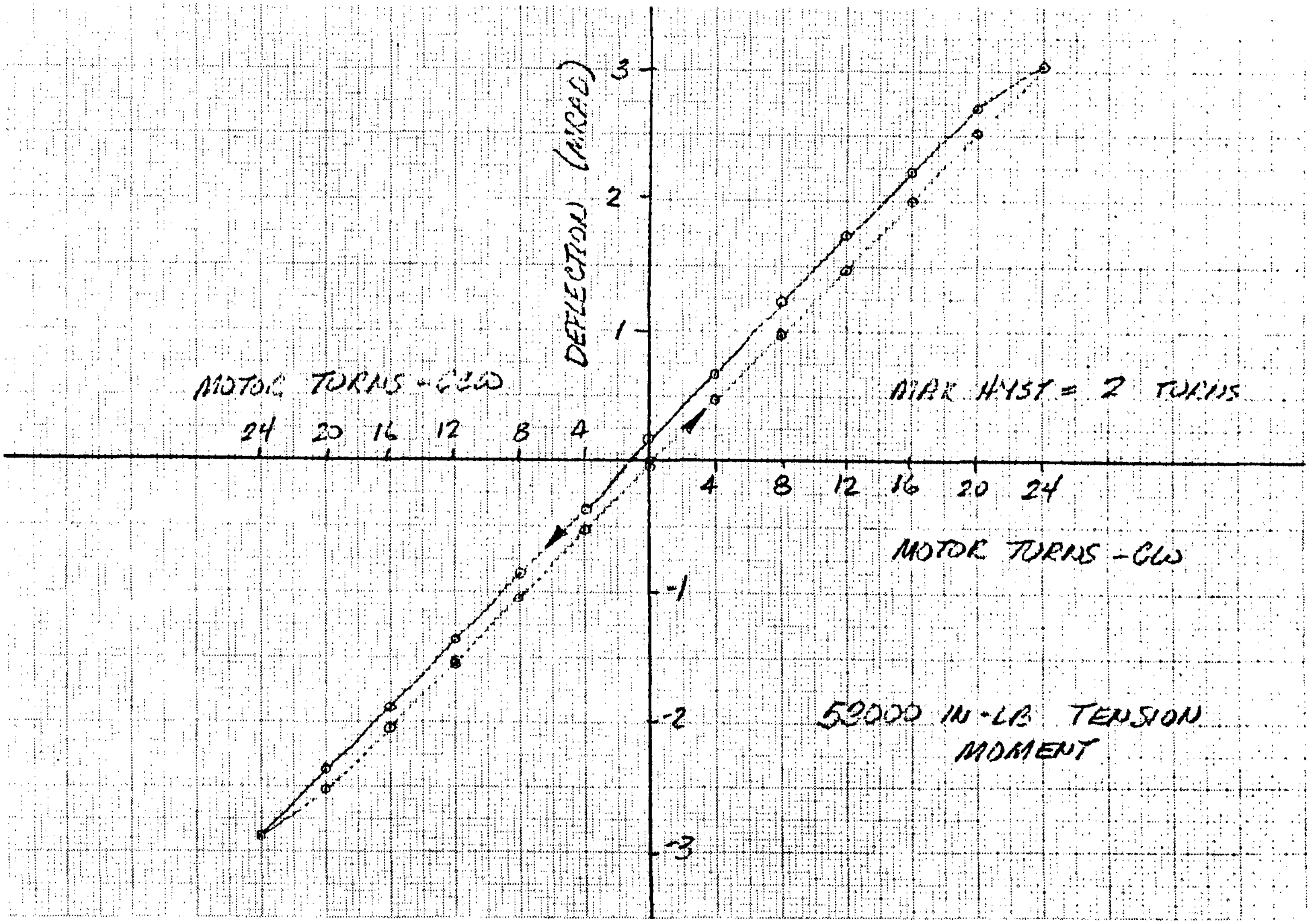

Figure B5-9. Elevation Drive Input Hysteresis (0.063-In. Shim)

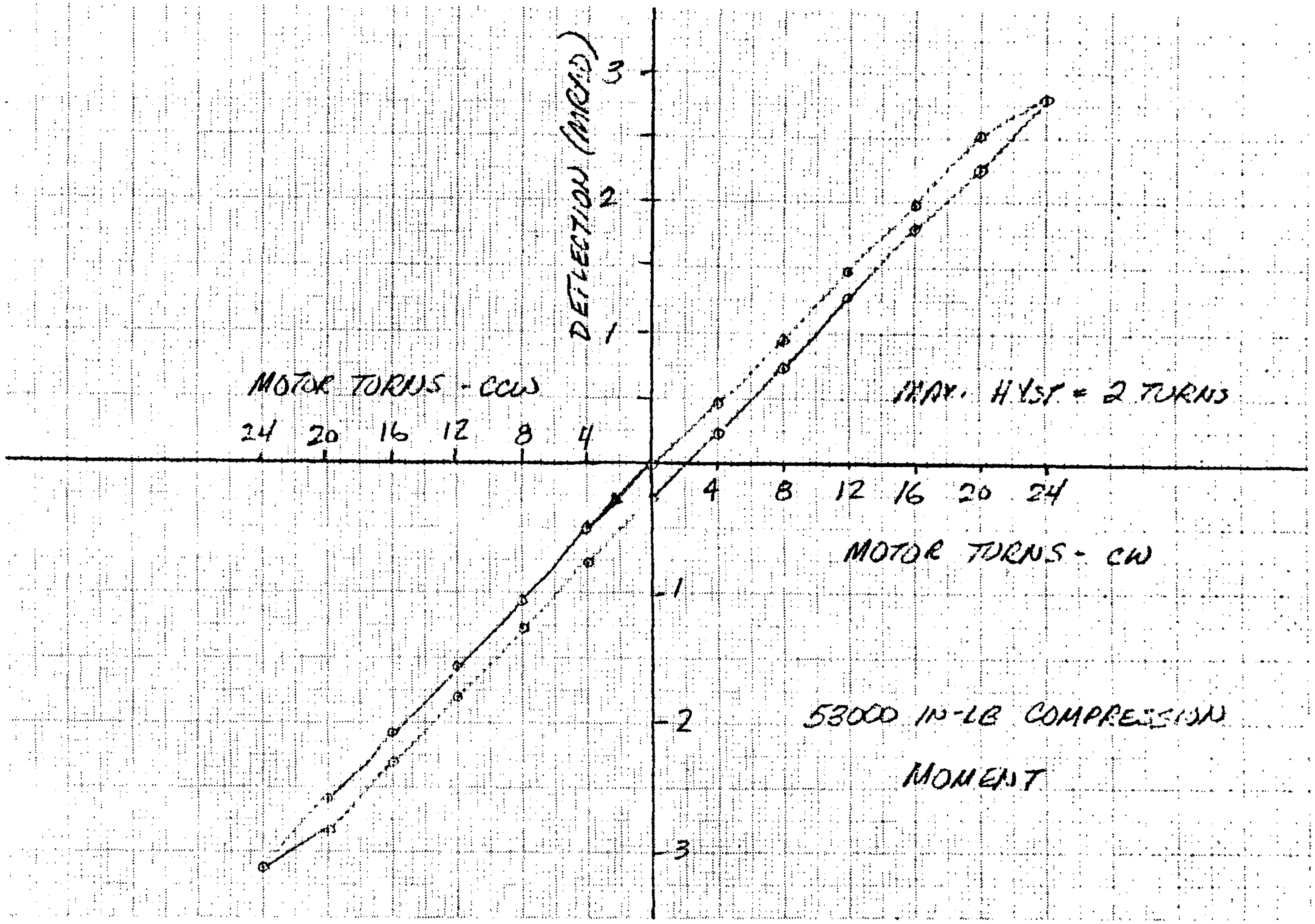

Figure B5-10. Elevation Drive Input Hysteresis (0.063-In. Shim)

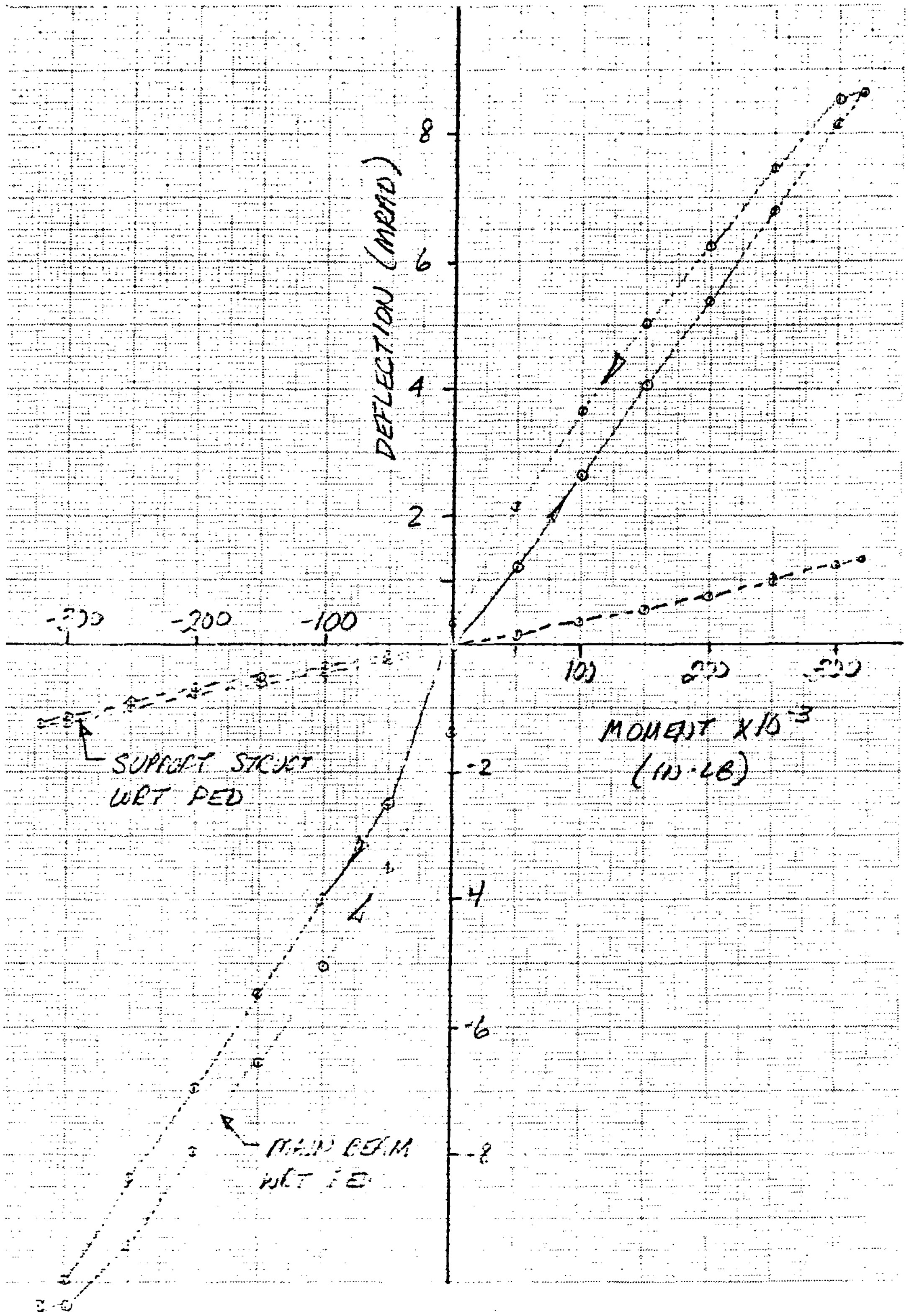

Figure B5-11. Elevation Drive Maximum Static Hysteresis at 0° (0.063-In. Shim)

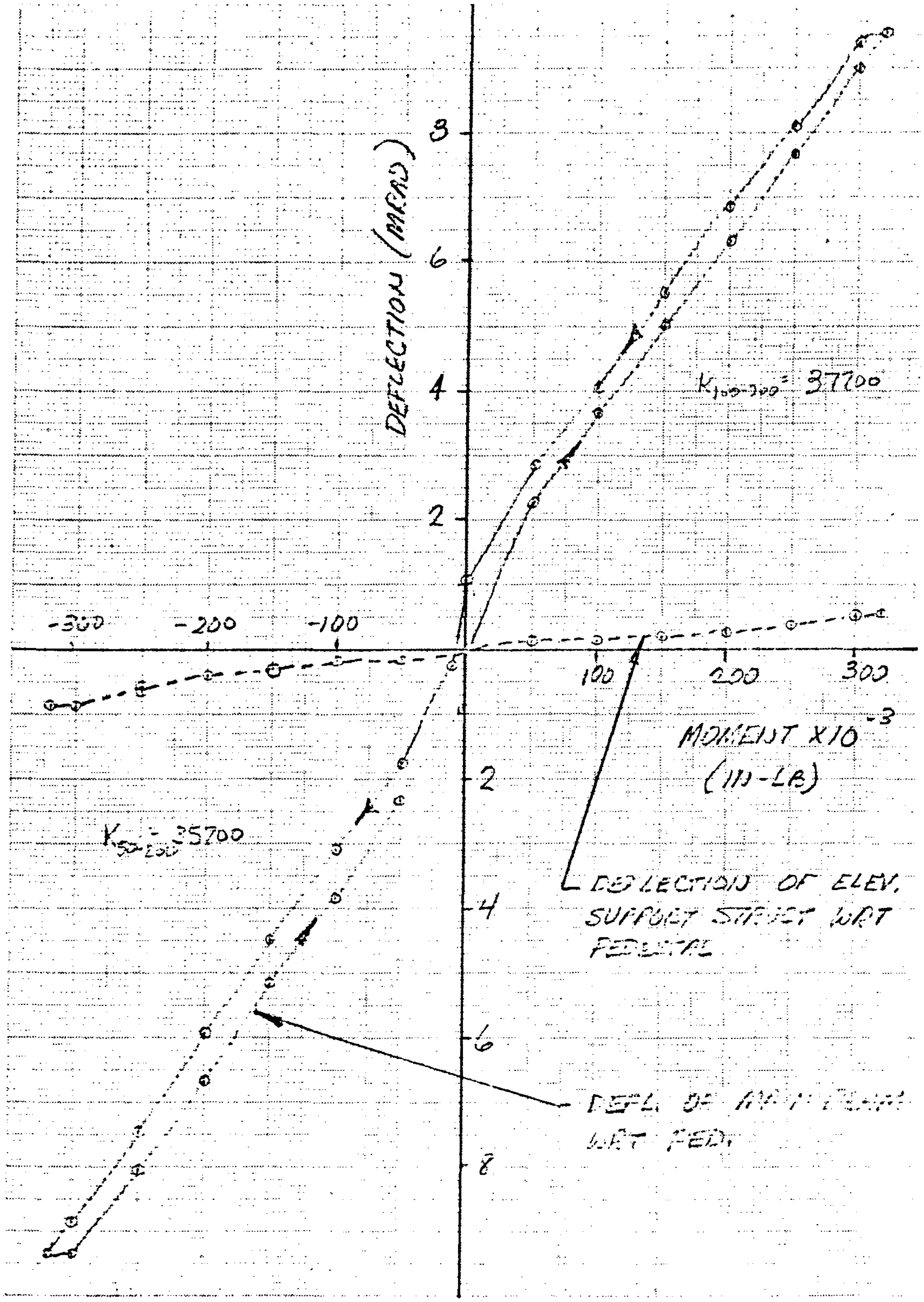

Figure B5-12. Elevation Drive Maximum Static Hysteresis at 90° (0.063-In. Shim)

Load (in-lb)	Breakout Torque (in-oz)		Breakout Voltage	
	With	Against	With	Against
80,900 CW	75-80	165-225	138	148
80,900 CCW	20-25	90-165	137	148

These values are very low and well within the capabilities of the 1/4 HP motor selected for the azimuth drive.

3.2 EFFICIENCIES

For this test the azimuth drive output member was loaded to 80,900 in-lbs. The load was maintained while the motor was driven against the load and with the load for 20 seconds. An electrical power meter monitored the voltage, current and power to the motor and a counter on the motor monitored the number of turns. These data were recorded for CW and CCW loads and then repeated at 40,000 in-lb load. The reduced data are presented in Table B5-2 and summarized below.

Load	Efficiency
40,000 in-lb	8.8 percent
80,900 in-lb	12.2 - 13.8 percent

3.3 OPERATING LOAD HYSTERESIS

The azimuth drive unit was loaded incrementally to ±42,000 in-lb and deflection readings were taken using a transit mounted on the drive centerline. This loading condition simulated maximum operational loads resulting from a 27 mph wind. The data are shown in Figure B5-13 and the average deflection is 1.90 mrad. For this condition 2.40 mrad is the design maximum.

Another indication of azimuth drive hysteresis and sensitivity measured was the input hysteresis characteristics. These data were generated by manually rotating the motor shaft and monitoring the output rotation of the harmonic drive using the transit.

This test was run at loads of 42,000 in-lb CW and CCW, and at the no-load condition, showed an input dead band of eight motor turns as shown in

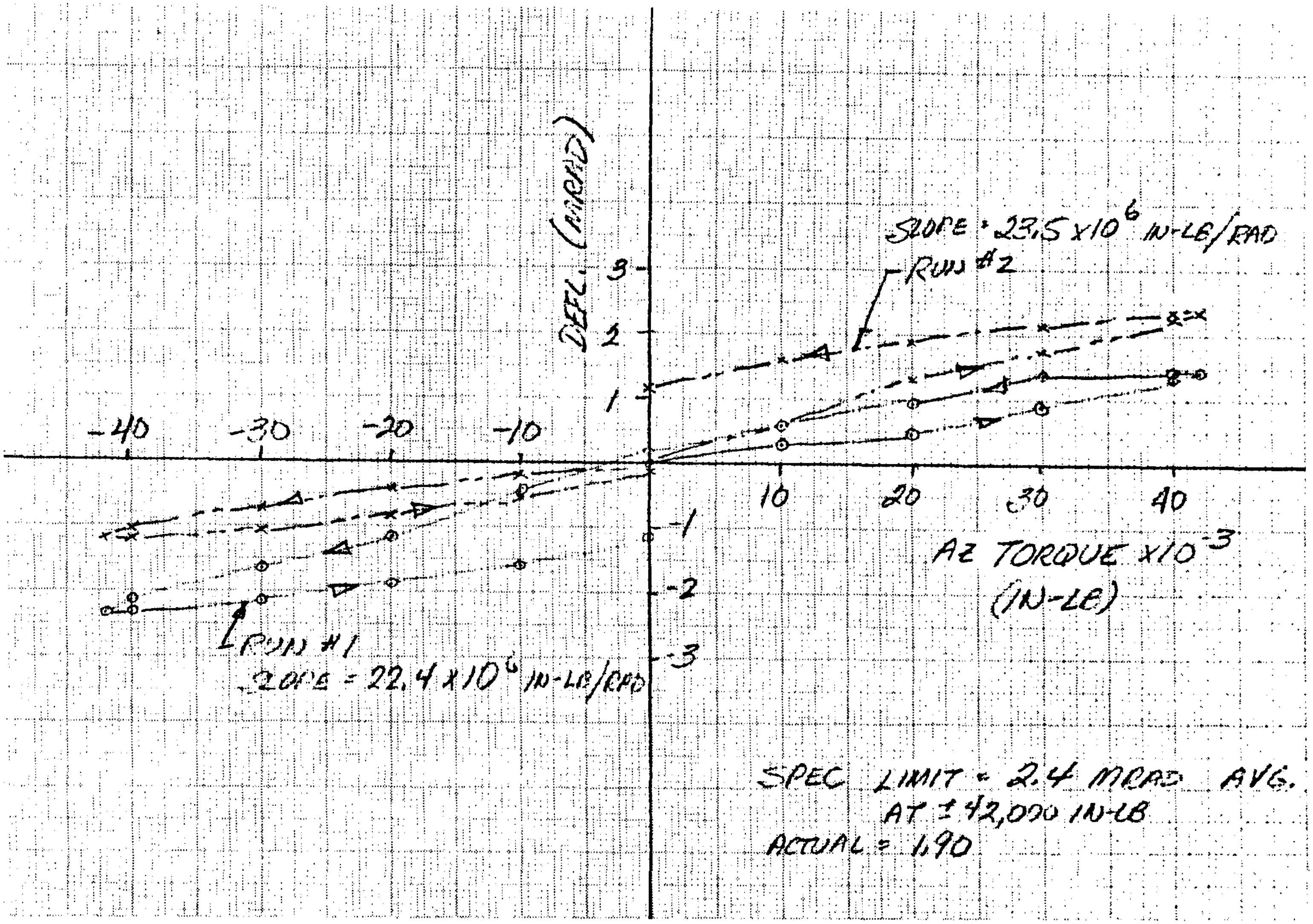

Figure B5-13. Azimuth Drive Torque Hysteresis — 27-mph Wind (0.063-In. Shim)

Figure B5-14. Eight motor turns results in potentially excessive positioning error. In an effort to troubleshoot the problem, a hysteresis test was run at a low external moment (±5,000 in-lb). These data are shown in Figure B5-15 and indicate 0.4 mrad bandwidth at this low level. Further troubleshooting determined that there was little or no backlash between the motor and the harmonic drive wave generator. All of this evidence pointed to a problem of excessive friction in the wire race bearing causing the circular spline (output drive member) to bind up.

The wire race bearing had been shimmed early in the test program to a tight condition to minimize deflections. It was now evident that this had an adverse effect on the drive input hysteresis and a median ground had to be reached where deflection was traded for acceptable friction and hysteresis. The rework and retest effort required to correct this problem is reported in Section 4.0 of this report.

3.4 MAXIMUM STATIC LOAD HYSTERESIS

With the problem identified in the preceding section, it was decided to complete the testing with the specimen prior to any rework. Load versus deflection readings were taken at moment loads up to ±144,000 in-lbs and are plotted in Figure B5-16. During this test effort it was discovered that 75 ft-lb torque on the NAS 1308-15 pedestal bolts was insufficient to prevent movement of the drive unit on the pedestal. The torque on these bolts was increased to 120 ft-lb and this solved the problem. This design change was incorporated into the 1D22457 assembly drawing.

3.5 REDUCTION RATIO

Using the transit and target as the origin, the number of motor turns for one complete revolution was determined to be 43,254. This is the reduction ratio expected for the harmonic drive mounting configuration (162:1 for the helicon gear set and 267:1 for the harmonic drive).

4.0 DRIVE UNIT REWORK AND RETEST

As a result of the excessive friction noted in the azimuth drive hysteresis test, a decision was made to reshim the wire race bearing. This was necessary

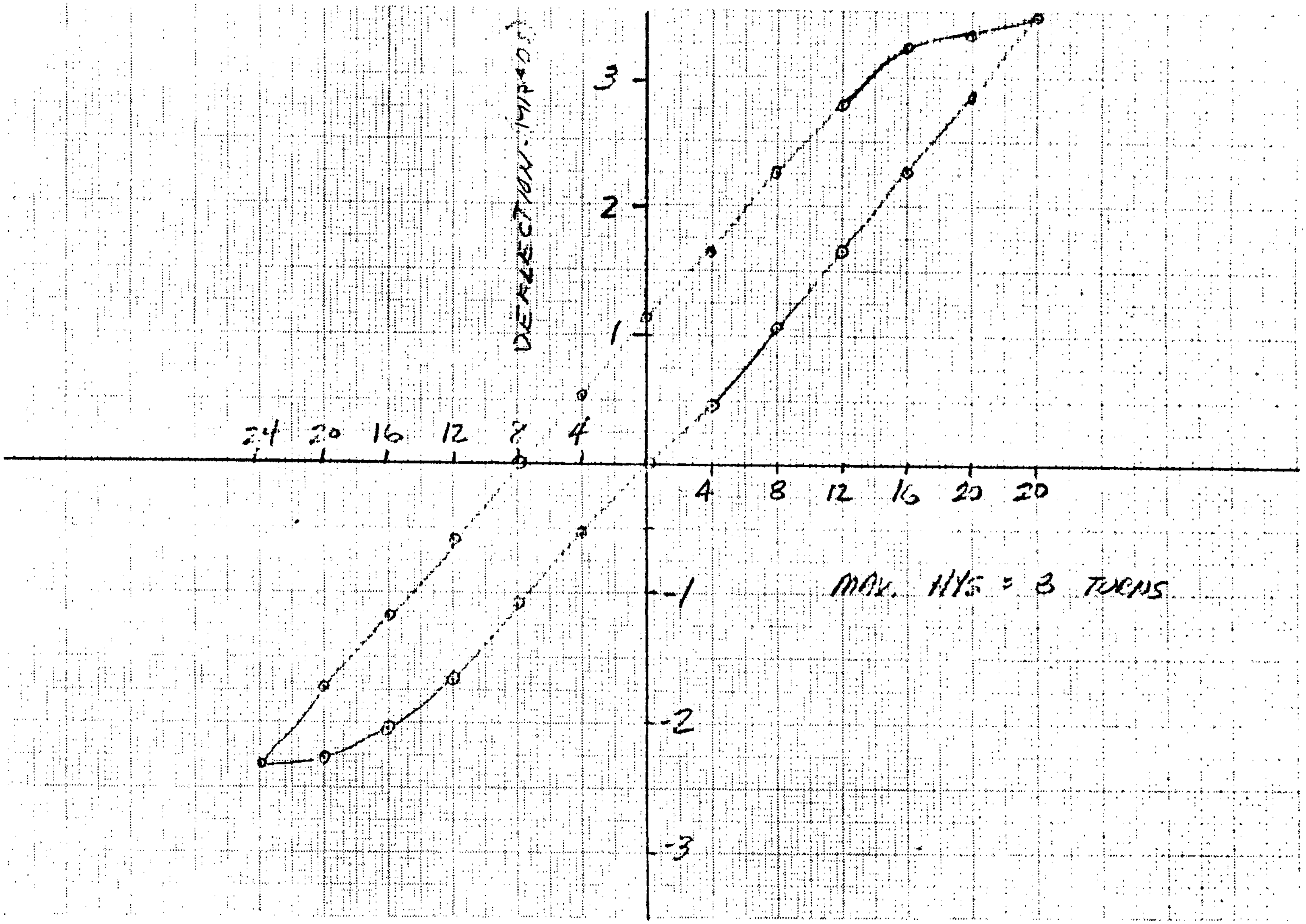

Figure B5-14. Azimuth Drive Input Hysteresis — No-Load (0.063-In. Shim)

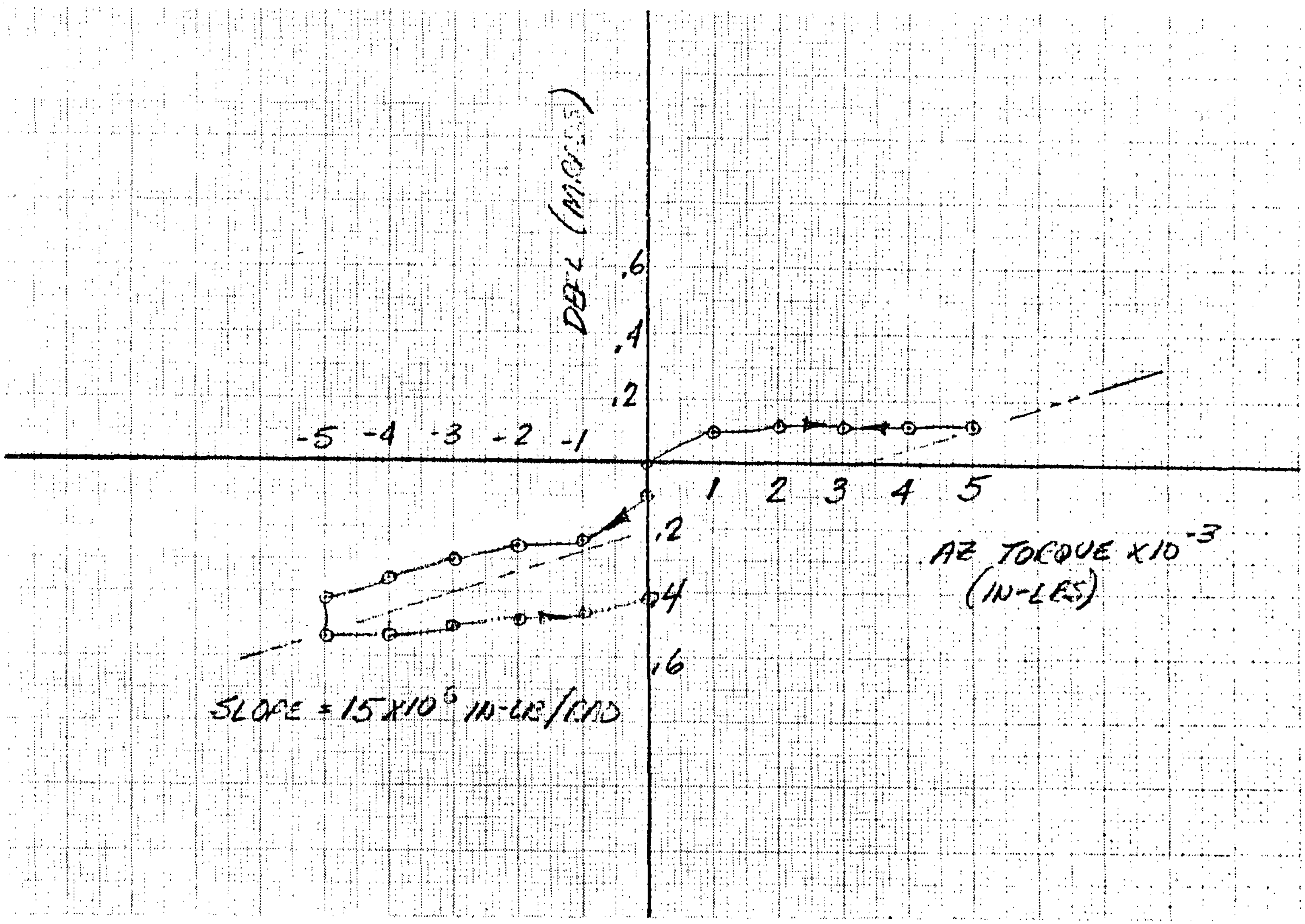

Figure B5-15. Azimuth 5000-In-Lb Hysteresis (0.063-In. Shim)

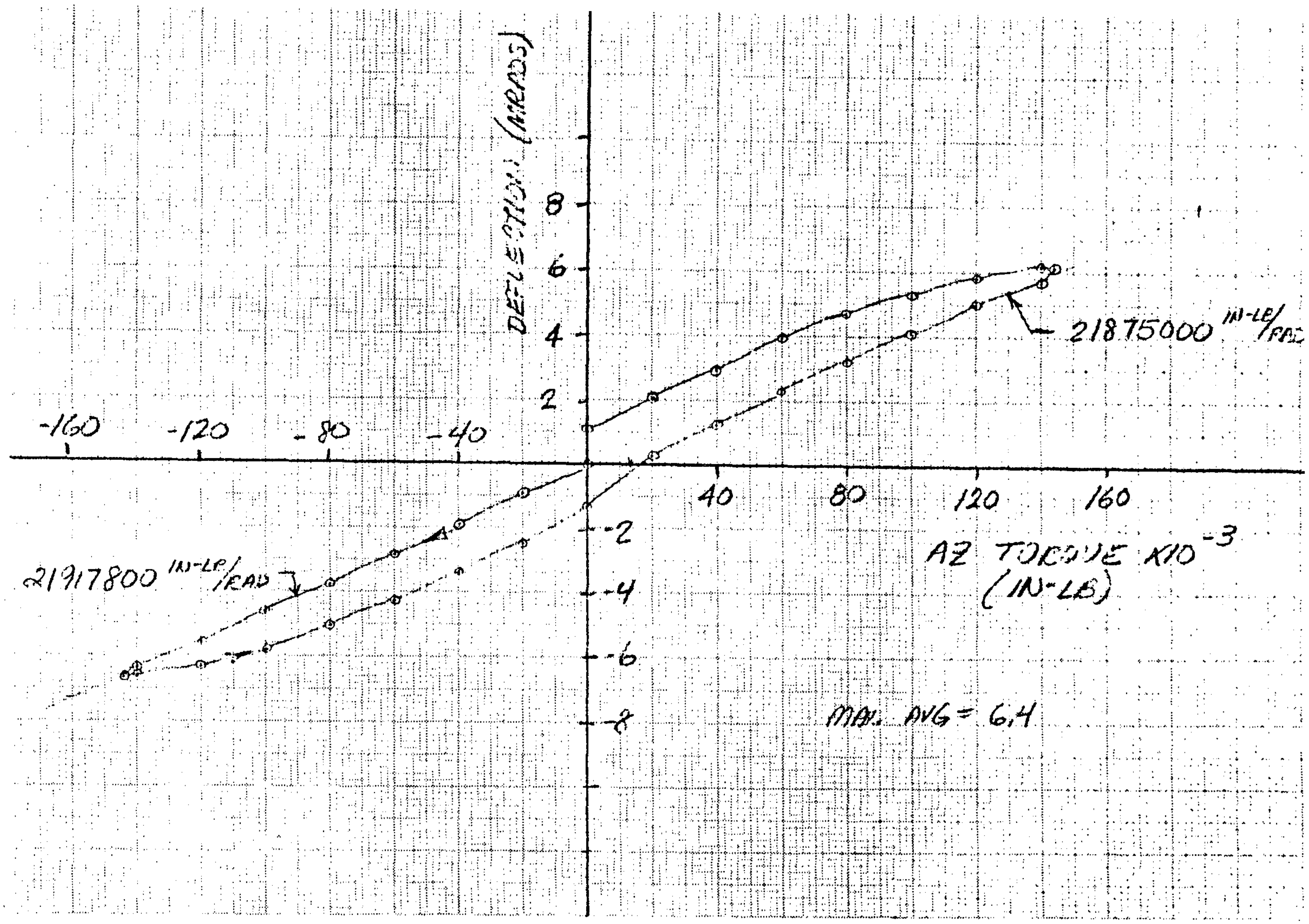

Figure B5-16. Azimuth Drive Maximum Static Load Hysteresis, Ped Bolts Torqued to 120-Ft-Lb (0.063-In. Shim) to reduce the dead band on the azimuth drive input hysteresis. The azimuth drive unit was partially disassembled and the bearing shim pack increased from 0.063 inch to 0.065 inch by adding one of the shim laminates removed earlier. It was anticipated that this would reduce the hysteresis without causing an unacceptable increase in the elevation drive compliance.

Some of the preceding tests were rerun to verify acceptable performance following rework. Startup torque and efficiency tests were not repeated since the rework would have insignificant effect.

4.1 AZIMUTH DRIVE INPUT HYSTERESIS - RETEST

Following the rework, the first test accomplished was to check the input drive hysteresis at the azimuth motor. This test was run at no load and at 42,000 in-lb CCW moment by counting motor turns and monitoring the rotation of the output drive. A reduction had occurred in total dead band from eight turns in previous testing to two and one half turns following this rework, as shown in Figure B5-17. This condition is acceptable and indicates reduced friction in the output stage of the harmonic drive.

4.2 AZIMUTH DRIVE HYSTERESIS, 27 MPH WIND - RETEST

Load versus deflection readings were taken at intervals up to ±42,000 in-lb which simulates the 27 mph maximum operating wind load. The data are shown in Figure B5-18 and indicate no significant change in average deflection due to reshimming. The test data show an average deflection of 1.70 mrad, with the specification limit being 2.4 mrad.

4.3 AZIMUTH DRIVE MAXIMUM STATIC LOAD HYSTERESIS - RETEST

Load versus deflection readings were taken at intervals up to azimuth loads of ±144,000 in-lb and are presented in Figure B5-19.

4.4 ELEVATION DRIVE HYSTERESIS - RETEST

Elevation drive operating and maximum static hysteresis tests were repeated following the rework. The maximum operating hysteresis test was accomplished at 40 degrees elevation angle and the maximum static test at 0 degrees. Results of these tests are presented in Figures B5-20 and B5-21.

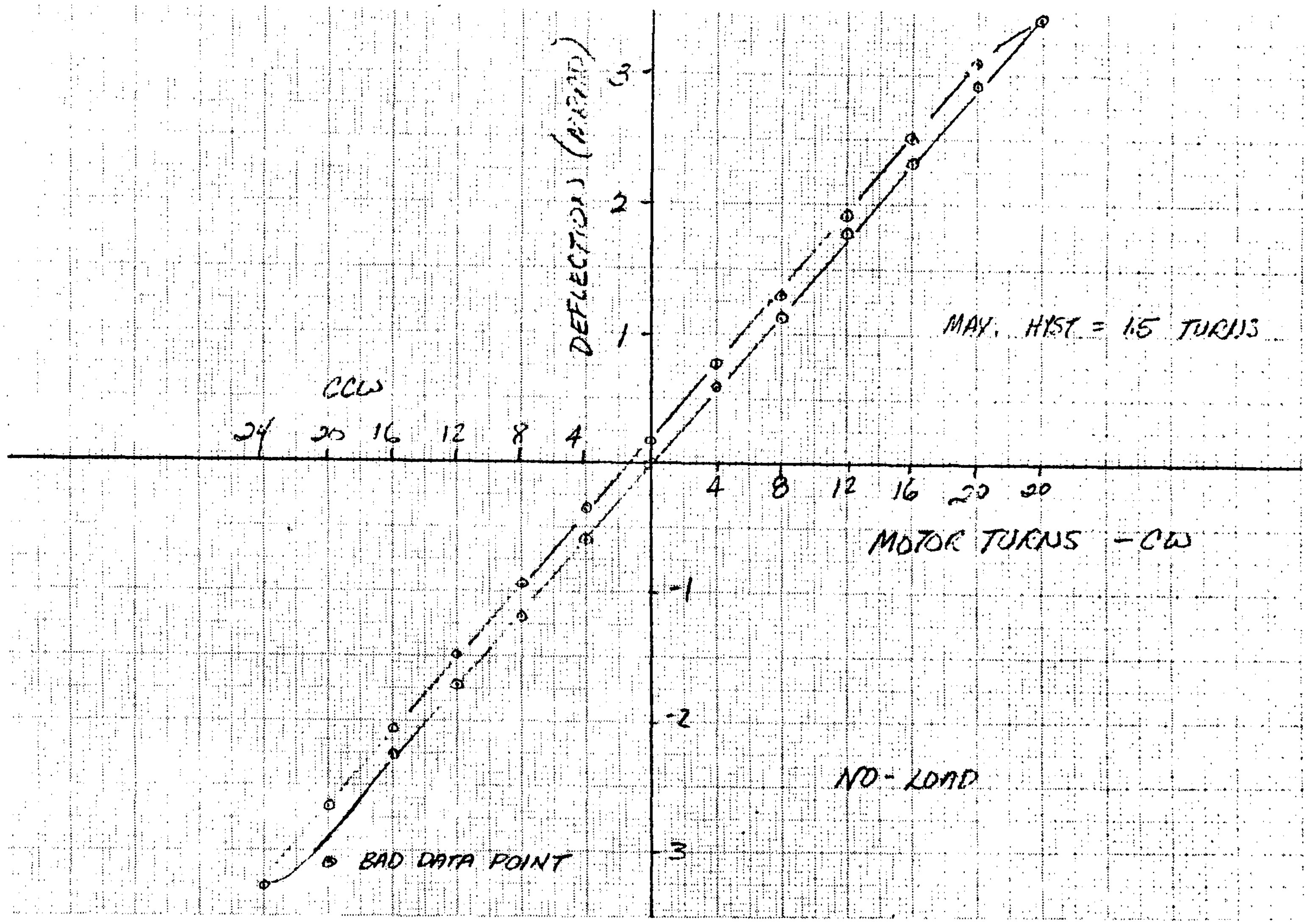

Figure B5-17. Azimuth Drive Input Hysteresis (0.065-In. Shim)

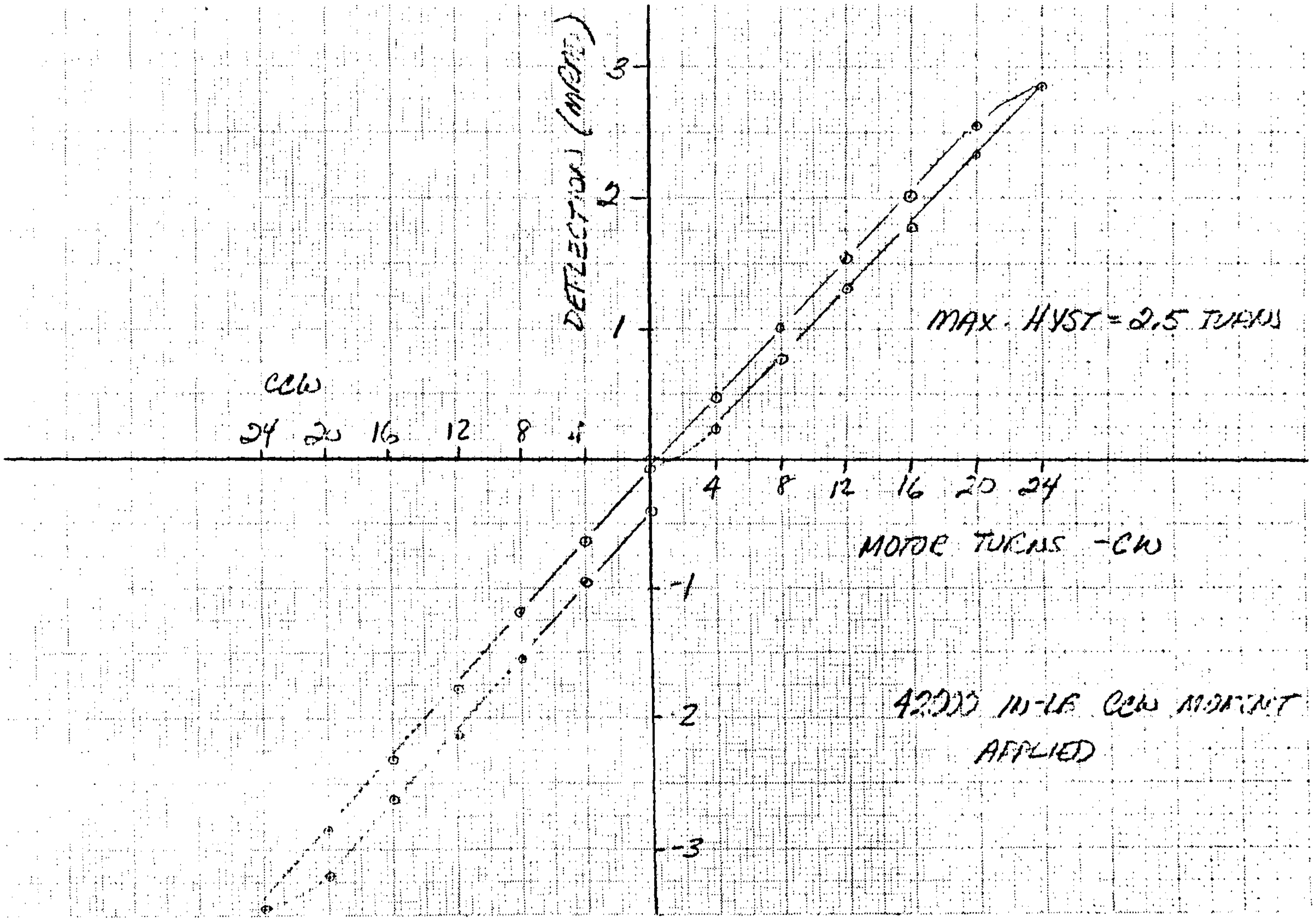

Figure B5-17A. Azimuth Drive Input Hysteresis (0.065-In. Shim)

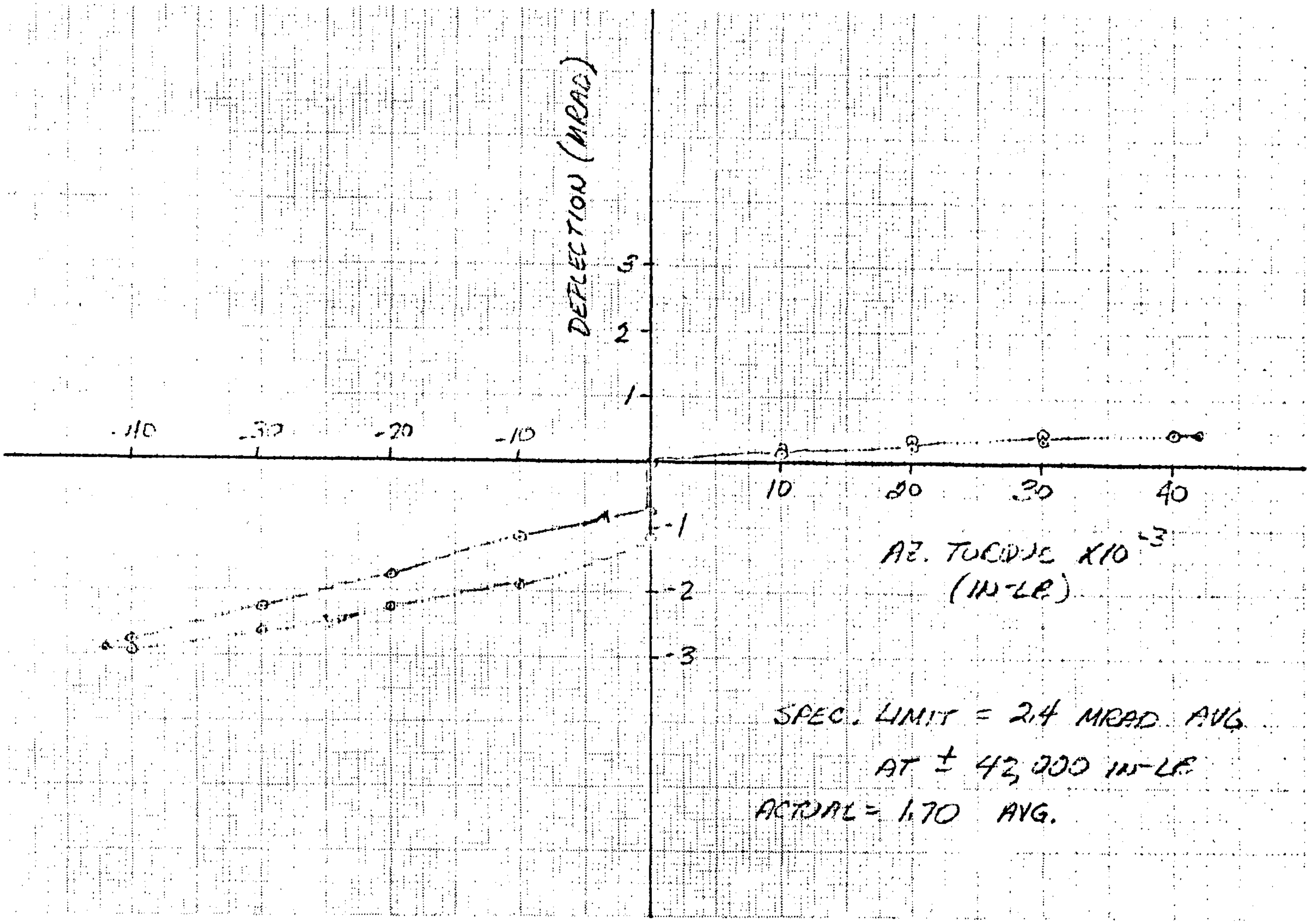

Figure B5-18. Azimuth Drive Torque Hysteresis — 27-mph Wind (0.065-In. Shim)

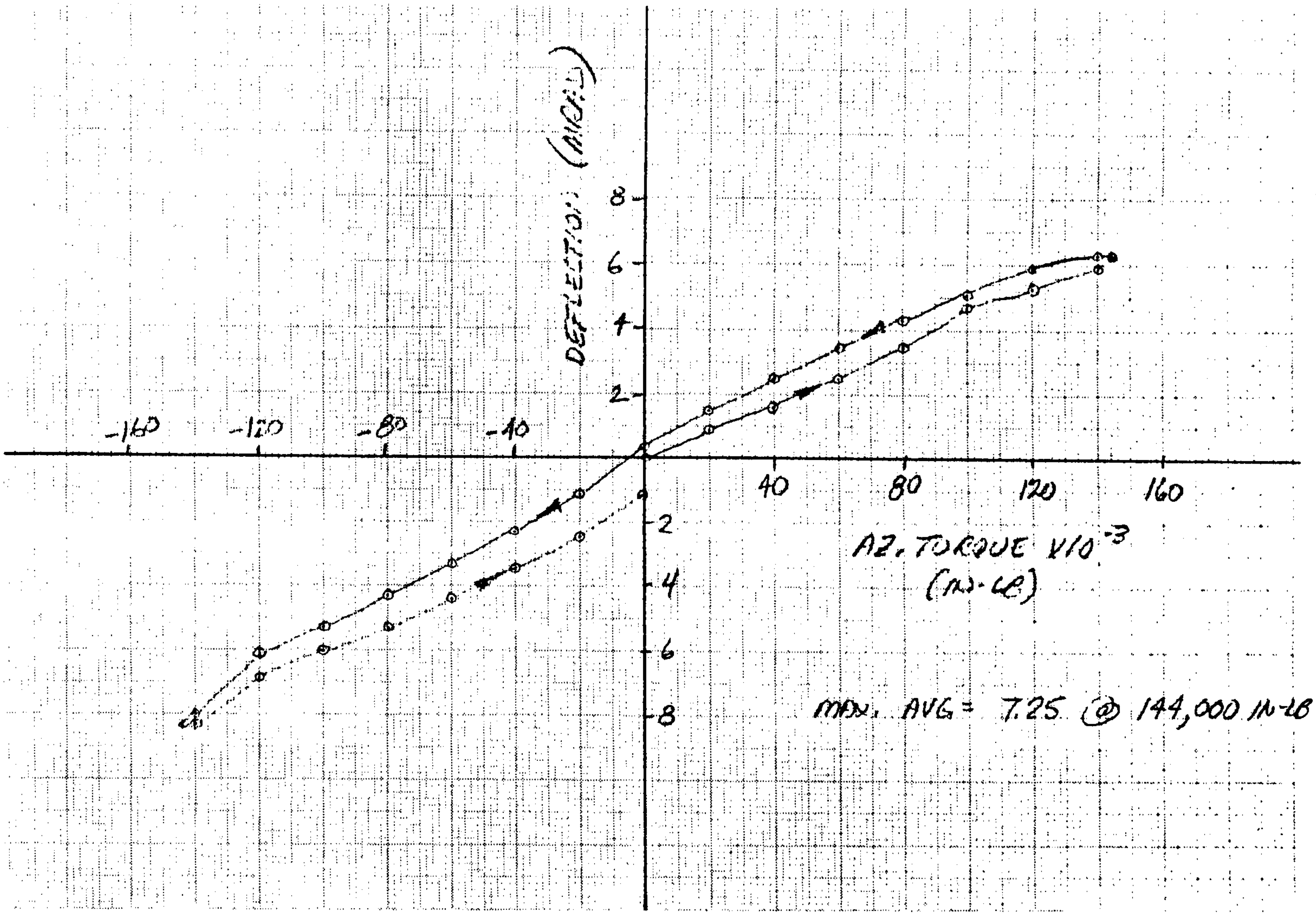

Figure B5-19. Azimuth Drive Maximum Static Load Hysteresis (0.065-In. Shim)

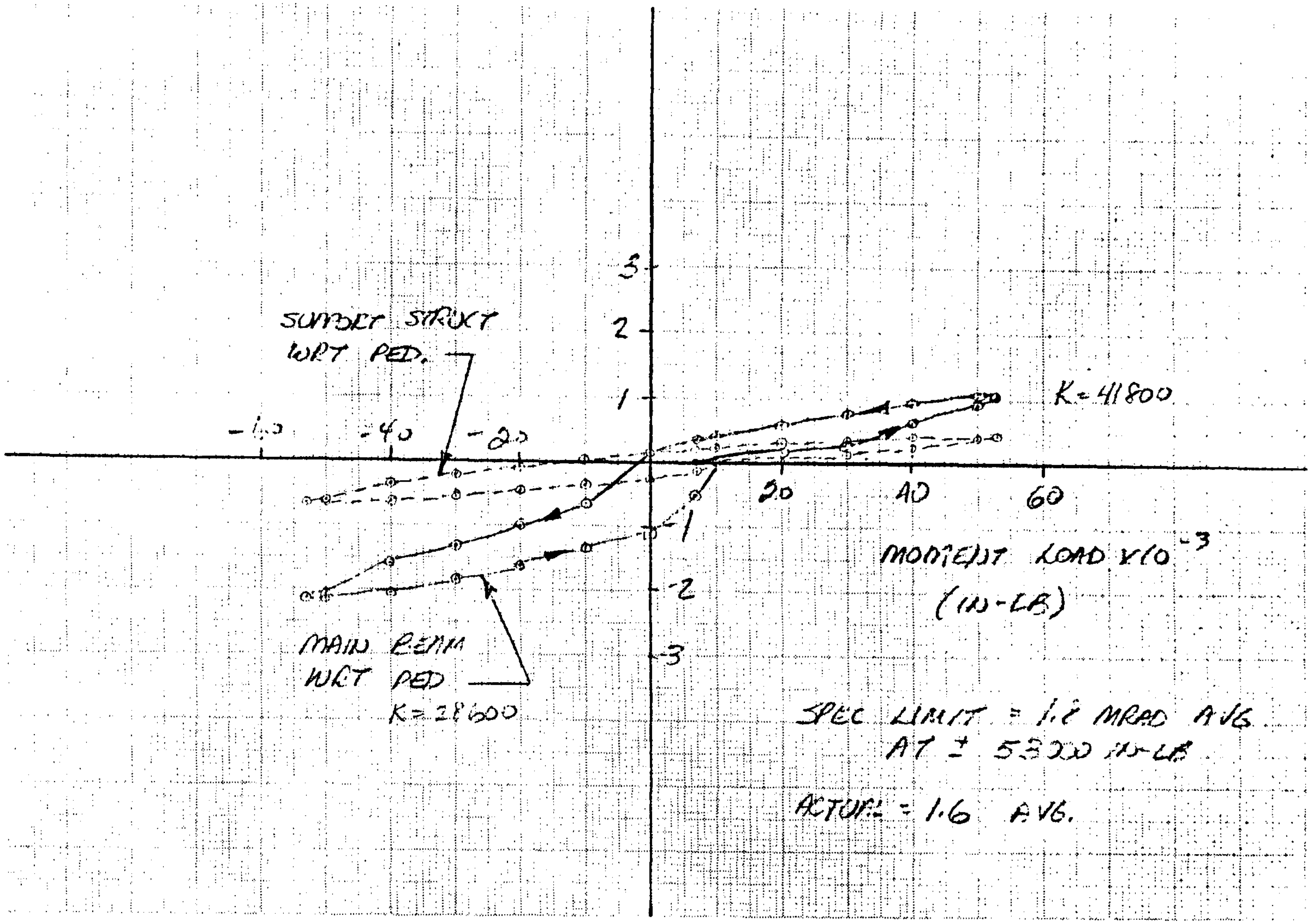

Figure B5-20. Elevation Drive Maximum Operating Hysteresis at 40° (0.065-In. Shim)

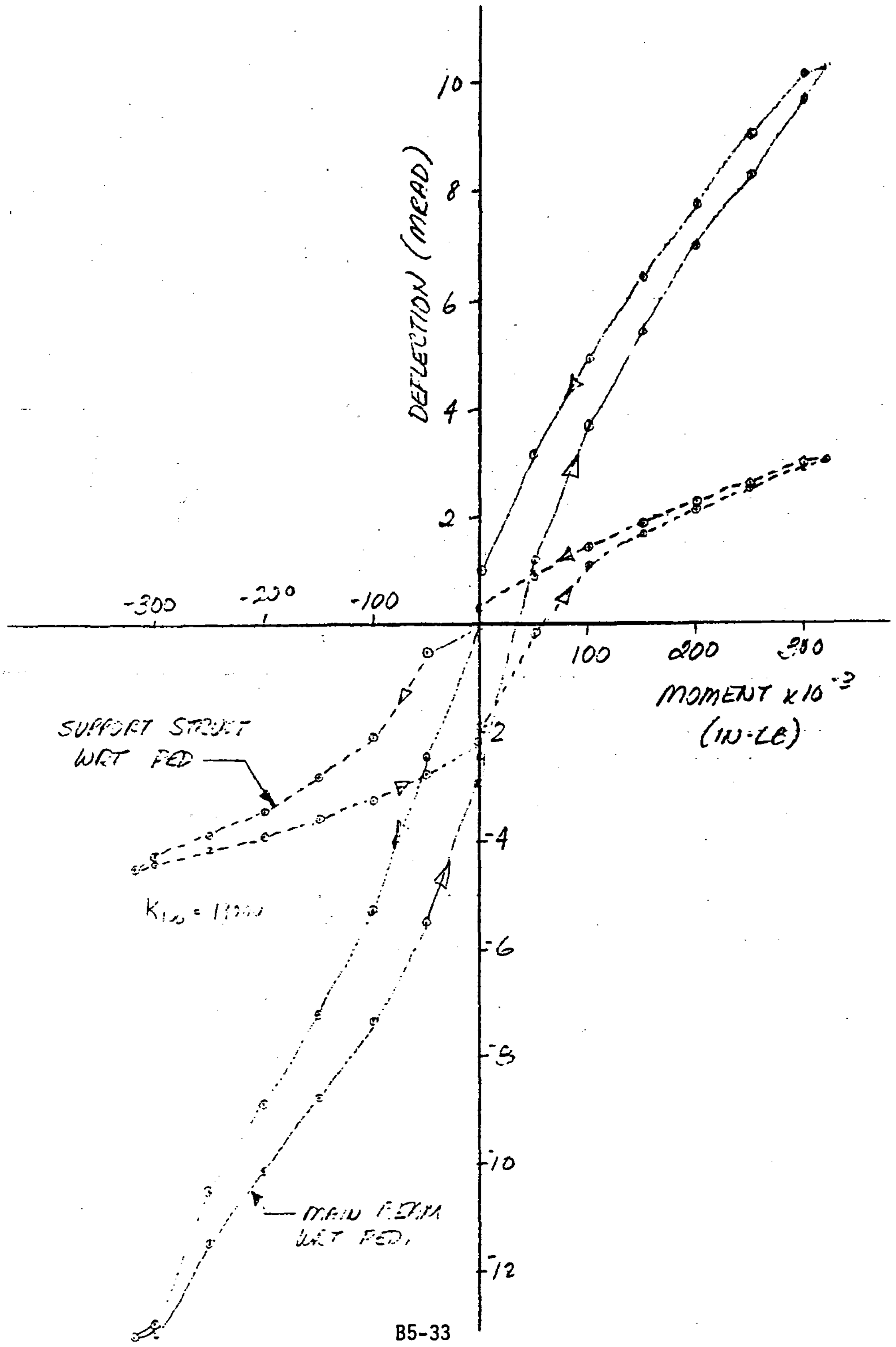

Figure B5-21. Elevation Drive Max Static Hysteresis at 0° (0.065-In. Shim)

The hysteresis at the maximum operating load increased from 1.2 to 1.6 mrad due to the reshimming, but was still within the 1.85 mrad limit.

CONCLUSIONS

Based on the preceding test results, the following conclusions are offered.

A. Testing of the 1D22436-1 drive unit has demonstrated the integrity of the design concept, and performance of the assembly meets all specified requirements.

B. The 1/3 HP motor selected for the elevation jack will provide sufficient torque margin for all operating conditions.

C. The range of size for the wire race bearing shim which will produce acceptable compliance without excessive friction is small. The shimming method should include a bearing friction test.

D. Current system oil seals are acceptable based on no leakage noted during the test program.

E. The drive system structural integrity was proven by the application of a 60 percent overload in the elevation axis.

F. The wire race bearing has demonstrated satisfactory performance for use in the heliostat drive application. This conclusion reinforces previous wire race bearing test results.

G. The drive motor capability is excessive for the requirements. Decrease in size is warranted for future development.

Appendix C
SUBSYSTEM ASSEMBLY TESTS

Appendix C-1
POWER CONSUMPTION TEST

Power Consumption measurements taken in the operating heliostat are provided in this section.

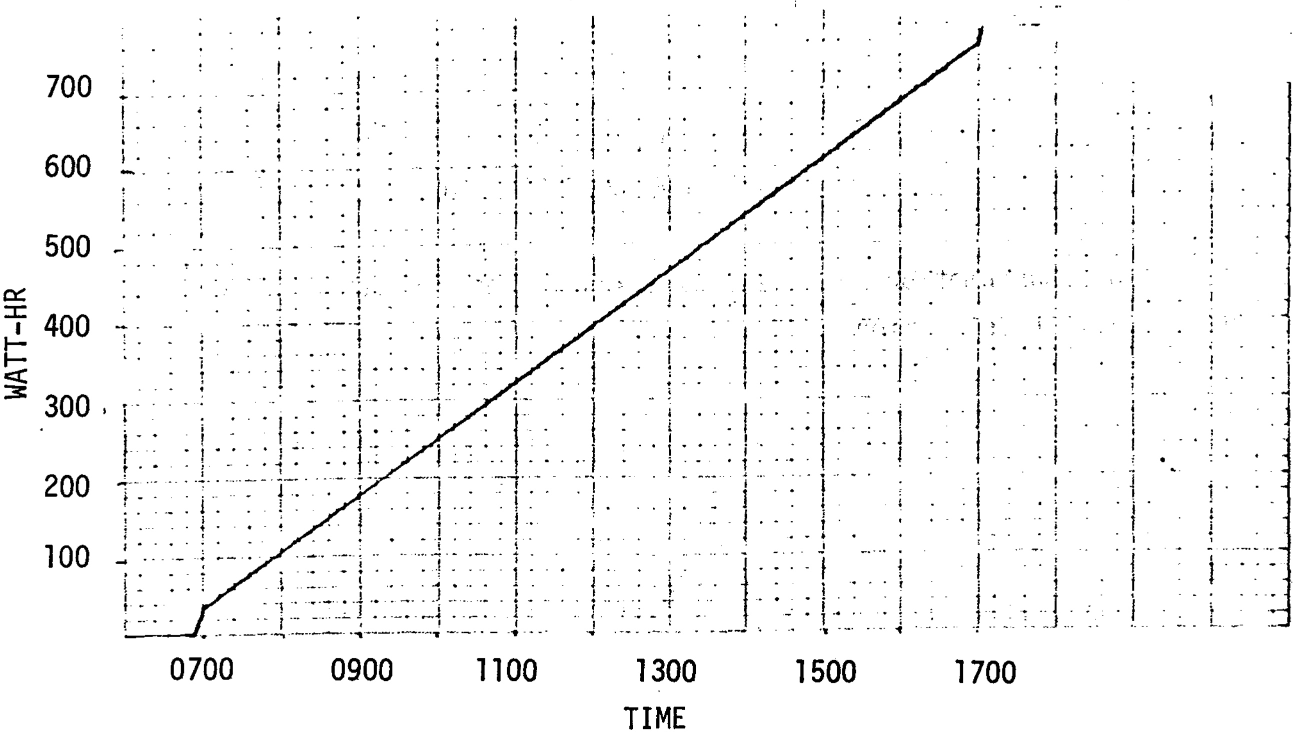

Figure C1-1. Typical Daily Power Consumption

Table C1-1. Gimbal Rate/Power Consumption

Elevation				Azimuth			
Rate (Turns/sec)	Direction	Angle (deg)	Power (watts)	Rate (Turns/sec)	Direction	Angle (deg)	Power (watts)
30	Up	0	330	30 SLEW RATE	Clockwise	--	168
		45	298				
		90	216				
30	Down	90	186				
		45	154				
		0	No data				
15	Up	0	676	15	Clockwise	--	506
		45	636				
		90	486				
15	Down	90	204				
		45	285				
		0	528				
5	Up	0	332	5	Clockwise	--	86
		45	224				
		90	148				
5	Down	90	92				
		45	206				
		0	96				
1	Up	0	196	1 TYPICAL TRACK	Clockwise	--	64
		45	132				
		90	102				
1	Down	90	62				
		45	66				
		0	62				
0.5	Up	0	134	0.5	Clockwise	--	50
		45	88				
		90	60				
0.5	Down	90	56				
		45	58				
		0	70				

Table C1-2. Voltage and Currents, Power Consumption Test

Voltage

ØA/ØB	204.6
ØB/ØC	204.7
ØA/ØC	205.9
ØA/N	118.4
ØB/N	117.5
ØC/N	118.1

Current

Axis	Motor Rate (Turns/Sec)	ØA (Amps)	ØB (Amps)	ØC (Amps)
Elevation (Retracting)	30.0	1.7	1.5	1.6
	15.0	∿4.0*	∿4.0*	∿3.3*
	5.0	2.5	2.5	2.2
	1.0	1.7	1.7	1.5
	0.5	∿1.4*	∿1.4*	∿1.2*
Azimuth	30.0	1.3	1.1	1.1
	15.0	∿4.0*	∿1.4*	∿3.2*
	5.0	1.5	1.5	1.2
	1.0	1.5*	1.5*	1.2*
	0.5	1.3*	1.3*	1.3*

*Maximum value, meter jumping due to pulse operation

Table C1-3. Power Demands

Mode	Typical Duration	Watts
Unstow (Stow to Standby)	3 to 5 minutes	520
Standby to Track (1)	--------------	---
Track to Standby	10 to 60 seconds	250
Stow (Standby to Stow)	3 to 5 minutes	290
Track	10 hours	72
Electronics Only	N/A	40
Reference Update(2)	--------------	---
Mini Update(3)	--------------	---

(1) No data taken - should be equal to Track to Standby

(2) No data taken - should be equal to Track to Standby to Stow

(3) No data taken - should be < Track to Standby

Table C1-4. Power Consumption (A)

Mode	Duration	Watt Hours
Unstow (9:00 am actual data)	4 minutes	33.5
Standby	10 seconds	0.2
Standby/Track	30 seconds	2.1
		35.8
		35.0 (B)
Track (5 hours actual data) (7:00 to 5:00)	10 hours	720.0
Track/Standby	30 seconds	2.1
Standby	10 seconds	0.2
Stow (2:30 actual data)	4 seconds	18.2
		20.5
		20.0 (C)
	DAILY TOTAL	775

(A) Extrapolated to summer solstice day

(B) Test durations long, therefore use 35.0 watt hours

(C) Test durations long, therefore use 20 watt hours

Appendix C-2
SUBSYSTEM ACCEPTANCE TEST

This appendix provides the procedures and results associated with the subsystem acceptance test performed at Huntington Beach on the HAC, HFC, and the two heliostats.

System Acceptance Test

Test	Test Procedure		Results/Comments
I. Data Base Verification	With the HAC operating, request the printout of the array location shown and compare them to the basic data documentation.		
	Array	Locations	
	GDB	1 to 64	All agree
	NCD	1,2,97,98,193,194,673,674,769,770,865,866,1153,1154 1249,1250	All agree
	NSD	385,386	All agree
	IDB	1 to 100	All agree
	IGV	720 to 731 and 742 to 745	All agree

System Acceptance Test

	Test		Test Procedure	Results/Comments
II.	System Startup	A)	Turn power off/on to HC and HFC. Load the HFC program into HFC. Before program is loaded, turn power off to HFC - note alarm and status. Load the HFC program, record all data base messages.	Failed when power turned off to HFC & no alarm. Aborting & restarting HAC allowed mem. load & re-initialization of values. Missed data load output. See Note 1 and note 2
		B)	Do reference update on HC #1 and then unstow heliostat. With heliostat at standby, use HFCDIS to check standby (CA & CE) aimpoint. Command to track and check track (CA&CE) aimpoint. Using DIS, check the following data base.	Standby Track CA(59BD) 3.030000 3.093400 CE(59CI) .1057000 .071300000
		C)	With heliostat in stow position, turn MOD8 off and turn debug print for MOD3 on. Do a data load and verify that the following messages are transmitted.	MES# HC# 10 1 6 1 4 1 10 2 6 2 4 2 All messages sent per printout

Note 1: B) Reference update programmed and subsequent standby aimpoint appeared to be off by 1 helicon gear. Repeated update and standby aimpoint appeared to be off by ~10 helicons.

Note 2: Repeated test 3 times without making any changes, worked right each time. Got correct alarms each time. Did data load and got print.

System Acceptance Test

	Test	Test Procedure	Results/Comments
III.	Reference Update	A) Command a full update on heliostats #1 & #2. Note status & alarms while doing & when finished. Verify that HAC HC NEL & NAL turn position are the same. Note alarms & status display	HAC Location / HFC Location HC#1 Azimuth NSD(1) 5C72 2936 HC#2 Azimuth NSD(2) 5C76 457 HC#1 Elevation NSD(193) 5C93 895 HC#2 Elevation NSD(194) 5C97 20 5880 5884 58A2 58A6 Status & alarms were correct
		B) Unstow both heliostats, command #1 to target, note position of both beams, repeat with #2, turn power off/on to both heliostats. Command mini update on heliostat #1 and full on heliostat #2. Note status & alarms when power turned off & during update. After update, command #1 to target, #2 to standby, #1 to standby and #2 to track. Note position of beams.	Deferred because of time
		C) Turn power off/on, command full update for both heliostats. Note status & alarms. When finished, command back to target & note position of beams.	Deferred because of time
		D) Stow both heliostats. When #2 is stowed, command full update. Note when complete.	Completed in 3 minutes.
		E) With PCU, move heliostat in CW direction about 20° turn power off/on, command full update & note heliostat motion.	Done during reference update checkout test.
		F) Command both heliostat to target. Turned power off/on and command mini update. During mini update, turn power off/on and note alarms.	

System Acceptance Test

Test	Test Procedure	Results/Comments
IV. Alarms	A) Disconnect the HFC communication line & note alarm. Connect HFC & activate HFC communication. Do not clear alarms.	A) Received alarm #1
	B) Disconnect HC #1 communication line & note alarm. Connect HC #1 communication line & clear alarms	B) Received alarm #4 for HC#1 HC #1 communications showed active (was in Stow)
	C) Disconnect HC #2 communication line & note alarm. Connect HC #2 & clear alarms.	C) Received alarm #4 for HC #2 HC #2 communications showed active
	D) Print the last 5 alarms	D) Last 5 alarms agreed w/above alarms as appeared.
	E) Type a bad command and note alarm	E) Received alarm #27
	F) With both heliostats inactive and HFC active command unstow for heliostat #1 and track for heliostat #2, note alarm and that heliostat does not move.	F) Received alarm #39 (S/B for HC#1)
	G) With one heliostat in track, command stow and note alarm	G) Received alarm #30
	H) Command heliostat to a gimbal angle. Before the angle is reached, make HC inactive. Wait until HC reaches a gimbal limit and record the alarms.	

System Acceptance Test

	Test		Test Procedure	Results/Comments
V.	Mode Test	A)	Command the heliostats through the different operating modes. Use DATREC to obtain time to complete each phase.	Completed successfully
		B)	Command both heliostats to standby, and then, command the heliostats to the different gimbal positions. Use DATREC to obtain time, mode and angle. Also, observe the heliostat position.	Completed successfully

System Acceptance Test

	Test	Test Procedure	Results/Comments
VI.	Life Cycle	Change elevation track aimpoint for mini life and full life cycle to:	Completed successfully
		A) Start mini life cycle for both heliostat #1 and heliostat #2. Display and record the same data locations	Completed successfully
		When the second life cycle starts, stop the life cycle and display and record the same data locations.	All aimpoints were changed correctly.

System Acceptance Test

	Test	Test Procedure	Results/Comments
VI.	Life Cycle (Continued)	B) When heliostats have reached standby, command to track and note beam position of both heliostats.	Beam at right aimpoints
		C) Display the same data as in part A above and start full life cycle for both heliostats. Note beam position during life cycle and time of each mode. Stop full life cycle just after the second cycle starts. Display and record the same data. When heliostats have reached standby, command to track and note position of beams.	Completed successfully
		D) Start heliostat #2 in mini life cycle and unstow heliostat #1 and command to target. Let track for 30 minutes and then stow. Repeat for heliostat #1 again, leaving heliostat #2 in life cycle.	Completed successfully

Appendix D
COST DATA

Appendix D-1
WEIGHT STATEMENT

The weight statement shows a summary breakdown of the total weight of an installed commercial heliostat. These weights are close to those provided for the test heliostat but may not correspond where certain parts may be "modified" for volume productions.

SECOND GENERATION HELIOSTAT
WEIGHT STATEMENT (lbs)

Foundation			8554.2
Foundation Cap (Approx.)		86.0	
Steel Rebar (Approx.)		286.0	
Concrete (Approx.)		8140.2	
Reflector Assembly (2 panels)			4469.2
Mirror Attach Kit		--	
Mirror Module		226.6	
Laminated Mirror	163.7		
Stiffener (2)	48		
Shims (2)	6.7		
Cross Brace	3		
Miscellaneous Details (Edge Seals, Etc.)	5.2		
Reflector Support Structure Assembly		645.6	
Inboard Cross Beam	184.7		
Diagonal Beam (2)	203.2		
Outboard Cross Beam	153.2		
Braces	62.7		
Misc. Details	41.8		
Drive Unit/Pedestal/Main Beam			1311.4
Hinge		0.19	
Switch		--	
Cover		0.41	
Mount		0.04	
Bracket		0.17	
Bracket		0.97	
Pin, Trunnion		1.68	
Mount		0.37	
Cap		0.43	
Support Assembly, Elevation Drive		123.4	
Pedestal Electrical Assembly		--	
Pin, Hinge		2.02	
Pedestal		436.3	
Main Beam		324.2	

Pin, Rod End		1.0
Controller		--
Cover		0.44
Elevation Actuator		101.0
Motor	20	
Bearing	--	
Jack	81	
Incremental Encoder Inst.	--	
Misc. Details		--
Drive Assembly, Azimuth		316.22
Bracket	0.27	
Switch	--	
Clip	0.02	
Block	4.57	
Block	6.00	
Support	0.15	
Cover	14.45	
Lub Pan	0.50	
Shim	1.13	
Spacer	0.17	
Support	69.83	
Bushing	0.00	
Retainer	0.13	
Shim	0.01	
Gear	5.57	
Retainer	49.60	
Bearing Kit	8.27	
Shaft, Drive	7.15	
Harmonic Drive Kit	128.21	
Wire Harness	--	
Motor	20.0	
Tube Assembly	0.10	
Electrical Installation	--	

Appendix D-2

WORK BREAKDOWN STRUCTURE

The cost breakdown structure is shown in two parts. The first on pages D2-1 thru D2-11 cover Investment costs while the second, starting on page D2-12, covers Operations and Maintenance, miscellaneous equipment, Initial Spares and the Heliostat Array Control portion of plant control. The first column shows the numbering logic used in the LEADER costing system, the second column shows the indentured line item titles, and the third column indicates the Sandia Work breakdown numbering logic for upper level items and the detail part number, drawing number or other identification at lower levels in the structure.

0.	GRAND TOTAL	
1.	REFLECTIVE UNIT	4410
101.	REFLECTIVE SURFACE	4411
10101.	MIRROR MOD. ASSY.	44111
10102.	STRINGERS	ID22462
1010201.	STRINGER ASSY.	441121
1010202.	STIFFENER	ID22462-3
1010203.	CLINCH FASTENER	S-0518-1-Z
10103.	EDGE MEMBER	ID22462-11,13
10104.	SHIM	ID22462-17
10106.	GLASS PRIMER	PR1506
10107.	STEEL PRIMER	COROGARD9
10108.	ADHESIVE	STABOND1894
10109.	ADHESIVE	EC3532
10110.	EDGE SEALANT	SCS1202
10111.	EDGE SEALANT	SCS1202
10112.	MIRROR	ID22428-3
10113.	BACKLITE	ID22428-5
10114.	ADHESIVE	PVB
10121.	INSPECTION	D1
10122.	MAT'L HANDLING	D2
102.	MIRROR BACK STRU	4412
10201.	WELD,MACH & STR.	44121
10202.	INBOARD CROSSBEAM	ID22465-1
10203.	DOUBLER ANGLE	ID22465-003-5
10204.	DIAGONAL BEAM	ID22466
10205.	DIAGONAL BEAM	ID22466
10206.	OUTBOARD CROSSBEAM	ID22467-1
10207.	DOUBLER	ID22463
10208.	GUSSET	ID22463-3
1020801.	PLATE	ID22463
1020802.	BAR	ID22463
10209.	BRACES	ID22470-0
1020901.	ANGLE	ID22470-1
10221.	INSPECTION	D3
10222.	MAT'L HANDLING	D4
103.	ASSY-REFLECTIVE UN	4413
10301.	REFL. PANEL ASSY.	44131
10302.	STUD	ID22778-501
10303.	SHOULDER WASHER	ID22591
10304.	SHOULDER WASHER	ID22591
10305.	FLANGENUT	21SFF51618
10306.	HEXNUT	.312-18
10321.	INSPECTION	D5
10322.	MAT'L HANDLING	D6
2.	DRIVE UNIT	4420
201.	AZIMUTH	4421
20101.	AZ.-EL. ASSY	44211
2010101.	MECHANICAL	442111
2010102.	PAINT	442112
2010103.	ELECT. ASSY.	442113

2010121.	INSPECTION	4421121
201012101.	MECH ASSY.	44211211
201012102.	PAINT	44211212
201012103.	ELECT. ASSY.	44211213
2010122.	MAT'L HANDLING	4421122
201012201.	MECH. ASSY.	44211221
201012202.	PAINT	44211222
201012203.	ELECT. ASSY	44211223
20102.	HARMONIC DR. KIT	ID22499-1
2010202.	WAVE GEN PLUG	AZDR1
201020201.	MACHINE	4421221
201020221.	INSPECTION	44212221
201020222.	MAT'L HANDLING	44212222
2010203.	WAVE GEN BEARING	AZDR2
2010204.	FLEX SPLINE	AZDR3
201020401.	MACHINE	4421241
201020421.	INSPECTION	44212421
201020422.	MAT'L HANDLING	44212422
2010205.	CIRCULAR SPLINE	AZDR4
201020501.	MACHINE	4421251
201020521.	INSPECTION	44212521
201020522.	MAT'L HANDLING	44212522
2010206.	DIAPHRAM HUB	AZDR5
20103.	BEARING KIT-TUR	ID22490-1
20104.	LUBE PAN	ID22442-1
20105.	TUBE ASSEMBLY	ID22593-1
20106.	DR. ASSY PARTS	44216
2010602.	GEAR-HELICON	ID22486-1
2010603.	S.TRRT BEARING	ID22443-1
2010604.	S.HELICON GEAR	ID22485-1
2010605.	P.B. RETAINER	ID22482-1
201060501.	PAINT	4421651
201060521.	INSPECTION	44216521
201060522.	MAT'L HANDLING	44216522
2010606.	SHAFT-H.D.I.	ID22495-1
201060601.	MACHINE	4421661
201060621.	INSPECTION	44216621
201060622.	MAT'L HANDLING	44216622
2010607.	RETAINER-T.B.	ID22489-1
201060701.	MACHINE	4421671
201060721.	INSPECTION	44216721
201060722.	MAT'L HANDLING	44216722
2010608.	BRACKET-MAGNET.AZ.	ID22424-1
2010609.	SPACER-SHAFT SEAL	ID22449-1
2010610.	BUSHING-G.D.S.	ID22481-1
2010611.	F.B.FLEX SPLINE	ID22422-1
2010612.	BRACKET-ELEC. AZ.	ID22411-501
2010613.	WELD ASSY-FLEX S.	ID22474
201061301.	FAB & ASSY.	44216131
20106130101.	MACHINE HOUSING	442161311

20106130102.	WELD HOUSING	442161312
201061302.	MOUNT	ID22474
201061303.	TUBE	ID22474
201061304.	TUBE	ID22474
201061305.	SHELL	ID22474
201061306.	RETAINER	ID22474
201061321.	INSPECTION	442161321
20106132101.	MACHING	4421613211
20106132102.	WELDING	4421613212
201061322.	MAT´L HANDLING	442161322
20106132201.	MACHINING	4421613221
20106132202.	WELDING	4421613222
2010614.	AZ. DR. COVER	ID22129
2010615.	BEARING	106-KSZZ
2010616.	SEAL	2-133V747-75
2010617.	SEAL	2-275V747-75
2010618.	SEAL	2-386V747-75
2010619.	SEAL	2-459V747-75
2010620.	SEAL	506-325G
2010621.	VITON SEAL	9651
2010622.	NUT	N-06
2010623.	NUT	N-08
2010624.	WASHER	W-06
2010625.	WASHER	W-08
2010626.	KEY	NAS558-606-24
2010627.	KEY	NAS558-1212-15
2010628.	EXPANSION CHAMBER	1010-104000
2010629.	MAGNET	M2
2010630.	WASHER	AN970-3
2010631.	RND.HEAD SCREW	.190-32UNF-2AX.3
2010632.	RND.HEAD SCREW	.190-32UNF-2AX.5
2010633.	FLT.HD.BRASS SCREW	.190-32UNF-2AX.8
2010634.	SPLT LK. WASHER	.190
2010635.	HEXNUT	.190-32UNF-2B
2010636.	HEX CAP SCREW	.250-20UNC-2AX.6
2010637.	HEX CAP SCREW	.250-20UNC-2AX.7
2010638.	SPLT LK. WASHER	.250
2010639.	HEX CAP SCREW	.375-24UNF-2AX1.
2010640.	SPLT LK. WASHER	.375
2010641.	BRACKET	TA4064E0610
2010642.	PLUG	1/8-27ANPT
2010643.	PLUG	3/8-18ANPT
2010644.	CLAMP	ST253C6
2010645.	TAPE	DPM2766
2010646.	PLASTIC GASKET	DPM5793
2010647.	ADHESIVE	DPM3279
2010648.	GEAR OIL	MOBILE626
2010649.	GREASE	ALUANIAEJP2
2010650.	BRACKET-ELEC.AZ.	ID22411-1
20107.	WIRE/SENSOR/INST´L	44217

2010702.	SENSOR-ELEC. ASSY	ID22414-503
201070201.	CONN SW TO PIN	4421721
201070202.	CONTACT-PIN	110238-0040
201070203.	CONTACT-SOCKET	11238-0085
201070204.	TUBING	STM0069-13-A6-02
201070205.	TUBING	DPM2617-15
201070206.	PROXIMITY SWITCH	LC2P-1839-1A-60
201070207.	CONNECTOR	120-1807-000
2010703.	ELECT. INST;L	ID22596-1
201070301.	CONN MAT TO PIN	4421731
201070302.	SCREW	NAS601-6P
201070303.	WASHER	NAS620-10L
201070304.	NUT	NAS671-10
201070305.	WASHER	MS35338-43
201070306.	RECEPTACLE	120-1806-000
201070307.	RECEPTACLE	120-1870-000
201070308.	GROMMET	351-1641-000
201070309.	GROMMET	351-1634-000
201070310.	RECEPTACLE	120-1805-000
201070311.	TUBING	STM0069-13-A6-02
201070312.	CLAMP	MS21919WDG-6
2010704.	WIRE HARNESS	ID22514-1
201070401.	ASSY CABLES	4421741
20107040101.	ASSY SENSOR	44217411
20107040102.	ASSY MAT.	44217412
201070402.	CONNECTOR	120-1869-000
201070403.	CONNECTOR	120-1873-000
201070404.	CONNECTOR	120-1865-000
201070405.	CONNECTOR	120-1804-000
201070406.	CONNECTOR	120-1870-000
201070407.	CONTACT PIN	110238-0040
201070408.	CONTACT SOCKET	110238-0085
201070409.	PLUG-FILLER	225-0072-000
201070410.	GROMMET	351-1634-000
201070411.	SPLICE	A1A
201070412.	WIRE	8918
201070413.	WIRE	8451
201070414.	SHRINK TUBING	DPM2617-15
201070415.	SHRINK TUBING	DPM2617-15
201070416.	SHRINK TUBING	DPM2617-15
201070417.	SHRINK TUBING	DPM2617-15
201070418.	SHRINK TUBING	DPM2617-15
201070419.	TUBING	STM0069-13-A6-02
201070420.	TUBING	DPM2517-15
2010721.	INSPECTION	44217210
201072101.	SENSORS/CABLES	44217211
201072102.	MAT./CABLE	44217212
2010722.	MAT'L HANDLING	4421722
201072201.	SUPPLY PARTS	44217221
201072202.	SUPPLY PARTS	44217222

202.	ELEVATION	4422
20201.	ELEV.DR. SUPPORT	ID22439-1
2020102.	BEARING-TFE LINED	ID22415-501
2020103.	BEARING	MS21230-16
2020104.	ELEV.DR.CASTING	ID22439-1
202010401.	MACHINE	4422141
202010421.	INSPECTION	44221421
202010422.	MAT´L HANDLING	44221422
20202.	JACK SCREW ASSY PT	44222
2020202.	JACK-ELEVATION	ID22497-1
2020203.	WASHER	MS35338-41
2020204.	WASHER	NAS620-10L
2020205.	CLAMP	ST253C2
2020206.	CLAMP	ST253C6
2020207.	CLAMP	S0985C50D
2020208.	CLAMP	S0985C60D
2020209.	PLUG	120-1808-000
2020210.	PLUG	120-1869-000
2020211.	PIN	110238-0040
2020213.	SLEEVING	STM0069-13-A6-0
2020214.	SHROUD	ID22595
2020215.	SHROUD	ID22595
2020216.	SOCKET	110238-0085
20203.	MAIN BEAM	ID40042
2020301.	FAB & ASSY.	442231
202030101.	MACHINE BEAM	4422311
202030102.	WELD BEAMS	4422312
2020302.	BODY	ID22464-3
2020303.	WEB	ID22464
2020304.	LUG	ID22464
2020305.	LUG	ID22464
2020306.	LUG	ID22464
2020307.	GUSSET	ID22464
2020308.	BAR	ID22464
2020309.	PAD	ID22464
2020310.	STIFFENER	ID22464
2020311.	STIFFENER	ID22464
2020312.	CHANNEL	ID22464
2020313.	STIFFENER	ID22464
2020314.	BEARING-TFE LINED	ID22415-1
2020315.	PIN	ID22464
2020321.	INSPECTION	4422321
202032101.	MACHINING	44223211
202032102.	WELDING	44223212
2020322.	MAT´L HANDLING	4422322
202032201.	MACHINING	44223221
202032202.	WELDING	44223222
203.	MOTORS-TOTAL	4423
20302.	AZIMUTH MOTOR	ID22487-501
20303.	ELEVATION MOTOR	ID22487-1

204.	POS/LIM INDICATOR	4424
20402.	INCREMENTAL ENCODE	44242
2040201.	ELECT. ASSY	442421
204020101.	ENCODER	4424211
204020102.	ENCODER LEADS	4424212
204020103.	ENCODER/CNTRL CABL	4424213
2040202.	CCA ENCODER	ID22573-1
2040203.	PWB COMPONENTS-TOT	442423
204020302.	PWB ENCODER	ID22574-1
204020303.	CAPACITOR	M39014-101-1513
204020304.	RESISTOR	RCR05G512JS
204020305.	I.C.	DM7830JB
204020306.	MICRO SWITCH	4AVIC-T1
204020307.	SOLDER	DMP3891
204020308.	INK	CMP3627-37875
204020309.	WIRE	#22-2SJ
204020310.	SPLICE	A1A
204020311.	TUBING	DPM2617-15
2040204.	GROMMET	MS35489-122
2040205.	PIN-CONTACTS	110238-0085
2040206.	SOCKET CONTACTS	110238-0085
2040207.	SPACER	NAS43DD-3-20
2040208.	CLAMP	NAS1715-D5T
2040209.	SCREW	NAS601-10P
2040210.	WASHER	NAS620-6
2040211.	SCREW	MS24693-C28
2040212.	VANE	ID22578-3
2040213.	COVER	ID22588-1
2040215.	TUBING	RJ102-3/8
2040221.	INSPECTION	4424221
204022101.	ENCODER	44242211
204022102.	ENCODER LEADS	44242212
204022103.	ENC./CNTRL CABLE	44242213
2040222.	MAT'L HANDLING	4424222
204022201.	ENCODER	44242221
204022202.	ENCODER LEADS	44242222
204022203.	ENC./CNTRL CABLE	44242223
20403.	ENCODER ASSY COMPO	44243
2040303.	LOCK WASHER	MS35338-41
2040304.	WASHER	NAS620-6
2040305.	STRAP	PLT8H-LP0
2040306.	CONNECTOR	120-1869-000
2040307.	TUBING	STM0069-13-A6-0
2040308.	SCREW	NAS601-5P
20404.	MOTOR CONTROLLER	T619
2040401.	ASSY. LABOR	442441
2040402.	DUEL FIFF LINE REC	9615
2040403.	OPT.ISOL.TRIACS	Q2T3244
2040404.	RESISTOR	11 Z 13
2040405.	CAPACITOR	0.1MF1400V

2040406.	PRINTED CIRCUIT BD	T107
2040407.	COVER	T226
205.	PWR SPLY/DIST	4425
20501.	EMER.PWR.SPLY	442501
20502.	PWR DIST EQ/WIRING	442502
2050201.	FEEDER CABLE	CLX
2050202.	TRANSFORMER	225T(19)H
2050203.	DIST PANEL	SQ.D-H-4172-4M
2050204.	BRANCH CIR BKR	SQD NO.FA-34040
2050205.	BRANCH CIR CABLE	CLX-ALS
20503.	PEDESTAL ELECT	442503
2050301.	ASSEMBLY	442531
205030101.	CIR.BRKR-BOX ASSY	4425311
205030102.	PWR/CTRL WIRE ASSY	4425312
20503010201.	WIRE HARNESS ASSY	44253121
20503010202.	ATTACH PINS	44253122
205030103.	FIBER OPTIC ASSY	4425313
20503010301.	FIBER OPTIC ASSY	44253131
205030104.	HARN.-OPTIC ASSY	4425314
2050302.	JUNCTION BOX	BOX-2
2050303.	TERMINAL STRIP	STRIP-1
2050304.	MOUNTING PANEL	MNT-1
2050305.	TERMINATOR	TERM-1
2050306.	CABLE FITTING	FIT-1
2050307.	CIRCUIT BREAKER	CB-3PH
2050308.	POWER CABLE	H-1
2050309.	CONTROL CABLE	CC-1
2050310.	FIBER OPTIC CABLE	FOCB-1
2050311.	FIBER OPTIC TERMIN	FOCN-1
2050312.	CONNECTOR	CON-2
2050313.	CONNECTOR	CON-3
2050321.	INSPECT & TEST	4425321
2050322.	MAT´L HANDLING	4425322
2050323.	PACKAGING	4425323
206.	ASSY DR/PED/ELCT P	4426
20601.	ASSY. LABOR	44261
20602.	DR/PED/ELECT PRTS	44262
2060202.	COVER-EL. SENSOR	ID22416
2060203.	MNT- EL. SENSOR	ID22417
2060204.	BRKT-MAGNET(EL.)	ID22418
2060205.	BRKT-EL SENSOR	ID22419-1
206020501.	PLATE	ID22419
206020502.	BASE	ID22419
2060206.	PIN-TRUNNION	ID22432
2060207.	MNT-SENSOR PTPT	ID22433
2060208.	CAP-ROD END PIN	ID22438
2060209.	PIN-HINGE	ID22455
2060210.	PIN-ROD END	ID22478
2060211.	COVER-EL.DR.	ID22594
2060212.	HINGE-HLF ASSY	ID22405-1

206021202.	ANGLE	ID22405
206021203.	PIN	ID22405
2060213.	HINGE-HLF ASSY	ID22405-501
206021302.	ANGLE	ID22405
206021303.	PIN	ID22405
2060214.	HINGE-HLF ASSY	ID22405
2060215.	COTTER PIN	MS24665-374
2060216.	COTTER PIN	MS24665-377
2060217.	BOLT	NAS1314-16
2060218.	BOLT	NAS1316-42D
2060220.	SET SCREW	NAS1081-4A12P
2060221.	SET SCREW	NAS1081-4A12P
2060222.	MAGNET	M2
2060223.	WASHER	5710-67-10
2060224.	WASHER	5710-245-90
2060225.	SHAFT	A3-17
2060226.	F.H.BRASS SCREW	.190-32UNF-2AX.7
2060227.	SPLT LK. WASHER	.190
2060228.	HEXNUT	.190-32UNF-2B
2060229.	HEX CAP SCREW	.250-20UNC-2AX.5
2060230.	HEX CAP SCREW	.250-20UNC-2AX.7
2060231.	HEX CAP SCREW	.250-20UNC-2AX.8
2060232.	SPLT LK. WASHER	.250
2060233.	HEXNUT	.250-20UNC-2B
2060234.	SPLT LK. WASHER	.500
2060235.	SPLT LK. WASHER	.875
2060236.	WAHER	AN960-1616
2060237.	NUT	AN130-15
2060238.	COTTER PIN	.062X.50
2060239.	HEX CAP SCREW	.250-28UNF-2AX.5
2060240.	JUMPER	ST268-09CC
2060241.	SENSOR-EL ASSY	ID22414-1
206024101.	CONN SW TO PIN	4426241
206024102.	CONNECTOR	120-1809-000
206024103.	CONTACT-PIN	110238-0040
206024104.	CONTACT-SOCKET	110238-0085
206024105.	TUBING	STM0069-13-A6-0
206024106.	TUBING	DPM2617-15
206024107.	PROXIMITY SWITCH	LC2P-1839-1A-60
2060242.	SENSOR-EL ASSY	ID22414-501
206024201.	CONN SW TO PIN	44262442
206024202.	CONNECTOR	120-1807-000
206024203.	CONTACT-PIN	110238-0040
206024204.	CONTACT-SOCKET	110238-0085
206024205.	TUBING	STM0069-13-A6-0
206024206.	TUBING	DPM2617-15
206024207.	PROXIMITY SWITCH	LC2P-1839-1A-60
2060243.	ELEC.INST'L-PED	ID22445-1
206024301.	ASSY. SEN/CABLE	4426243
206024302.	CLAMP	ST253C6

206024303.	JUMPER	ST263-16CC
206024304.	RNDHEAD SCREW	.190-32UNF-2AX.5
206024305.	SPLT LK. WASHER	.190
206024306.	CABLE TIES	PLT1M
2060244.	CABLE-ASSY PED	ID22514-501
206024402.	CONNECTOR	120-1869-000
206024403.	CONTACT-PIN	110238-0040
206024404.	CONTACT-SOCKET	11238-0085
206024405.	PLUG FILLER	225-0072-000
206024406.	SPLICE	A1A
206024407.	WIRE	8918
206024408.	WIRE	8451
206024409.	TUBING	DPM2617-15
206024410.	TUBING	STM0069-13-A6-0
2060245.	BOLT	NAS1308-15
20621.	INSPECTION	442621
2062101.	FINAL	4426211
2062102.	SENSOR	4426212
20622.	MAT'L HANDLING	442622
2062201.	PACKAGE	4426221
2062202.	LOAD/UNLOAD	4426222
2062203.	SUPPLY	4426223
3.	CONTROL/INSTRMT EQ	4430
301.	SENSOR/CALIB EQUIP	4431
30101.	BCS HARDWARE	44311
3010101.	CAMRA/CABLE/MOUNT	2850C-207
3010102.	COMP CNTRL/TEST EQ	ER-8807
3010103.	MULTPLE CAMRA SWIT	VS504H
30102.	FACTORY TRAINING	44312
30103.	INSTL AND CHKOUT	44313
302.	FIELD CONTROL	4432
30201.	ASSEMBLY	44321
3020101.	FINAL HC ASSY	443211
3020102.	PWB COMPONENT ASSY	443212
30202.	DATA DIST.INT	443202
3020201.	TWO SIDED PWB	PWB-2
3020202.	CONNECTOR	CON-25M
3020203.	LED	SG-1010
3020204.	OPT TRANSCEIVER	SIM 75116
3020205.	MICRO-COMPUTER	SEMI 8748
3020206.	OPT TRANSCEIVER	SIM 75116
3020207.	RELAY	R10E6-Y2V185
3020208.	CERAMIC CAPS	CCAP-1
3020209.	MODULAR PWR-SUPPLY	SIMI LOS-W5
3020210.	FOAM PADS	FPAD-1
3020211.	PHOTO DETECTOR	C30807
3020212.	PHOTO TRANSISTORS	FPT100A
3020213.	BOX	BOX-1
3020214.	CONNECTOR	CON-25F
30221.	INSPECT/TEST	443221

30222.	MAT´L HANDLING	443222
303.	CNTRL/SIG EQ	4433
30301.	ASSEMBLY	44331
3030101.	FINAL HC ASSY	443311
3030102.	PWB COMPONENT ASSY	443312
30302.	HELIO CONTROL	443201
3030201.	PRINTED CIRCUIT BD	T100
3030203.	CONNECTOR	24-28P
3030204.	MU.COMPUTER	SIMI 8748
3030205.	QUAD.DIFF. LINE DR	SIMIDS1688
3030206.	QUAD.DIFF. LINE RE	SIMI DS1689
3030207.	HEX D-FLIP FLOP	SN7474N
3030208.	CAPACITOR	0.1MF-50V
3030209.	POWER SUPPLY	3425-0000
3030210.	BOX	BOX-1
3030211.	CONNECTOR	CON-1
3030212.	OPT TRANSCEIVER	SIM 75116
30321.	INSPECT/TEST	443321
30322.	MAT´L HANDLING	443322
4.	FOUND/SITE PREP	4440
401.	FOUNDATION	4441
40101.	INSTALLATION	44411
4010101.	FORM, POUR/FINISH	444111
4010102.	CAGES	444112
4010103.	EQUIP OPER _ DRIVR	444113
40102.	CONCRETE	44412
40103.	CAGES	44413
40104.	TAPERED PIPE	44414
40105.	BRACING	44415
402.	SITE PREPARATION	4442
40201.	SURVEY	44421
40202.	DRILLING	44422
5.	HELIO SPT ST/PR EN	4450
501.	HELIO SUPP STRUCT	4451
50101.	ASSY. & PAINT	44511
5010101.	WELD	445111
5010102.	PAINT	445112
50102.	TUBE-TOTAL	T456
5010201.	TUBE	ID22461-3
5010202.	PLATE	ID22461
5010203.	CONE	ID22461
5010204.	RING	ID22461
5010205.	NUT	1.00-8
50121.	MAT´L HANDLING	445121
50122.	INSPECTION	445122
7.	FIELD ASSY & C/O	4460
701.	HELIOSTAT	4461
70101.	FIELD ASSEMBLY	44611
70102.	INSTALATION & C/O	44612
7010201.	DRIVE/PED/ELTRONC	446121

7010202.	REFLECTOR PANELS	446122
702.	SENSOR/CALIB EQ	4462
70203.	CALIBRATE	44622
703.	ELECTRICAL/DISTRIB	4463
70302.	INSTALL CABLE	44631
70303.	PWR TR/DISTRIB PNL	44632
70304.	CONN.C/O&CLOSE OUT	44633
704.	ALIGN HELIOSTATS	4464
705.	FIELD SUPPORT	4465
70501.	INSTALLATION MGMT	44651
70502.	LOGISTICS	44652
7050201.	SUPERVISION	446521
7050202.	RECORDS	446522
7050203.	FIELD COORDINATION	446523
7050204.	PERSONNEL	446524
70503.	QUALITY CONTROL	44653
70504.	FIELD ENGINEERING	44654
706.	PACK & TRANS	4466
70601.	CONTAINERS	44661
7060101.	DRIVE	44661-1
7060102.	REFLECTOR	44661-2
7060103.	DISTRIB ELECT	44661-3
7060104.	REBAR CAGE/CONE	44661-4
7060105.	CABLING	44661-5
70602.	TRANSPORTATION	44662
7060201.	DRIVE	44662-1
7060202.	REFLECTOR	44662-2
706020201.	PERMITS	44662-2-1
7060203.	DISTRIB ELECT	44662-3
7060204.	REBAR CAGE/CONE	44662-4
7060205.	CABLING	44662-5

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      0. GRAND TOTAL
      1.   REFLECTOR ASMBLY                               4410
    101.     REFLECTIVE SURFACE                           4411
    102.     MIRROR BACK STRU                             4412
      2.   DRIVE UNIT                                     4420
    201.     AZIMUTH DRIVE                                4421
    202.     ELEVATION                                    4422
  20202.       JACK SCREW ASSY PT                         44222
2020202.         JACK-ELEVATION                           ID22497-1
    203.     MOTOR TOTAL                                  4423
  20302.       AZ.DRIVE MOTOR                             40ID22487-501
  20303.       EL.DRIVE MOTOR                             40ID22487-1
    204.     POS/LIMIT INDICATO                           4424
  20402.       ENCODER ASSEMBLY                           40410242
2040201.         INCR.ENCODER                             40ID22571-501
2040202.         INCR.ENCODER                             40ID22571-1
  20404.       MOTOR CONTROL                              40T619
    205.     PWR SPLY/DIST                                4425
  20502.       PWR DIST EQ/WIRING                         442502
2050201.         FLD.PWR/DATA CABLE                       40CLX
2050202.         POWER TRANSFORMER                        40225T(19)H
2050203.         PWR.DISTRIB PANEL                        40SQ.DH-4172-4N
2050205.         HEL.PWR/DATA CABLE                       40CLX-ALS
      3.   CONTROL/INSTRMT EQ                             4430
    302.     FIELD CONTROL                                4432
  30202.       DATA DIST.INTERFAC                         443202
    303.     CNTRL/SIG EQ                                 4433
  30302.       HELIO CONTROLLER                           443302
      5.   HELIO SPT ST/PR EN                             4450
    501.     PEDESTAL                                     4451
  50102.       TUBE - TOTAL                               T456
5010201.         TUBE-CAP-COVER                           ID22461-1
5010204.         J BOX                                    40ID40046-9
      9.   COMMON O&M                                     OM000
    902.     MAINT.MATERIAL                               OM200
  90203.       OTHER                                      OM230
9020301.         WASHING SOLUTION                         OM231
9020302.         DEIONIZED WASH WAT                       OM232
9020303.         DEIONIZED RNSE WAT                       OM233
9020304.         DIESEL FUEL                              OM234
9020305.         OTHER FUEL                               OM235
9020306.         LUBRICANT-AZ DRIV                        OM236
9020307.         LUBRICANT-JACK                           OM237
9020308.         ELECT POWER REQMTS                       OM238
    903.     MAINTENANCE LABOR                            OM300
  90301.       SCHEDULED MAINT                            OM310
9030101.         WASHING LABOR                            OM311
9030102.         OILING DRIVES                            OM312
9030103.         CORROSION CONTRL                         OM313
     41.   SITE/STRU/MISC EQ                              4100
   4130.     MISC.EQUIP                                   4130
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      413001.       MAINT.SUPP./EQ.         4131
    41300101.         COLLECTOR             41311
  4130010101.           MOBILE CRANE        ME-1
  4130010102.           FORKLIFT            ME-2
  4130010103.           HYDRASET            ME-3
  4130010104.           PICK-UP TRUCK       ME-4
  4130010105.           WYLER MINILEVEL     ME-5
  4130010106.           OIL INJECTOR        ME-6
  4130010107.           PORTBLE CNTRL UNIT  ME-7
  4130010108.           SERVICE LINK KIT    ME-8
  4130010109.           JACK ADJSTMNT TOOL  ME-9
  4130010110.           CLINOMETER MOUNT    ME-10
  4130010111.           HOISTING TOOL       ME-11
  4130010112.           HOISTING TOOL       ME-12
  4130010113.           PANEL LEVELING TOO  ME-13
  4130010114.           SLING               ME-14
  4130010115.           REPAIR EQUIP.       ME-15
  4130010116.           WASHING EQUIP.      ME-16
          43.   ELECT PLT EQ                4300
        4305.     PLANT CONTROL             4350
      430503.       HELIO ARRAY CONTRL      4353
    43050301.         HAC HARDWARE          43531
  4305030101.           COMPUTER-PERH       KDF11-HF
  4305030102.           MASS STORAGE        RXV21-BA
  4305030103.           DISPLAY CONSOLE     ISC-8001G
  4305030104.           HARD COPY/LOGGER    LA180
  4305030105.           CONSOLE RACKS       2-42B-1-A-2Y-30
  4305030106.           WWV UPDATED CLOCK   60-DC
  4305030107.           RSX11-M SYS SFTWRE  RSV11-S
  4305030108.           DATA ACQTIN PKG     ADK11-KT
    43050302.         HRDWARE DESGN ENG     43532
    43050303.         SFTWARE DESGN ENG     43533
    43050304.         INSTL AND CHKOUT      43534
          48.   INITIAL SPARES              4800
        4801.     HELIO INIT SPARES         4841
      480101.       REFLECTOR ASMBLY        484101
    48010101.         REFLECTIVE SURFACE    48ID22462-501
    48010102.         MIRROR BACK STRU      48ID22463-1
      480102.       DRIVE UNIT              484102
    48010201.         AZIMUTH DRIVE         48ID22494-1
    48010202.         JACK-ELEVATION        48ID22497-1
    48010203.         MOTOR TOTAL           4841023
  4801020302.           AZIMUTH DRIVE MOTO  48ID22487-501
  4801020303.           EL.DRIVE MOTOR      48ID22487-1
    48010204.         POS/LIMIT INDICATO    4841024
  4801020402.           ENCODER ASSEMBLY    48410242
480102040201.             INCR.ENCODER      48ID22571-1
480102040202.             INCR.ENCODER      48ID22571-501
  4801020403.           MOTOR CONTORL       48T619
    48010205.         PWR SUPPLY/DIST.      4841025
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4801020502.	PWR DIST EQ/WIRING	48410252
480102050201.	FLD.PWR/DATA CABLE	48CLX
480102050202.	POWER TRANSFORMER	48225T(19)H
480102050203.	PWR.DITRIB.PANEL	SQ.DH-4172-4N
480102050205.	HEL.PWR/DATA CABLE	48CLX-ALS
480103.	CONTROL/INSTRMT EQ	484103
48010302.	DATA DIST.INTERFAC	484432
48010303.	HELIO CONTROLLER	484433
480105.	HELIO SPT ST/PR EN	484450
48010501.	PEDESTAL	4451
4801050102.	TUBE - TOTAL	T456
480105010201.	TUBE-CAP-COVER	48ID22461-1
480105010204.	J BOX	48ID40046-9

Appendix D-3
INVESTMENT COSTS

The costs presented in the tables contained in Appendix D-3 indicate the total cost, rather than price, per heliostat for the 494 thousandth unit installed in a field of 5412 heliostats. Costs for each material item or activity have been collected by WBS categories such as Reflective surface, Mirror backing structure or Azimuth drive. The sum of the costs for a given category tie directly to the total values shown for each WBS category in the summary of costs at the beginning of Appendix D-3, and in Table 25.

The costs have been developed in accordance with the costing approach described in Section 6.3.3, and also using rates as developed in Appendix D-5. The cost data is presented in terms of one heliostats worth of material or labor. For some items, such as field controllers, the cost will appear very small because of the ratio of field controllers to heliostats. In addition, the values as shown in the tables are rounded at printout so that their products may not equal the totals shown in the printout for many of the line items. However, the printout totals indicate the true products.

The text attached to each line item is provided in terms of the data peg point. Thus, a cost per pound shown in the text may be somewhat higher than that exhibited when the cost shown in the table is divided by the weight shown in the text.

The following provides a further description of the contents of each column in the tables:

1. Cost Element, CBS or PN and Technical Cost Drivers. This column provides the description and reference numbers for each costed line item. The first line of the description gives the reference number used by the LEADER system to logically orient the various cost elements within a WBS hierarchy. The next line gives cost element title and the Sandia CBS number

down to the required CBS reporting level. For lower levels, the vendor part number, MDAC drawing or part number, standard specification number, or description index number is provided. Following lines provide a description of the element which may include: technical cost drivers, activity descriptions, and for important cost elements, the source of the estimate.

2. Cost Classifications (no heading). This column indicates whether the line refers to LBR-labor hours, PP-purchased parts, or RM-raw materials, or NR-nonrecurring.

3. Quantity/Hours/Annual Failures (Qty/Hrs/Ann. Fail.). The quantity shows the number of items per heliostat and is indicated where materials are involved. For example, the quantity 28 after Stiffeners indicates that there are 28 stiffeners per heliostat. Hours indicate the total direct labor hours required to accomplish the described task for one heliostat at the 494 thousandth unit. This value will be lower than that for the GM peg point. These hours consider efficiency and other factors as-well-as cost reductions. Annual failures do not show up on the investment cost tables.

4. Reference Unit Cost (Ref. Unit Cost). The labor reference unit cost is the base labor rate plus certain allowances for overtime, cost of living, and, the case of field effort, fringe benefits. For materials, the reference unit cost is the cost of one end item of a "heliostat" (e.g., one stringer of a heliostat of 28 stringers) after cost reduction and other factors, if any, are considered.

5. Subtotals. The subtotal is the product of the value in the Quantity/hours column and the value in Reference unit cost column.

6. Factors. The factors columns are subheaded CRC, (cost reduction curve), Overhead and G and A. The CRC column is not used where the resource loading technique is used because the technique already accounts for much of the cost reduction impact. In addition, the overhead and G and A columns are not applied against materials since these elements are included as factors of labor. All overhead and G and A including the material scrap allowance, is loaded against labor. Three sets of rates are employed--one for field effort applied to Foundations, Site prep and Field assembly, a second for transportation, and a third for factory effort. Derivations of the latter is detailed on page D5-3 while field rates are based on the Prototype heliostat study and transport rates are those experienced by MDC's transportation department.

7. Total. Except for materials the total column is the product of the value in the subtotal column and the values contained in the factors columns. For materials, the factors shown for overhead and G and A are zeros which intended the meaning of "not applicable". The material subtotal is factored only by the value in the CRC column in-order-to arrive at the total value.

8. Dollars per Square Meter ($/SM). Dollars per square meter provides the quotient of the total cost of the line item and the heliostat reflective surface area.

SECOND GENERATION HELIOSTAT 50K/YR.

WBS NUMBER AND TITLE		NON	CAPITAL INVESTMENT					
		RECUR	LABOR		MATL DOLLAR			INVST
		(THOU)	HOURS	DOLL	PUR PT	RAW MTL	TOTAL	$/SM
	GRAND TOTAL	0.	36.2	1447.	1518.	1844.	4808.	84.57
4410	REFLECTIVE UNIT	0.	1.9	138.	8.	1501.	1648.	28.98
4411	REFLECTIVE SURFACE	0.	.9	68.	0.	1023.	1091.	19.18
4412	MIRROR BACK STRU	0.	.3	22.	0.	451.	474.	8.33
4413	ASSY-REFLECTIVE UN	0.	.7	48.	8.	27.	83.	1.46
4420	DRIVE UNIT	0.	7.3	528.	1173.	137.	1838.	32.33
4421	AZIMUTH	0.	3.6	263.	253.	31.	548.	9.64
4422	ELEVATION	0.	1.7	125.	452.	87.	663.	11.66
4423	MOTORS-TOTAL	0.	0.0	0.	109.	0.	109.	1.92
4424	POS/LIM INDICATOR	0.	.4	30.	51.	4.	84.	1.49
4425	PWR SPLY/DIST	0.	.8	55.	288.	0.	343.	6.03
4426	ASSY DR/PED/ELCT P	0.	.7	54.	20.	16.	90.	1.59
4430	CONTROL/INSTRMT EQ	0.	.3	24.	167.	0.	191.	3.36
4431	SENSOR/CALIB EQUIP	0.	.0	1.	6.	0.	8.	.14
4432	FIELD CONTROL	0.	.0	0.	2.	0.	2.	.04
4433	CNTRL/SIG EQ	0.	.3	22.	158.	0.	181.	3.18
4440	FOUND/SITE PREP	0.	13.3	342.	148.	79.	569.	10.00
4441	FOUNDATION	0.	9.6	247.	148.	79.	474.	8.34
4442	SITE PREPARATION	0.	3.7	94.	0.	0.	94.	1.66
4450	HELIO SPT ST/PR EN	0.	.4	32.	0.	126.	158.	2.78
4451	HELIO SUPP STRUCT	0.	.4	32.	0.	126.	158.	2.78
4460	FIELD ASSY & C/O	0.	13.0	384.	21.	0.	405.	7.13
4461	HELIOSTAT	0.	3.0	77.	0.	0.	77.	1.35
4462	SENSOR/CALIB EQ	0.	.0	0.	0.	0.	0.	.00
4463	ELECTRICAL/DISTRIB	0.	1.7	43.	0.	0.	43.	.75
4464	ALIGN HELIOSTATS	0.	.7	19.	0.	0.	19.	.33
4465	FIELD SUPPORT	0.	1.2	30.	0.	0.	30.	.53
4466	PACK & TRANS	0.	6.4	216.	21.	0.	237.	4.17
4300	ELECT PLT EQ	0.	.3	14.	8.	0.	22.	.38
4350	PLANT CONTROL	0.	.3	14.	8.	0.	22.	.38

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SECOND GENERATION HELIOSTAT 50K/YR.                                           13.11.34.        DATE 02/09/81

  REFLECTIVE SURFACE  4411

DESCRIPTION                               QTY/HRS/      REF UNIT  SUB TOTAL    F A C T O R S         TOTAL
                                         ANN. FAIL        COST                CRC  OVERHEAD  G_A              $/SM

        10101.
  MIRROR MOD. ASSY.   44111
 ASSEMBLE MIRROR MODULE USING      LBR       .55  HRS        9.64       5.28  1.00   5.96    1.26      39.79    .70
 MAINLINE POWER AND FREE CONVEYORS,
 SPRAY WASHER,DEIONIZED WATER RINS-
 ER,WARM AIR DRYER,ADHESIVE SPRAYER
 ADHESIVE EXTRUDER, AND HANDLING EQ
 LISTED BELOW
 CREW SIZE = 8
                        SOURCE : GM

      1010201.
  STRINGER ASSY.      441121
 ASSEMBLE CLINCH NUTS TO STRINGERS  LBR      .17  HRS        9.64       1.68  1.00   5.96    1.26      12.68    .22
 AT INTEGRATED ASSY STATION WITH
 PALLET,INDEXING MECHANISM,VIBRAT-
 ING BOWL HOPPERS:DRIVE CLINCH NUTS
 WITH AIR PRESSES
 AUTOMATICALLY SPRAY PRIMER WITH
 BRIDGE TYPE SPRAY MACHINE
 CREW SIZE = 6
                       SOURCE: GM

      1010202.
  STIFFENER            ID22462-3
 MATERIAL 16GA(0.064)HAT SECTION(INSIR M   28.00 UNITS       4.70     131.58  1.00   0.00    0.00     131.58   2.31
 GALV,OUTSIDE PAINTED)
 WT.=24LBS. PER STIFFENER
 SOURCE: G.M.-(COST ADJUSTED FOR WEIGHT
 INCREASE

      1010203.
  CLINCH FASTENER     S-0518-1-Z
 PER SPEC.                          R M    56.00 UNITS        .02       1.12  1.00   0.00    0.00       1.12    .02
 SOURCE: PENN ENG. & MFG. CO.

        10103.
  EDGE MEMBER          ID22462-11,13
 PER SPEC.                          R M    56.00 UNITS        .42      23.53  1.00   0.00    0.00      23.53    .41
 SOURCE: G.M.-(COST ADJUSTED FOR WEIGHT
 INCREASE)

        10104.
  SHIM                 ID22462-17
 PER SPEC.                          R M    28.00 UNITS       1.33      37.20  1.00   0.00    0.00      37.20    .65
 SOURCE: LAMB
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REFLECTIVE SURFACE 4411

DESCRIPTION		QTY/HRS/ ANN. FAIL	REF UNIT COST	SUB TOTAL	F A C T O R S			TOTAL	$/SM
					CRC	OVERHEAD	G_A		
10106. GLASS PRIMER PR1506 PER SPEC. SOURCE: MDAC PROCUREMENT EST.	R M	14.00 UNITS	.02	.28	1.00	0.00	0.00	.28	.00
10107. STEEL PRIMER COROGARD9 PER SPEC. SOURCE: MDAC PROCUREMENT EST.	R M	14.00 UNITS	.24	3.36	1.00	0.00	0.00	3.36	.06
10108. ADHESIVE STABOND1894 GLASS TO SHIM BONDING ADHESIVE $15.00 PER GALLON SOURCE: MDAC PROCUREMENT EST.	R M	14.00 UNITS	.94	13.16	1.00	0.00	0.00	13.16	.23
10109. ADHESIVE EC3532 SHIM TO STIFFENER BONDING ADHESIVE $38.18 PER GALLON SOURCE: MDAC PROCUREMENT EST.	R M	14.00 UNITS	3.23	45.22	1.00	0.00	0.00	45.22	.80
10110. EDGE SEALANT SCS1202 SILICONE SEALANT, $15.00 PER GALLON SOURCE: MDAC PROCUREMENT EST.	R M	14.00 UNITS	1.07	14.98	1.00	0.00	0.00	14.98	.26
10111. EDGE SEALANT SCS1202 SILICONE SEALANT, $15.00 PER GALLON SOURCE: MDAC PROCUREMENT EST.	R M	14.00 UNITS	.82	11.48	1.00	0.00	0.00	11.48	.20
10112. MIRROR ID22428-3 PER SPEC., .059 FUSION GLASS 132" X 48" INCLUDES SILVER,COPPER, AND PAINT SOURCE: CORNING	R M	14.00 UNITS	29.62	414.73	1.00	0.00	0.00	414.73	7.29
10113. BACKLITE ID22428-5 PER SPEC., .190 FLOAT GLASS 132" X 48" SOURCE: MDAC	R M	14.00 UNITS	13.82	193.54	1.00	0.00	0.00	193.54	3.40
10114. ADHESIVE PVB 0.015PVB,PINCHED ROLLED AND AUTOCLAV SOURCE: MDAC PROCUREMENT EST.	R M	14.00 UNITS	9.48	132.71	1.00	0.00	0.00	132.71	2.33

SECOND GENERATION HELIOSTAT 50K/YR. 13.11.34. DATE 02/09/81

REFLECTIVE SURFACE 4411

DESCRIPTION		QTY/HRS/ ANN. FAIL		REF UNIT COST	SUB TOTAL	FACTORS CRC	FACTORS OVERHEAD	FACTORS G_A	TOTAL	$/SM
10121. INSPECTION D1 FLOOR INSPECTION CREW SIZE = 2 SOURCE ; GM	LBR	.12	HRS	9.64	1.19	1.00	5.96	1.26	9.00	.16
10122. MAT'L HANDLING D2 AUTOMATIC HANDLING WITH: SPECIAL SHIPPING PALLETS,FORK-TRUCKS,BRIDGE CRANE,GLASS LOADERS, STRINGER LOADER,PINCH ROLLER, PALLET CONVEYOR,PALLET LOAD AND UNLOAD STATIONS,HEATING ELEMENTS BETWEEN ROLLERS,RACKS,ROLLER SUPPORT GUIDES,LOAD JIG GONDOLAS SOURCE: GM	LBR	.09	HRS	9.64	.83	1.00	5.96	1.26	6.27	.11
REFLECTIVE SURFACE 4411									1091.	19.18

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  MIRROR BACK STRU    4412

DESCRIPTION                                       QTY/HRS/        REF UNIT  SUB TOTAL     F A C T O R S         TOTAL
                                                 ANN. FAIL         COST                 CRC  OVERHEAD  G_A              $/SM

        10201.
  WELD,MACH & STR.    44121
 TRIM ENDS WITH D.E.DIELINE               LBR        .25  HRS        9.64      2.44    1.00   5.96     1.26      18.40    .32
 MANUALLY ARC WELD USING SEMI-AUTO.
 "SQUIRT-GUN"
 WELD,DRILL WITH RESISTANCE WELDING
 AND DRILLING MACHINE
 CREW SIZE = 9
                           SOURCE: GM

        10202.
  INBOARD CROSSBEAM   ID22465-1
 LENGTH= 324.5 IN., WEIGHT= 184.7 LBSR M    2.00 UNITS      64.93    129.86    1.00   0.00     0.00     129.86   2.28
 MATERIAL #14GA(0.0784)GALV. STL
 COST BASIS=WT. TIMES DOLLARS/LB.
 SOURCE: MDAC  ($ .39/LB.)

        10203.
  DOUBLER ANGLE       ID22465-003-5
 2" X 2" X 1/8" GALV. ANGLE               R M   28.00 UNITS        .41     11.48    1.00   0.00     0.00      11.48    .20
 COST BASIS= WT. TIMES DOLLARS/LB.
 SOURCE: MDAC

        10204.
  DIAGONAL BEAM       ID22466
 LENGTH= 121.5 IN., WEIGHT= 101.6 LBSR M    2.00 UNITS      37.30     74.60    1.00   0.00     0.00      74.60   1.31
 MATERIAL #12GA(0.1084)GALV.
 COST BASIS= WT TIMES DOLLARS/LB
 SOURCE: MDAC ($ .39/LB.)

        10205.
  DIAGONAL BEAM       ID22466
 LENGTH= 121.5 IN., WEIGHT= 101.6 LBSR M    2.00 UNITS      37.30     74.60    1.00   0.00     0.00      74.60   1.31
 MATERIAL #12GA(0.1084)GALV.
 COST BASIS= WT TIMES DOLLARS/LB
 SOURCE: MDAC ($ .39/LB.)

        10206.
  OUTBOARD CROSSBEAM  ID22467-1
 LENGTH= 324.5 IN., WEIGHT= 153.2 LBSR M    2.00 UNITS      56.78    113.57    1.00   0.00     0.00     113.57   2.00
 MATERIAL #12GA(0.1084)GALV.
 COST BASIS= WT. TIMES DOLLARS/LB.
 SOURCE: MDAC ($ .39/LB.)

        10207.
  DOUBLER             ID22463
 PER SPEC.                                R M    4.00 UNITS       2.58     10.31    1.00   0.00     0.00      10.31    .18
 COST BASIS= WT. TIMES DOLLARS/LB.
 SOURCE: MDAC
1
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SECOND GENERATION HELIOSTAT 50K/YR.                                                     13.11.34.        DATE 02/09/81

   MIRROR BACK STRU    4412

DESCRIPTION                                           QTY/HRS/       REF UNIT  SUB TOTAL      F A C T O R S          TOTAL
                                                     ANN. FAIL         COST                 CRC  OVERHEAD  G_A                 $/SM

      1020801.
   PLATE               ID22463
 PER SPEC.                                  R M       4.00 UNITS        3.52      14.08    1.00    0.00    0.00        14.08     .25
 COST BASIS= WT. TIMES DOLLARS/LB.
 SOURCE: MDAC

      1020802.
   BAR                 ID22463
 PER SPEC.                                  R M       4.00 UNITS        3.47      13.88    1.00    0.00    0.00        13.88     .24
 COST BASIS= WT. TIMES DOLLARS/LB.
 SOURCE: MDAC

      1020901.
   BRACES              ID22470-1
 LENGTH=78 IN.,TOTAL WT=62.7 LBS.           R M       8.00 UNITS        1.11       8.88    1.00    0.00    0.00         8.88     .16
 COST BASIS= WT. TIMES DOLLARS/LB.
 SOURCE: MDAC ($ .39/LB.)

        10221.
   INSPECTION          D3
 INSPECTION BY FLOOR INSPECTOR              LBR        .02  HRS         9.64        .19    1.00    5.96    1.26         1.40     .02
 CREW SIZE = 1
                       SOURCE: GM

        10222.
   MAT'L HANDLING      D4
 HANDLING WITH WALKING BEAM TRANS-          LBR        .04  HRS         9.64        .34    1.00    5.96    1.26         2.58     .05
 FER MECHANISM
 MANUAL LOADING
 AUTOMATIC UNLOADING WITH POWER AND
 FREE O'HEAD CONVEYOR
                       SOURCE: GM


   MIRROR BACK STRU    4412                                                                                        474.     8.33
1
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SECOND GENERATION HELIOSTAT 50K/YR.                                                        13.11.34.       DATE 02/09/81

   ASSY-REFLECTIVE UN  4413

DESCRIPTION                                 QTY/HRS/      REF UNIT  SUB TOTAL     F A C T O R S        TOTAL
                                           ANN. FAIL        COST               CRC  OVERHEAD  G_A               $/SM

        10301.
   REFL. PANEL ASSY.   44131
 DRIVE STUDS AND NUTS WITH           LBR       .28  HRS        9.64      2.70  1.00   5.96    1.26      20.40    .36
 AIR WRENCH HEADS AND MANIFOLDED
 BOWL FEEDERS
 CREW SIZE = 4
                        SOURCE: GM

        10302.
   STUD                ID22778-501
 PER SPEC.                           R M     56.00 UNITS        .49     27.20  1.00   0.00    0.00      27.20    .48
 SOURCE: MDAC PROCUREMENT EST.

        10303.
   SHOULDER WASHER     ID22591
 PER SPEC.                           P P     28.00 UNITS        .07      2.01  1.00   0.00    0.00       2.01    .04
 SOURCE: MDAC PROCUREMENT EST.

        10304.
   SHOULDER WASHER     ID22591
 PER SPEC.                           P P     28.00 UNITS        .06      1.76  1.00   0.00    0.00       1.76    .03
 SOURCE: MDAC PROCUREMENT EST.

        10305.
   FLANGENUT           21SFF51618
 PER SPEC.                           P P     56.00 UNITS        .03      1.68  1.00   0.00    0.00       1.68    .03
 SOURCE: MACLEAN-FOG

        10306.
   HEXNUT              .312-18
 ZINC-PLATED                         P P     56.00 UNITS        .05      2.86  1.00   0.00    0.00       2.86    .05
 SOURCE: MDAC PROCUREMENT EST.

        10321.
   INSPECTION          D5
 FLOOR INSPECTION,UNLOADING WITH     LBR       .14  HRS        9.64      1.35  1.00   5.96    1.26      10.20    .18
 OVERHEAD CRANE
 CREW SIZE = 2
                         SOURCE: GM

        10322.
   MAT'L HANDLING      D6
 AUTOMATIC LOADING ON POWER ROLLER   LBR       .24  HRS        9.64      2.28  1.00   5.96    1.26      17.17    .30
 CONVEYOR,MONORAIL HOOKS
 CREW SIZE = 2
                    SOURCE: GM


   ASSY-REFLECTIVE UN  4413                                                                             83.     1.46
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SECOND GENERATION HELIOSTAT 50K/YR.                                                  13.11.34.        DATE 02/09/81

   AZIMUTH           4421

DESCRIPTION                                       QTY/HRS/       REF UNIT  SUB TOTAL     F A C T O R S        TOTAL
                                                 ANN. FAIL         COST                 CRC  OVERHEAD  G_A               $/SM

      2010101.
   MECHANICAL             442111
 ASSEMBLE USING ASSY MACHINE,         LBR          .99  HRS         9.64       9.51   1.00    5.96    1.26      71.71   1.26
 JIB HOISTS,PNEUMATIC WRENCHES,
 AUTO GAGE AND SHIM SELECTION,
 BEARING PRESS,BOWL FEEDERS
 CREW SIZE = 8
                     SOURCE: GM

      2010102.
   PAINT                  442112
 SPRAY PRIME,PAINT AND CURE DR ASSY   LBR          .12  HRS         9.64       1.15   1.00    5.96    1.26       8.66    .15
 WITH BINKS PRIME AND PAINT SPRAY
 LINE-SPECIAL
 CREW SIZE = 2
                     SOURCE: GM

      2010103.
   ELECT. ASSY.           442113
 ELECTRICAL ASSY OF AZ/EL DR ASSY     LBR          .22  HRS         9.64       2.14   1.00    5.96    1.26      16.10    .28
 WITH 9 STATION MONORAIL ASSY MACH
 CREW SIZE = 4
                    SOURCE: GM

    201012101.
   MECH ASSY.             44211211
 INSPECTION BY FLOOR INSPECTOR        LBR          .07  HRS         9.64        .68   1.00    5.96    1.26       5.15    .09
                     SOURCE: GM

    201012102.
   PAINT                  44211212
 INSPECTION BY FLOOR INSPECTOR        LBR          .04  HRS         9.64        .34   1.00    5.96    1.26       2.58    .05
                     SOURCE: GM

    201012103.
   ELECT. ASSY.           44211213
 INSPECTION BY FLOOR INSPECTOR        LBR          .06  HRS         9.64        .53   1.00    5.96    1.26       4.03    .07
                    SOURCE: GM

    201012201.
   MECH. ASSY.            44211221
 HANDLING BY MONORAILS                LBR          .07  HRS         9.64        .68   1.00    5.96    1.26       5.15    .09
                     SOURCE: GM

    201012202.
   PAINT                  44211222
 HANDLING WITH MONORAILS              LBR          .07  HRS         9.64        .70   1.00    5.96    1.26       5.31    .09
                    SOURCE: GM
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SECOND GENERATION HELIOSTAT 50K/YR. 13.11.34. DATE 02/09/81

AZIMUTH 4421

DESCRIPTION		QTY/HRS/ ANN. FAIL	REF UNIT COST	SUB TOTAL	FACTORS			TOTAL	$/SM
					CRC	OVERHEAD	G_A		
201012203. ELECT. ASSY 44211223 HANDLING WITH OVERHEAD MONORAILS SOURCE: GM	LBR	.06 HRS	9.64	.53	1.00	5.96	1.26	4.03	.07
2010202. WAVE GEN PLUG AZDR1 PER SPEC. SOURCE: LAMB	P P	1.00 UNITS	5.98	5.98	1.00	0.00	0.00	5.98	.11
201020201. MACHINE 4421221 TURN, FACE, BORE, CHAMF, CUT OFF WITH: NAT'L ACME MODEL SST-10-5/8 LATHE. GRIND BOTH SIDES WITH BLANCHARD GRINDER MODEL 26 HD BROACH KEYWAY WITH MITTS AND MERRILL KEYSEATER PROFILE GRIND O.D. WITH LANDIS POLYGON GRINDER CREW SIZE = 3.25 SOURCE: GM	LBR	.19 HRS	9.64	1.84	1.00	5.96	1.26	13.90	.24
201020221. INSPECTION 44212221 INSPECTION DONE BY FLOOR INSPECTOR SOURCE: GM	LBR	.02 HRS	9.64	.17	1.00	5.96	1.26	1.29	.02
201020222. MAT'L HANDLING 44212222 MAT'L HANDLING WITH LT. CONVEYORS SOURCE: GM	LBR	.02 HRS	9.64	.21	1.00	5.96	1.26	1.61	.03
2010203. WAVE GEN BEARING AZDR2 PER SPEC. SOURCE: LAMB	P P	1.00 UNITS	74.67	74.67	1.00	0.00	0.00	74.67	1.31
2010204. FLEX SPLINE AZDR3 PER SPEC. SOURCE: LAMB	P P	1.00 UNITS	9.67	9.67	1.00	0.00	0.00	9.67	.17

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   AZIMUTH            4421

DESCRIPTION                                   QTY/HRS/      REF UNIT   SUB TOTAL     F A C T O R S         TOTAL
                                             ANN. FAIL        COST                 CRC  OVERHEAD  G_A                $/SM

    201020401.
   MACHINE            4421241
  HONE I.D. WITH                      LBR        .06  HRS       9.64        .60   1.00    5.96    1.26        4.54     .08
   MICROMATIC HONE MODEL 10 VH
  BROACH FLEX SPLINE TEETH WITH
   APEX BROACH MACH. CAP.
  PART WASH IN SPRAY BOOTH
  CREW SIZE = 1
                      SOURCE: GM

    201020421.
   INSPECTION         44212421
  MASTER GAGE INSPECTION              LBR        .01  HRS       9.64        .09   1.00    5.96    1.26         .64     .01
                      SOURCE: GM

    201020422.
   MAT'L HANDLING     44212422
  MAT'L HANDLING WITH GONDOLAS, AND   LBR        .03  HRS       9.64        .26   1.00    5.96    1.26        1.93     .03
  LT CONVEYORS
                        SOURCE: GM

      2010205.
   CIRCULAR SPLINE    AZDR4
  PER SPEC.                           P P       1.00 UNITS     33.18      33.18   1.00    0.00    0.00       33.18     .58
  SOURCE: LAMB

    201020501.
   MACHINE            4421251
  TURN,FACE,BORE,CHAMF WITH 2 BULL-   LBR        .36  HRS       9.64       3.50   1.00    5.96    1.26       26.42     .46
  ARD TEMPLA TURN VERT.TURRET LATHES
  BLANCHARD GRIND TO THICKNESS WITH
   BLANCHARD GRINDER MODEL 26HD
  GRIND O.D.BEARING RACE CONTOUR
   WITH LANDIS MODEL 4R GRINDER
  DRILL AND TAP HOLES WITH 2 BUHR
   N.C. MACHINES
  BROACH SPLINE TEETH WITH
   APEX BROACH MACH.CAP.
  CREW SIZE = 4
                       SOURCE: GM

    201020521.
   INSPECTION         44212521
  INSPECTION DONE BY FLOOR INSPECTOR  LBR        .03  HRS       9.64        .26   1.00    5.96    1.26        1.93     .03
                      SOURCE: GM
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SECOND GENERATION HELIOSTAT 50K/YR. 13.11.34. DATE 02/09/81

AZIMUTH 4421

DESCRIPTION		QTY/HRS/ ANN. FAIL	REF UNIT COST	SUB TOTAL	F A C T O R S CRC	OVERHEAD	G_A	TOTAL	$/SM
201020522. MAT'L HANDLING 44212522 MAT'L HANDLING WITH GONDOLAS AND LIGHT CONVEYORS SOURCE: GM	LBR	.08 HRS	9.64	.77	1.00	5.96	1.26	5.80	.10
2010206. DIAPHRAM HUB AZDR5 PER SPEC. SOURCE: LAMB	P P	1.00 UNITS	.71	.71	1.00	0.00	0.00	.71	.01
20103. BEARING KIT-TUR ID22490-1 SOURCE: G.M. (MDAC ENG. COST ADJ.)	P P	1.00 UNITS	18.31	18.31	1.00	0.00	0.00	18.31	.32
20104. LUBE PAN ID22442-1 PER SPEC., WT.= .5 LBS. SOURCE: MDAC	P P	1.00 UNITS	3.32	3.32	1.00	0.00	0.00	3.32	.06
20105. TUBE ASSEMBLY ID22593-1 PER SPEC. SOURCE: MDAC	P P	1.00 UNITS	3.99	3.99	1.00	0.00	0.00	3.99	.07
2010602. GEAR-HELICON ID22486-1 PER SPEC., WT. = 5.57 LBS. SOURCE: MDAC	P P	1.00 UNITS	12.02	12.02	1.00	0.00	0.00	12.02	.21
2010603. S.TRRT BEARING ID22443-1 PER SPEC., WT. = 1.13 LBS. SOURCE: MDAC	P P	1.00 UNITS	1.44	1.44	1.00	0.00	0.00	1.44	.03
2010604. S.HELICON GEAR ID22485-1 PER SPEC., WT. = .01 LBS. SOURCE: MDAC	P P	4.00 UNITS	.16	.65	1.00	0.00	0.00	.65	.01
2010605. P.B. RETAINER ID22482-1 MACHINE LABOR AND MAT'L HANDLING, FLOOR INSPECTION SOURCE: GM	R M	1.00 UNITS	.52	.52	1.00	0.00	0.00	.52	.01

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SECOND GENERATION HELIOSTAT 50K/YR.                                                     13.11.34.        DATE 02/09/81

   AZIMUTH            4421

DESCRIPTION                                      QTY/HRS/      REF UNIT  SUB TOTAL     F A C T O R S        TOTAL
                                                ANN. FAIL        COST                 CRC  OVERHEAD  G_A                $/SM

    201060501.
   PAINT                  4421651
  SPRAY TECTYL INSIDE COVER AND OUT-  LBR          .06  HRS         9.64        .56   1.00   5.96     1.26       4.23     .07
  LIDE RETAINER WITH BINKS SPINDLE
  MACHINE
  CREW SIZE = 1
                       SOURCE: GM

    201060521.
   INSPECTION             44216521
  INSPECTION DONE BY FLOOR INSPECTOR  LBR          .02  HRS         9.64        .17   1.00   5.96     1.26       1.29     .02
                       SOURCE: GM

    201060522.
   MAT'L HANDLING         44216522
  HANDLING WITH MONORAIL TROLLEYS,    LBR          .03  HRS         9.64        .26   1.00   5.96     1.26       1.93     .03
  HOOKS AND HOISTS
                       SOURCE: GM

      2010606.
   SHAFT-H.D.I.           ID22495-1
  MACHINE LABOR AND MAT'L HANDLING,   P P         1.00 UNITS        4.37       4.37   1.00   0.00     0.00       4.37     .08
  FLOOR INSPECTION
                       SOURCE: GM

    201060601.
   MACHINE                4421661
  CUT STOCK INTO SLUGS WITH MARVEL    LBR          .07  HRS         9.64        .71   1.00   5.96     1.26       5.38     .09
  9A HACK SAW
  MACHINE ENDS,TURN AND THREAD SLUGS
  WITH MILES FOUR STATION TRUNNION
  MACHINE
  GRIND BEARING AND WAVE GENERATOR
  PILOT DIAMETERS WITH
  LANDIS #2R GRINDER
  MILL 4 KEYWAYS WITH MILES SINGLE
  PURPOSE DOUBLE END MACHINE
  CREW SIZE = 1
                      SOURCE: GM

    201060621.
   INSPECTION             44216621
  INSPECTION DONE BY FLOOR INSPECTOR  LBR          .02  HRS         9.64        .17   1.00   5.96     1.26       1.29     .02
                      SOURCE: GM
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SECOND GENERATION HELIOSTAT 50K/YR.                                                   13.11.34.        DATE 02/09/81

  AZIMUTH           4421

DESCRIPTION                                       QTY/HRS/       REF UNIT  SUB TOTAL      F A C T O R S        TOTAL
                                                 ANN. FAIL        COST               CRC  OVERHEAD  G_A                  $/SM

    201060622.
  MAT'L HANDLING       44216622
 MAT'L HANDLING WITH TOTE PANS AND    LBR          .03  HRS         9.64       .26   1.00    5.96    1.26        1.93     .03
 LIGHT CONVEYORS
                          SOURCE: GM

      2010607.
  RETAINER-T.B.        ID22489-1
 MACHINE LABOR AND MAT'L HANDLING,    P P         1.00 UNITS       17.86     17.86   1.00    0.00    0.00       17.86     .31
 FLOOR INSPECTION
                         SOURCE: GM

    201060701.
  MACHINE              4421671
 MACHINE SIDES OF RINGS WITH BLANCH-  LBR          .13  HRS         9.64      1.23   1.00    5.96    1.26        9.31     .16
 ARD
 TURN I.D. BEARING RACE CONTOUR AND
 'O' RING GROOVES WITH BULLARD
 TEMPLA TURN VERT. TURRET LATHE
 DRILL HOLES WITH
  LAMB 4 STATION DIAL MACHINE
 CREW SIZE = 1.25
                        SOURCE: GM

    201060721.
  INSPECTION           44216721
 INSPECTION BY FLOOR INSPECTOR        LBR          .03  HRS         9.64       .26   1.00    5.96    1.26        1.93     .03
                          SOURCE: GM

    201060722.
  MAT'L HANDLING       44216722
 MAT'L HANDLING WITH GONDOLAS AND     LBR          .05  HRS         9.64       .47   1.00    5.96    1.26        3.54     .06
 LIGHT CONVEYORS
                          SOURCE: GM

      2010608.
  BRACKET-MAGNET.AZ.   ID22424-1
 PER SPEC., COST BASIS= WT. TIMES     R M         1.00 UNITS        1.10      1.10   1.00    0.00    0.00        1.10     .02
 DOLLARS PER LB.
 SOURCE: MDAC

      2010609.
  SPACER-SHAFT SEAL    ID22449-1
 PER SPEC., COST BASIS= WT. TIMES     R M         1.00 UNITS         .69       .69   1.00    0.00    0.00         .69     .01
 DOLLARS PER LB.
 SOURCE: MDAC
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AZIMUTH 4421

DESCRIPTION		QTY/HRS/ ANN. FAIL	REF UNIT COST	SUB TOTAL	FACTORS CRC	OVERHEAD	G_A	TOTAL	$/SM
2010610. BUSHING-G.D.S. ID22481-1 PER SPEC., COST BASIS= WT. TIMES DOLLARS PER LB. SOURCE: MDAC	R M	1.00 UNITS	.50	.50	1.00	0.00	0.00	.50	.01
2010611. F.B.FLEX SPLINE ID22422-1 PER SPEC., COST BASIS= WT. TIMES DOLLARS PER LB. SOURCE: MDAC	P P	1.00 UNITS	4.89	4.89	1.00	0.00	0.00	4.89	.09
2010612. BRACKET-ELEC. AZ. ID22411-501 PER SPEC. SOURCE: MDAC	P P	1.00 UNITS	.10	.10	1.00	0.00	0.00	.10	.00
20106130101. MACHINE HOUSING 442161311 QUALIFY LOC. DIA. AND FACE 2 MOUNTING SURFACES WITH BULLARD TEMPLA-TURN VERT.TURRET LATHE PLUNGE FACE,BORE,TAP DRILL AND TAP WITH LAMB 9-STA. SHUTTLE MACHINE DOUBLE END PART WASH TAP DRILL AND TAP WITH LAMB 6-STA. SHUTTLE CREW SIZE = 3 SOURCE: GM	LBR	.22 HRS	9.64	2.15	1.00	5.96	1.26	16.24	.29
20106130102. WELD HOUSING 442161312 DOLLAR WELD MACHINE USED TO WELD: 1-BEARING SLEEVE TO LOWER HOUSING 2-MOUNTING RING TO LOWER HOUSING 3-(PLUG WELD)LOWER HOUSING AND INNER ASSY 4-HOUSING EXTENSION TO LOWER HOUSING SUB-ASSY 5-MOTOR MOUNTING PLATE TO HOUSING SUB ASSY 6-UPPER AND LOWER FILLER STAMPINGS CREW SIZE = 4.5 SOURCE: GM	LBR	.14 HRS	9.64	1.31	1.00	5.96	1.26	9.91	.17
201061302. MOUNT ID22474 PER SPEC.	P P	1.00 UNITS	1.31	1.31	1.00	0.00	0.00	1.31	.02

AZIMUTH 4421

DESCRIPTION			QTY/HRS/ ANN. FAIL		REF UNIT COST	SUB TOTAL	FACTORS			TOTAL	$/SM
							CRC	OVERHEAD	G_A		
201061303. TUBE PER SPEC.	ID22474	P P	1.00	UNITS	2.68	2.68	1.00	0.00	0.00	2.68	.05
201061304. TUBE PER SPEC.	ID22474	P P	1.00	UNITS	7.63	7.63	1.00	0.00	0.00	7.63	.13
201061305. SHELL PER SPEC.	ID22474	P P	1.00	UNITS	6.66	6.66	1.00	0.00	0.00	6.66	.12
201061306. RETAINER PER SPEC.	ID22474	P P	1.00	UNITS	11.45	11.45	1.00	0.00	0.00	11.45	.20
20106132101. MACHING INSPECTION BY FLOOR INSPECTOR SOURCE: GM	4421613211	LBR	.02	HRS	9.64	.17	1.00	5.96	1.26	1.29	.02
20106132102. WELDING INSPECTION BY FLOOR INSPECTOR SOURCE: GM	4421613212	LBR	.03	HRS	9.64	.30	1.00	5.96	1.26	2.25	.04
20106132201. MACHINING HANDLING WITH MONORAIL HOISTS, TROLLEYS, AND HOOKS SOURCE: GM	4421613221	LBR	.02	HRS	9.64	.17	1.00	5.96	1.26	1.29	.02
20106132202. WELDING HANDLING WITH GONDOLAS,MONORAIL TROLLEYS,HOOKS,AND HOISTS SOURCE: GM	4421613222	LBR	.02	HRS	9.64	.22	1.00	5.96	1.26	1.67	.03
2010614. AZ. DR. COVER PER SPEC. SOURCE: LAMB	ID22129	P P	1.00	UNITS	6.07	6.07	1.00	0.00	0.00	6.07	.11
2010615. BEARING PER SPEC. SOURCE: TRW-MARLIN ROCKWELL DIV.	106-KSZZ	P P	1.00	UNITS	.73	.73	1.00	0.00	0.00	.73	.01

AZIMUTH 4421

DESCRIPTION			QTY/HRS/ ANN. FAIL	REF UNIT COST	SUB TOTAL	FACTORS CRC	OVERHEAD	G_A	TOTAL	$/SM
2010616. SEAL PER SPEC. SOURCE: PARKER SEAL CO.	2-133V747-75	P P	1.00 UNITS	.23	.23	1.00	0.00	0.00	.23	.00
2010617. SEAL PER SPEC. SOURCE: PARKER SEAL CO.	2-275V747-75	P P	1.00 UNITS	.58	.58	1.00	0.00	0.00	.58	.01
2010618. SEAL PER SPEC. SOURCE: PARKER SEAL CO.	2-386V747-75	P P	1.00 UNITS	.44	.44	1.00	0.00	0.00	.44	.01
2010619. SEAL PER SPEC. SOURCE: PARKER SEAL CO.	2-459V747-75	P P	1.00 UNITS	.44	.44	1.00	0.00	0.00	.44	.01
2010620. SEAL PER SPEC. SOURCE: BAL-SEAL ENG. CO.	506-325G	P P	2.00 UNITS	.88	1.76	1.00	0.00	0.00	1.76	.03
2010621. VITON SEAL PER SPEC. SOURCE: JOHNS-MANSVILLE	9651	P P	1.00 UNITS	.88	.88	1.00	0.00	0.00	.88	.02
2010622. NUT PER SPEC.	N-06	P P	1.00 UNITS	.60	.60	1.00	0.00	0.00	.60	.01
2010623. NUT PER SPEC., AFBA STD SOURCE: MDAC PROCUREMENT EST.	N-08	P P	1.00 UNITS	.60	.60	1.00	0.00	0.00	.60	.01
2010624. WASHER PER SPEC., AFBA STD SOURECL MDAC PROCUREMENT EST.	W-06	P P	1.00 UNITS	.21	.21	1.00	0.00	0.00	.21	.00
2010625. WASHER PER SPEC., AFBA STD SOURCE: MDAC PROCUREMENT EST.	W-08	P P	1.00 UNITS	.21	.21	1.00	0.00	0.00	.21	.00

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SECOND GENERATION HELIOSTAT 50K/YR.                                                        13.11.34.         DATE 02/09/81

   AZIMUTH             4421

DESCRIPTION                                 QTY/HRS/       REF UNIT  SUB TOTAL     F A C T O R S        TOTAL
                                           ANN. FAIL         COST               CRC  OVERHEAD  G_A               $/SM

      2010626.
   KEY                 NAS558-606-24
 PER SPEC.                           P P      1.00 UNITS        .04       .04   1.00   0.00    0.00         .04   .00
 SOURCE: LAMB

      2010627.
   KEY                 NAS558-1212-15
 PER SPEC.                           P P      1.00 UNITS        .04       .04   1.00   0.00    0.00         .04   .00
 SOURCE: LAMB

      2010628.
   EXPANSION CHAMBER   1010-104000
 PER SPEC., COST BASIS= MDAC         P P      2.00 UNITS       2.34      4.68   1.00   0.00    0.00        4.68   .08
 PROCUREMENT EST.
 SOURCE: GITS BROS. MFG.

      2010629.
   MAGNET              M2
 PER SPEC., CRC ADJUSTED             P P      1.00 UNITS        .14       .14   1.00   0.00    0.00         .14   .00
 SOURCE: KESSLER-ELLIS PROD.

      2010630.
   WASHER              AN970-3
 PER SPEC.                           P P      3.00 UNITS        .01       .04   1.00   0.00    0.00         .04   .00
 SOURCE: LAMB

      2010631.
   RND.HEAD SCREW      .190-32UNF-2AX.3
 PER SPEC.                           P P      4.00 UNITS        .00       .01   1.00   0.00    0.00         .01   .00
 SOURCE: LAMB

      2010632.
   RND.HEAD SCREW      .190-32UNF-2AX.5
 PER SPEC.                           P P     15.00 UNITS        .00       .05   1.00   0.00    0.00         .05   .00
 SOURCE: LAMB

      2010633.
   FLT.HD.BRASS SCREW  .190-32UNF-2AX.8
 PER SPEC.                           P P      1.00 UNITS        .02       .02   1.00   0.00    0.00         .02   .00
 SOURCE: LAMB

      2010634.
   SPLT LK. WASHER     .190
 PER SPEC.                           P P     20.00 UNITS        .01       .29   1.00   0.00    0.00         .29   .01
 SOURCE: LAMB
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SECOND GENERATION HELIOSTAT 50K/YR.                                         13.11.34.        DATE 02/09/81

   AZIMUTH             4421

DESCRIPTION                                        QTY/HRS/       REF UNIT  SUB TOTAL      F A C T O R S        TOTAL
                                                  ANN. FAIL        COST                 CRC  OVERHEAD  G_A                $/SM

      2010635.
   HEXNUT              .190-32UNF-2B
 PER SPEC.                            P P     2.00 UNITS        .00        .01    1.00    0.00     0.00        .01     .00
 SOURCE: LAMB

      2010636.
   HEX CAP SCREW       .250-20UNC-2AX.6
 PER SPEC.                            P P     8.00 UNITS        .01        .07    1.00    0.00     0.00        .07     .00
 SOURCE: LAMB

      2010637.
   HEX CAP SCREW       .250-20UNC-2AX.7
 PER SPEC.                            P P     4.00 UNITS        .01        .04    1.00    0.00     0.00        .04     .00
 SOURCE: LAMB

      2010638.
   SPLT LK. WASHER     .250
 PER SPEC.                            P P    12.00 UNITS        .00        .03    1.00    0.00     0.00        .03     .00
 SOURCE: LAMB

      2010639.
   HEX CAP SCREW       .375-24UNF-2AX1.
 PER SPEC., GRADE B, ZINC-PLATED      P P    16.00 UNITS        .04        .56    1.00    0.00     0.00        .56     .01
 SOURCE: MDAC PROCUREMENT EST.

      2010640.
   SPLT LK. WASHER     .375
 PER SPEC., ZINC PLATED               P P    16.00 UNITS        .01        .10    1.00    0.00     0.00        .10     .00
 SOURCE: LAMB

      2010641.
   BRACKET             TA4064E0610
 PER SPEC.,COST BASIS=MDAC PROCUREMENP P      1.00 UNITS        .06        .06    1.00    0.00     0.00        .06     .00
 EST.
 SOURCE: TA MFG. CORP.

      2010642.
   PLUG                1/8-27ANPT
 PER SPEC., INTERNAL WRENCHING        P P     1.00 UNITS        .06        .06    1.00    0.00     0.00        .06     .00
 SOURCE: MDAC PROCUREMENT EST.

      2010643.
   PLUG                3/8-18ANPT
 PER SPEC., INTERNAL WRENCHING        P P     2.00 UNITS        .12        .23    1.00    0.00     0.00        .23     .00
 SOURCE: MDAC PROCURENENT EST.
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SECOND GENERATION HELIOSTAT 50K/YR.                                                    13.11.34.      DATE 02/09/81

   AZIMUTH            4421

DESCRIPTION                                             QTY/HRS/      REF UNIT   SUB TOTAL      F A C T O R S         TOTAL
                                                       ANN. FAIL       COST                 CRC  OVERHEAD  G_A              $/SM

      2010644.
   CLAMP              ST253C6
 PER SPEC.                               P P       1.00 UNITS          .09         .09   1.00    0.00     0.00       .09    .00
 SOURCE: MDAC PROCUREMENT EST.

      2010645.
   TAPE               DPM2766
 PER SPEC.,1/2 X 13.2, ANTISEIZE         P P       1.00 UNITS          .04         .04   1.00    0.00     0.00       .04    .00
 SOURCE: MDAC PROCUREMENT EST.

      2010646.
   PLASTIC GASKET     DPM5793
 PER SPEC., LOCTITE(549-41)              R M       1.00 UNITS          .22         .22   1.00    0.00     0.00       .22    .00
 SOURCE: MDAC PROCUREMENT EST.

      2010647.
   ADHESIVE           DPM3279
 PER SPEC.                               R M       1.00 UNITS          .11         .11   1.00    0.00     0.00       .11    .00
 SOURCE: MDAC PROCUREMENT EST.

      2010648.
   GEAR OIL           MOBILE626
 FILL AZ DRIVE HOUSING WITH MOBIL        P P       2.00 UNITS          .50        1.00   1.00    0.00     0.00      1.00    .02
     626 OIL THROUGH THE MOUNTING
 HOLE OF THE UPPER EXPANSION CHAMBER
 UNTIL OIL LEVEL RISES TO APPROX
 .25 INCH ABOVE GENERATOR
 UPPER SURFACE (1/2 GAL),EXPANSION
 CHAMBER IS THEN REPLACED.
                      SOURCE: GM

      2010649.
   GREASE             ALUANIAEJP2
 PER SPEC.                               P P       1.00 UNITS         1.40        1.40   1.00    0.00     0.00      1.40    .02
 SOURCE: LAMB

      2010650.
   BRACKET-ELEC.AZ.   ID22411-1
 PER SPEC., COST BASIS= WT. TIMES        P P       1.00 UNITS          .10         .10   1.00    0.00     0.00       .10    .00
 DOLLARS PER LB.
 SOURCE: MDAC ENG. EST.

    201070201.
   CONN SW TO PIN     4421721
 MANUALLY ASSEMBLE LEADS TO JACKS,       LBR        .01  HRS          9.64         .09   1.00    5.96     1.26       .67    .01
 APPLY GROMMET AND SHRINK TUBING
 CREW SIZE = 1
                     SOURCE: GM
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AZIMUTH 4421

DESCRIPTION		QTY/HRS/ ANN. FAIL	REF UNIT COST	SUB TOTAL	FACTORS CRC	OVERHEAD	G_A	TOTAL	$/SM
201070202. CONTACT-PIN 110238-0040 PER SPEC., CRC ADJUSTED SOURCE: ITT CANNON	R M	1.00 UNITS	.04	.04	1.00	0.00	0.00	.04	.00
201070203. CONTACT-SOCKET 11238-0085 PER SPEC. SOURCE: MDAC PROCUREMENT EST.	P P	1.00 UNITS	.07	.07	1.00	0.00	0.00	.07	.00
201070204. TUBING STM0069-13-A6-02 PER SPEC. SOURCE: MDAC PROCUREMENT EST.	R M	1.00 UNITS	.36	.36	1.00	0.00	0.00	.36	.01
201070205. TUBING DPM2617-15 PER SPEC. SOURCE: MDAC PROCUREMENT EST.	R M	1.00 UNITS	.09	.09	1.00	0.00	0.00	.09	.00
201070206. PROXIMITY SWITCH LC2P-1839-1A-60 PER SPEC., CRC ADJUSTED SOURCE: MDAC PROCUREMENT EST.	P P	1.00 UNITS	.55	.55	1.00	0.00	0.00	.55	.01
201070207. CONNECTOR 120-1807-000 PER SPEC. SOURCE: ITT CANNON	P P	1.00 UNITS	.33	.33	1.00	0.00	0.00	.33	.01
201070301. CONN MAT TO PIN 4421731 MANUALLY ASSEMBLE MOTOR LEADS TO JACKS CREW SIZE = 1 SOURCE: GM	LBR	.02 HRS	9.64	.18	1.00	5.96	1.26	1.36	.02
201070302. SCREW NAS601-6P PER SPEC. SOURCE: LAMB	P P	1.00 UNITS	.02	.02	1.00	0.00	0.00	.02	.00
201070303. WASHER NAS620-10L PER SPEC. SOURCE: LAMB	P P	2.00 UNITS	.01	.02	1.00	0.00	0.00	.02	.00

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SECOND GENERATION HELIOSTAT 50K/YR.                                              13.11.34.       DATE 02/09/81

   AZIMUTH          4421

DESCRIPTION                                 QTY/HRS/      REF UNIT  SUB TOTAL    F A C T O R S        TOTAL
                                           ANN. FAIL       COST                 CRC  OVERHEAD  G_A                $/SM

    201070304.
   NUT              NAS671-10
  PER SPEC.                         P P      1.00 UNITS       .07       .07   1.00   0.00     0.00        .07     .00
  SOURCE: LAMB

    201070305.
   WASHER           MS35338-43
  PER SPEC.                         P P      1.00 UNITS       .00       .00   1.00   0.00     0.00        .00     .00
  SOURCE: LAMB

    201070306.
   RECEPTACLE       120-1806-000
  PER SPEC., CRC ADJUSTED           P P      1.00 UNITS       .33       .33   1.00   0.00     0.00        .33     .01
  SOURCE: ITT CANNON

    201070307.
   RECEPTACLE       120-1870-000
  PER SPEC., CRC ADJUSTED           P P      1.00 UNITS       .30       .30   1.00   0.00     0.00        .30     .01
  SOURCE: ITT CANNON

    201070308.
   GROMMET          351-1641-000
  PER SPEC., CRC ADJUSTED           P P      2.00 UNITS       .39       .79   1.00   0.00     0.00        .79     .01
  SOURCE: ITT CANNON

    201070309.
   GROMMET          351-1634-000
  PER SPEC., CRC ADJUSTED           P P      1.00 UNITS       .40       .40   1.00   0.00     0.00        .40     .01
  SOURCE: ITT CANNON

    201070310.
   RECEPTACLE       120-1805-000
  PER SPEC., CRC ADJUSTED           P P      1.00 UNITS       .33       .33   1.00   0.00     0.00        .33     .01
  SOURCE: ITT CANNON

    201070311.
   TUBING           STM0069-13-A6-02
  PER SPEC.                         P P      1.00 UNITS       .32       .32   1.00   0.00     0.00        .32     .01
  SOURCE: MDAC PROCUREMENT EST.

    201070312.
   CLAMP            MS21919WDG-6
  PER SPEC.                         P P      1.00 UNITS       .04       .04   1.00   0.00     0.00        .04     .00
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SECOND GENERATION HELIOSTAT 50K/YR. 13.11.34. DATE 02/09/81

AZIMUTH 4421

DESCRIPTION		QTY/HRS/ ANN. FAIL	REF UNIT COST	SUB TOTAL	F A C T O R S CRC	OVERHEAD	G_A	TOTAL	$/SM
20107040101. ASSY SENSOR 44217411 AUTOMATICALLY CUT WIRES TO LENGTH, STRIP,TERMINATE WITH ARTOS CS-9-AT MANUALLY ASSEMBLE WIRES TO PLUGS CREW SIZE = 2 SOURCE : GM	LBR	.02 HRS	9.64	.22	1.00	5.96	1.26	1.68	.03
20107040102. ASSY MAT. 44217412 AUTOMATICALLY CUT WIRES TO LENGTH, STRIP,TERMINATE WITH ARTOS CS-9-AT MANUALLY ASSEMBLE WIRES TO PLUGS CREW SIZE = 2 SOURCE: GM	LBR	.09 HRS	9.64	.89	1.00	5.96	1.26	6.73	.12
201070402. CONNECTOR 120-1869-000 PER SPEC/,CRC ADJUSTED SOURCE: ITT CANNON	P P	2.00 UNITS	.65	1.29	1.00	0.00	0.00	1.29	.02
201070403. CONNECTOR 120-1873-000 PER SPEC., CRC ADJUSTED SOURCE: ITT CANNON	P P	1.00 UNITS	.33	.33	1.00	0.00	0.00	.33	.01
201070404. CONNECTOR 120-1865-000 PER SPEC., CRC ADJUSTED SOURCE: ITT CANNON	P P	1.00 UNITS	.39	.39	1.00	0.00	0.00	.39	.01
201070405. CONNECTOR 120-1804-000 PER SPEC., CRC ADJUSTED SOURCE: ITT CANNON	P P	2.00 UNITS	.26	.52	1.00	0.00	0.00	.52	.01
201070406. CONNECTOR 120-1870-000 PER SPEC., CRC ADJUSTED SOURCE: ITT CANNON	P P	1.00 UNITS	.30	.30	1.00	0.00	0.00	.30	.01
201070407. CONTACT PIN 110238-0040 PER SPEC., CRC ADJUSTED SOURCE: ITT CANNON	P P	31.00 UNITS	.05	1.49	1.00	0.00	0.00	1.49	.03

AZIMUTH 4421

DESCRIPTION			QTY/HRS/ ANN. FAIL	REF UNIT COST	SUB TOTAL	FACTORS CRC	FACTORS OVERHEAD	FACTORS G_A	TOTAL	$/SM
201070408. CONTACT SOCKET PER SPEC., CRC ADJUSTED SOURCE: ITT CANNON	110238-0085	P P	27.00 UNITS	.05	1.45	1.00	0.00	0.00	1.45	.03
201070409. PLUG-FILLER PER SPEC., CRC ADJUSTED SOURCE: ITT CANNON	225-0072-000	P P	4.00 UNITS	.01	.04	1.00	0.00	0.00	.04	.00
201070410. GROMMET PER SPEC., CRC ADJUSTED SOURCE: ITT CANNON	351-1634-000	P P	2.00 UNITS	.40	.81	1.00	0.00	0.00	.81	.01
201070411. SPLICE PER SPEC. SOURCE: T & B	A1A	P P	4.00 UNITS	.12	.48	1.00	0.00	0.00	.48	.01
201070412. WIRE PER SPEC., #18AWG SOURCE: BELDEN	8918	R M	1.00 UNITS	10.70	10.70	1.00	0.00	0.00	10.70	.19
201070413. WIRE PER SPEC., #22-2SJ SOURCE: BELDEN	8451	R M	1.00 UNITS	13.78	13.78	1.00	0.00	0.00	13.78	.24
201070414. SHRINK TUBING PER SPEC. SOURCE: MDAC PROCUREMENT EST.	DPM2617-15	R M	1.00 UNITS	.06	.06	1.00	0.00	0.00	.06	.00
201070415. SHRINK TUBING PER SPEC. SOURCE: MDAC PROCUREMENT EST.	DPM2617-15	R M	1.00 UNITS	.06	.06	1.00	0.00	0.00	.06	.00
201070416. SHRINK TUBING PER SPEC. SOURCE: MDAC PROCUREMENT EST.	DPM2617-15	R M	1.00 UNITS	.06	.06	1.00	0.00	0.00	.06	.00
201070417. SHRINK TUBING PER SPEC. SOURCE: MDAC PROCUREMENT EST.	DPM2617-15	R M	1.00 UNITS	.20	.20	1.00	0.00	0.00	.20	.00

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SECOND GENERATION HELIOSTAT 50K/YR.                                                  13.11.34.         DATE 02/09/81

   AZIMUTH            4421

DESCRIPTION                                             QTY/HRS/       REF UNIT   SUB TOTAL      F A C T O R S          TOTAL
                                                       ANN. FAIL         COST                 CRC  OVERHEAD  G_A                 $/SM

    201070418.
   SHRINK TUBING        DPM2617-15
  PER SPEC.                                R M       1.00 UNITS          .20         .20   1.00    0.00     0.00          .20     .00
  SOURCE: MDAC PROCUREMENT EST.

    201070419.
   TUBING               STM0069-13-A6-02
  PER SPEC.                                R M       1.00 UNITS         2.52        2.52   1.00    0.00     0.00         2.52     .04
  SOURCE: MDAC PROCUREMENT EST.

    201070420.
   TUBING               DPM2517-15
  PER SPEC.                                R M       1.00 UNITS          .06         .06   1.00    0.00     0.00          .06     .00
  SOURCE: MDAC PROCUREMENT EST.

    201072101.
   SENSORS/CABLES       44217211
  AUTOMATIC INSPECTION:DITMICO TESTR       LBR        .01   HRS         9.64         .13   1.00    5.96     1.26          .97     .02
  AND FLOOR INSPECT.OF SENSOR CABLES
                        SOURCE: GM

    201072102.
   MAT./CABLE           44217212
  AUTOMATIC INSPECTION:DITMICO TESTR       LBR        .03   HRS         9.64         .26   1.00    5.96     1.26         1.93     .03
  AND FLOOR INSPECT.OF MOTOR CABLES
                      SOURCE: GM

    201072201.
   SUPPLY PARTS         44217221
  MANUALLY HANDLED SENSOR CABLES           LBR        .05   HRS         9.64         .53   1.00    5.96     1.26         3.99     .07
                      SOURCE: GM

    201072202.
   SUPPLY PARTS         44217222
  MANUALLY HANDLED MOTOR CABLES            LBR        .02   HRS         9.64         .24   1.00    5.96     1.26         1.80     .03
                     SOURCE: GM


   AZIMUTH            4421                                                                                        548.     9.64
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SECOND GENERATION HELIOSTAT 50K/YR.                                          13.11.34.        DATE 02/09/81

   ELEVATION          4422

DESCRIPTION                                    QTY/HRS/     REF UNIT  SUB TOTAL     F A C T O R S          TOTAL
                                              ANN. FAIL       COST                CRC  OVERHEAD  G_A                  $/SM

      2020102.
   BEARING-TFE LINED   ID22415-501
  PER SPEC.                           P P       1.00 UNITS       8.23       8.23   1.00    0.00    0.00        8.23     .14
  SOURCE: MDAC PROCUREMENT EST/

      2020103.
   BEARING             MS21230-16
  PER SPEC.                           P P       1.00 UNITS       7.89       7.89   1.00    0.00    0.00        7.89     .14
  SOURCE: MDAC PROCUREMENT EST.

      2020104.
   ELEV.DR. CASTING    ID22439-1
  PER SPEC.                           P P       1.00 UNITS     157.09     157.09   1.00    0.00    0.00      157.09    2.76
  SOURCE: LAMB

    202010401.
   MACHINE             4422141
  QUALIFY MTG.SURFACE AND LOCATING    LBR        .19  HRS        9.64       1.85   1.00    5.96    1.26       13.97     .25
  HOLES WITH LAMB 3 STA.SPEC.MACHINE
  MILL LUGS AND RIB,TAP,DRILL,SPOT-
  FACE WITH LAMB SHUTTLE MACHINE
  CREW SIZE = 2
                       SOURCE: GM

    202010421.
   INSPECTION          44221421
  INSPECTION BY FLOOR INSPECTOR       LBR        .03  HRS        9.64        .30   1.00    5.96    1.26        2.25     .04
                      SOURCE: GM

    202010422.
   MAT'L HANDLING      44221422
  MAT'L HANDLING WITH PALLETS,MONO-   LBR        .06  HRS        9.64        .56   1.00    5.96    1.26        4.19     .07
  RAIL CONVEYORS,TROLLEYS,HOOKS
                       SOURCE: GM

      2020202.
   JACK-ELEVATION      ID22497-1
  PER SPEC., SEALED MODULE WITH EXPANSP P       1.00 UNITS     266.04     266.04   1.00    0.00    0.00      266.04    4.68
  CHAMBER AND MAGNETIC SENSOR. HELICON
  REDUCTION RATIO = 106:1, WEIGHT =
  81 LBS..
  SOURCE: DUFF-NORTON

      2020203.
   WASHER              MS35338-41
  PER SPEC.                           P P       2.00 UNITS        .00        .00   1.00    0.00    0.00         .00     .00
  SOURCE: LAMB
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SECOND GENERATION HELIOSTAT 50K/YR.                                        13.11.34.      DATE 02/09/81

   ELEVATION          4422

DESCRIPTION                                   QTY/HRS/      REF UNIT   SUB TOTAL      F A C T O R S          TOTAL
                                             ANN. FAIL        COST                  CRC  OVERHEAD  G_A                  $/SM

      2020204.
   WASHER             NAS620-10L
 PER SPEC.                           P P        3.00 UNITS        .01        .04   1.00    0.00    0.00        .04     .00
 SOURCE: LAMB

      2020205.
   CLAMP              ST253C2
 PER SPEC.                           P P        2.00 UNITS        .22        .45   1.00    0.00    0.00        .45     .01
 SOURCE: MDAC PROCUREMENT EST.

      2020206.
   CLAMP              ST253C6
 PER SPEC.                           P P        1.00 UNITS        .09        .09   1.00    0.00    0.00        .09     .00
 SOURCE: MDAC PROCUREMENT EST.

      2020207.
   CLAMP              S0985C50D
 PER SPEC.                           P P        3.00 UNITS        .06        .17   1.00    0.00    0.00        .17     .00
 SOURCE: MDAC PROCUREMENT EST.

      2020208.
   CLAMP              S0985C60D
 PER SPEC.                           P P        2.00 UNITS        .06        .12   1.00    0.00    0.00        .12     .00
 SOURCE: MDAC PROCUREMENT EST.

      2020209.
   PLUG               120-1808-000
 PER SPEC.                           P P        1.00 UNITS        .33        .33   1.00    0.00    0.00        .33     .01
 SOURCE: MDAC PROCUREMENT EST.

      2020210.
   PLUG               120-1869-000
 PER SPEC/,CRC ADJUSTED              P P        1.00 UNITS        .33        .33   1.00    0.00    0.00        .33     .01
 SOURCE: ITT CANNON

      2020211.
   PIN                110238-0040
 PER SPEC., CRC ADJUSTED             P P        6.00 UNITS        .04        .22   1.00    0.00    0.00        .22     .00
 SOURCE: ITT CANNON

      2020213.
   SLEEVING           STM0069-13-A6-0
 PER SPEC.                           P P        1.00 UNITS        .32        .32   1.00    0.00    0.00        .32     .01
 SOURCE: MDAC PROCUREMENT EST.

      2020214.
   SHROUD             ID22595
 PER SPEC.                           P P        1.00 UNITS        .99        .99   1.00    0.00    0.00        .99     .02
 SOURCE: MDAC PROCUREMENT EST.
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ELEVATION 4422

DESCRIPTION		QTY/HRS/ ANN. FAIL	REF UNIT COST	SUB TOTAL	FACTORS CRC	OVERHEAD	G_A	TOTAL	$/SM
2020215. SHROUD ID22595 PER SPEC. SOURCE: MDAC PROCUREMENT EST.	P P	1.00 UNITS	.80	.80	1.00	0.00	0.00	.80	.01
2020216. SOCKET 110238-0085 PER SPEC., CRC ADJUSTED SOURCE: ITT CANNON	P P	7.00 UNITS	.06	.44	1.00	0.00	0.00	.44	.01
202030101. MACHINE BEAM 4422311 MILL ENDS,TAP DRILL AND TAP,DRILL, REAM WITH LAMB SHUTTLE MACHINE CREW SIZE = 3 SOURCE: GM	LBR	.21 HRS	9.64	2.02	1.00	5.96	1.26	15.22	.27
202030102. WELD BEAMS 4422312 WELD MAIN BEAM WITH DOLLAR WELD MACHINE CREW SIZE = 15 SOURCE: GM	LBR	.99 HRS	9.64	9.57	1.00	5.96	1.26	72.16	1.27
2020302. BODY ID22464-3 LEHGTH= 139 IN., COST BASIS =WT. TIMES DOLLARS/LB. SOURCE: MDAC	R M	2.00 UNITS	19.47	38.94	1.00	0.00	0.00	38.94	.68
2020303. WEB ID22464 PER SPEC. SOURCE: LAMB	R M	2.00 UNITS	2.63	5.26	1.00	0.00	0.00	5.26	.09
2020304. LUG ID22464 PER SPEC. SOURCE: LAMB	R M	2.00 UNITS	4.34	8.69	1.00	0.00	0.00	8.69	.15
2020305. LUG ID22464 PER SPEC. SOURCE: LAMB	R M	2.00 UNITS	2.41	4.81	1.00	0.00	0.00	4.81	.08
2020306. LUG ID22464 PER SPEC. SOURCE: LAMB	R M	2.00 UNITS	2.72	5.44	1.00	0.00	0.00	5.44	.10

ELEVATION 4422

DESCRIPTION			QTY/HRS/ ANN. FAIL	REF UNIT COST	SUB TOTAL	FACTORS CRC	OVERHEAD	G_A	TOTAL	$/SM
2020307. GUSSET PER SPEC. SOURCE: LAMB	ID22464	R M	2.00 UNITS	.84	1.69	1.00	0.00	0.00	1.69	.03
2020308. BAR PER SPEC. SOURCE: LAMB	ID22464	R M	4.00 UNITS	2.15	8.58	1.00	0.00	0.00	8.58	.15
2020309. PAD PER SPEC. SOURCE: LAMB	ID22464	R M	2.00 UNITS	1.97	3.95	1.00	0.00	0.00	3.95	.07
2020310. STIFFENER PER SPEC. SOURCE: LAMB	ID22464	R M	1.00 UNITS	.90	.90	1.00	0.00	0.00	.90	.02
2020311. STIFFENER PER SPEC. SOURCE: LAMB	ID22464	R M	1.00 UNITS	.47	.47	1.00	0.00	0.00	.47	.01
2020312. CHANNEL PER SPEC. SOURCE: LAMB	ID22464	R M	2.00 UNITS	1.08	2.15	1.00	0.00	0.00	2.15	.04
2020313. STIFFENER PER SPEC. SOURCE: LAMB	ID22464	R M	1.00 UNITS	.27	.27	1.00	0.00	0.00	.27	.00
2020314. BEARING-TFE LINED PER SPEC. SOURCE: LAMB	ID22415-1	P P	2.00 UNITS	4.04	8.08	1.00	0.00	0.00	8.08	.14
2020315. PIN PER SPEC. SOURCE: LAMB	ID22464	R M	4.00 UNITS	1.35	5.39	1.00	0.00	0.00	5.39	.09
202032101. MACHINING INSPECTION BY FLOOR INSPECTOR	44223211 SOURCE: GM	LBR	.02 HRS	9.64	.21	1.00	5.96	1.26	1.61	.03

ELEVATION 4422

DESCRIPTION			QTY/HRS/ ANN. FAIL		REF UNIT COST	SUB TOTAL	FACTORS CRC	OVERHEAD	G_A	TOTAL	$/SM
202032102. WELDING INSPECTION BY FLOOR INSPECTOR SOURCE: GM	44223212	LBR	.07	HRS	9.64	.68	1.00	5.96	1.26	5.15	.09
202032201. MACHINING HANDLING WITH MONORAIL CONVEYORS, HOISTS,TROLLEYS,AND HOOKS SOURCE: GM	44223221	LBR	.07	HRS	9.64	.68	1.00	5.96	1.26	5.15	.09
202032202. WELDING HANDLING WITH LT.MONORAILS, TROLLEYS,HOOKS,AND HOISTS SOURCE: GM	44223222	LBR	.07	HRS	9.64	.68	1.00	5.96	1.26	5.15	.09
ELEVATION	4422									663.	11.66

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SECOND GENERATION HELIOSTAT 50K/YR.                                                       13.11.34.         DATE 02/09/81

   MOTORS-TOTAL        4423

DESCRIPTION                                           QTY/HRS/       REF UNIT   SUB TOTAL       F A C T O R S          TOTAL
                                                     ANN. FAIL        COST                  CRC   OVERHEAD   G_A                  $/SM

        20302.
   AZIMUTH MOTOR       ID22487-501
 AC,1/4 HP,208V,60 CYCLE,3-PHASE     P P       1.00 UNITS      54.70       54.70   1.00    0.00      0.00        54.70     .96
 CRC ADJUSTED
 SOURCE: EMERSON ELECTRIC

        20303.
   ELEVATION MOTOR     ID22487-1
 AC,1/3 HP,208V,60 CYCLE,3-PHASE     P P       1.00 UNITS      54.70       54.70   1.00    0.00      0.00        54.70     .96
 CRC ADJUSTED
 SOURCE: EMERSON ELECTRIC


   MOTORS-TOTAL        4423                                                                                      109.      1.92
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POS/LIM INDICATOR 4424

DESCRIPTION		QTY/HRS/ ANN. FAIL	REF UNIT COST	SUB TOTAL	FACTORS CRC	FACTORS OVERHEAD	FACTORS G_A	TOTAL	$/SM
204020101. ENCODER 4424211 MANUALLY ASSEMBLE PLUG TO ENCODER COVER, THREAD LEADS AND CONNECTOR WIRES THROUGH PLUG AUTOMATICALLY INSERT TWO HALL SENSORS, RESISTORS, 1 LINE DRIVER, AND CAPACITOR ON 2-SIDED BOARD WITH SEMI-AUTOMATIC INSERTION MACHINE UNIVERSAL INSTRUMENTS CORP MANUALLY ASSEMBLE CONNECTOR WIRES TO BOARD AUTOMATICALLY TRIM/CRIMP WIRES TO BOARD WITH HOLLIS FLOW SOLDER MACH CREW SIZE = 8 SOURCE: GM	LBR	.11 HRS	9.64	1.01	1.00	5.96	1.26	7.65	.13
204020102. ENCODER LEADS 4424212 AUTOMATICALLY PREPARE WIRES WITH ARTOS WIRE CUTTER, STRIPPER, AND TERMINATOR CS-9-AT MANUALLY ASSEMBLE CREW SIZE = 2 SOURCE: GM	LBR	.03 HRS	9.64	.33	1.00	5.96	1.26	2.47	.04
204020103. ENCODER/CNTRL CABL 4424213 LABOR REQUIRED FOR ASSEMBLY OF ENCOD /CONTROL CABLE.	LBR	.04 HRS	9.64	.39	1.00	5.96	1.26	2.94	.05
2040202. CCA ENCODER ID22573-1 PER SPEC. SOURCE: G.M.	P P	2.00 UNITS	2.69	5.39	1.00	0.00	0.00	5.39	.09
204020302. PWB ENCODER ID22574-1 ENCODER PLASTIC WORKBOARD PER SPEC. SOURCE: MDAC PROCUREMENT EST.	P P	2.00 UNITS	.12	.24	1.00	0.00	0.00	.24	.00
204020303. CAPACITOR M39014-101-1513 PER SPEC. SOURCE: MDAC PROCUREMENT EST.	P P	2.00 UNITS	.34	.68	1.00	0.00	0.00	.68	.01

MCDONNELL DOUGLAS

SECOND GENERATION HELIOSTAT 50K/YR. 13.11.34. DATE 02/09/81

POS/LIM INDICATOR 4424

DESCRIPTION		QTY/HRS/ ANN. FAIL	REF UNIT COST	SUB TOTAL	FACTORS CRC	OVERHEAD	G_A	TOTAL	$/SM
204020304. RESISTOR RCR05G512JS PER SPEC. SOURCE: MDAC PROCUREMENT EST.	P P	4.00 UNITS	.05	.20	1.00	0.00	0.00	.20	.00
204020305. I.C. DM7830JB PER SPEC. SOURCE: MDAC PROCUREMENT EST.	P P	2.00 UNITS	3.99	7.98	1.00	0.00	0.00	7.98	.14
204020306. MICRO SWITCH 4AVIC-T1 PER SPEC. SOURCE: MICROSWITCH	P P	4.00 UNITS	.61	2.45	1.00	0.00	0.00	2.45	.04
204020307. SOLDER DMP3891 PER SPEC. SOURCE: MDAC PROCUREMENT EST.	R M	2.00 UNITS	.03	.06	1.00	0.00	0.00	.06	.00
204020308. INK CMP3627-37875 PER SPEC. SOURCE: MDAC PROCUREMENT EST.	R M	2.00 UNITS	.01	.02	1.00	0.00	0.00	.02	.00
204020309. WIRE #22-2SJ PER SPEC., #22-2SJ SOURCE: BELDEN	R M	2.00 UNITS	1.28	2.56	1.00	0.00	0.00	2.56	.05
204020310. SPLICE A1A PER SPEC. SOURCE: T & B	P P	2.00 UNITS	.06	.12	1.00	0.00	0.00	.12	.00
204020311. TUBING DPM2617-15 PER SPEC. SOURCE: MDAC PROCUREMENT EST.	R M	2.00 UNITS	.09	.18	1.00	0.00	0.00	.18	.00
2040204. GROMMET MS35489-122 PER SPEC. SOURCE: LAMB	P P	2.00 UNITS	.04	.09	1.00	0.00	0.00	.09	.00
2040205. PIN-CONTACTS 110238-0085 PER SPEC., CRC ADJUSTED SOURCE: ITT CANNON	R M	4.00 UNITS	.04	.16	1.00	0.00	0.00	.16	.00

POS/LIM INDICATOR 4424

DESCRIPTION			QTY/HRS/ ANN. FAIL	REF UNIT COST	SUB TOTAL	FACTORS CRC	OVERHEAD	G_A	TOTAL	$/SM
2040206. SOCKET CONTACTS PER SPEC., CRC ADJUSTED SOURCE: ITT CANNON	110238-0085	P P	10.00 UNITS	.06	.63	1.00	0.00	0.00	.63	.01
2040207. SPACER PER SPEC. SOURCE: LAMB	NAS43DD-3-20	P P	2.00 UNITS	.04	.09	1.00	0.00	0.00	.09	.00
2040208. CLAMP PER SPEC. SOURCE: LAMB	NAS1715-D5T	P P	2.00 UNITS	.07	.14	1.00	0.00	0.00	.14	.00
2040209. SCREW PER SPEC. SOURCE: LAMB	NAS601-10P	P P	2.00 UNITS	.02	.04	1.00	0.00	0.00	.04	.00
2040210. WASHER PER SPEC. SOURCE: LAMB	NAS620-6	P P	2.00 UNITS	.01	.02	1.00	0.00	0.00	.02	.00
2040211. SCREW PER SPEC. SOURCE: LAMB	MS24693-C28	P P	4.00 UNITS	.03	.11	1.00	0.00	0.00	.11	.00
2040212. VANE .0359" X 3" X 3.3" LC STL QQ-S-698-CR SOURCE: MDAC PROCUREMENT EST.	ID22578-3	P P	2.00 UNITS	2.10	4.21	1.00	0.00	0.00	4.21	.07
2040213. COVER PER SPEC. SOURCE: MDAC	ID22588-1	R M	2.00 UNITS	.16	.32	1.00	0.00	0.00	.32	.01
2040215. TUBING PER SPEC. SOURCE: MDAC PROCUREMENT EST.	RJ102-3/8	R M	1.00 UNITS	.15	.15	1.00	0.00	0.00	.15	.00

POS/LIM INDICATOR 4424

DESCRIPTION		QTY/HRS/ ANN. FAIL	REF UNIT COST	SUB TOTAL	CRC	OVERHEAD	G_A	TOTAL	$/SM
204022101. ENCODER 44242211 AUTOMATIC INSPECTION OF 5 PERCENT FOR WORKMANSHIP WITH HUGHES INDUSTRIAL PRODUCTS SCANNER AUTOMATICALLY TEST CIRCUITS ON BOARD WITH DITMICO TESTER SOURCE: GM	LBR	.11 HRS	9.64	1.05	1.00	5.96	1.26	7.95	.14
204022102. ENCODER LEADS 44242212 AUTOMATICALLY TEST CONDUCTORS WITH DITMICO TESTER SAMPLE TEST TENSILE STRENGTH WITH ITT CANNON TOOL CCT-SS SOURCE: GM	LBR	.02 HRS	9.64	.15	1.00	5.96	1.26	1.16	.02
204022103. ENC./CNTRL CABLE 44242213 TEST AS ABOVE (DITMICO TESTER) SOURCE: GM	LBR	.01 HRS	9.64	.09	1.00	5.96	1.26	.64	.01
204022201. ENCODER 44242221 HANDLING WITH TOTEBOXES AND STORAGE RACKS SOURCE: GM	LBR	.04 HRS	9.64	.34	1.00	5.96	1.26	2.58	.05
204022202. ENCODER LEADS 44242222 HANDLED MANUALLY SOURCE: GM	LBR	.03 HRS	9.64	.24	1.00	5.96	1.26	1.83	.03
204022203. ENC./CNTRL CABLE 44242223 HANDLED MANUALLY SOURCE: GM	LBR	.03 HRS	9.64	.33	1.00	5.96	1.26	2.47	.04
2040303. LOCK WASHER MS35338-41 PER SPEC. SOURCE: LAMB	P P	8.00 UNITS	.00	.01	1.00	0.00	0.00	.01	.00
2040304. WASHER NAS620-6 PER SPEC. SOURCE: LAMB	P P	8.00 UNITS	.00	.04	1.00	0.00	0.00	.04	.00

POS/LIM INDICATOR 4424

DESCRIPTION			QTY/HRS/ ANN. FAIL	REF UNIT COST	SUB TOTAL	F A C T O R S CRC	OVERHEAD	G_A	TOTAL	$/SM
2040305. STRAP PER SPEC. SOURCE: PANDUIT	PLT8H-LP0	P P	1.00 UNITS	.16	.16	1.00	0.00	0.00	.16	.00
2040306. CONNECTOR PER SPEC/,CRC ADJUSTED SOURCE: ITT CANNON	120-1869-000	P P	1.00 UNITS	.33	.33	1.00	0.00	0.00	.33	.01
2040307. TUBING PER SPEC. SOURCE: MDAC PROCUREMENT EST.	STM0069-13-A6-0	R M	1.00 UNITS	.15	.15	1.00	0.00	0.00	.15	.00
2040308. SCREW PER SPEC. SOURCE: LAMB	NAS601-5P	P P	6.00 UNITS	.02	.09	1.00	0.00	0.00	.09	.00
2040401. ASSY. LABOR TOTAL COMPONENT ASSEMBLY	442441	LBR	.01 HRS	9.64	.09	1.00	5.96	1.26	.64	.01
2040402. DUEL FIFF LINE REC PER SPEC. SOURCE: FAIRCHILD	9615	P P	2.00 UNITS	.87	1.74	1.00	0.00	0.00	1.74	.03
2040403. OPT.ISOL.TRIACS PER SPEC. SOURCE: RCA/MOTOROLA	Q2T3244	P P	8.00 UNITS	.94	7.50	1.00	0.00	0.00	7.50	.13
2040404. RESISTOR PER SPEC., 1/2 WATT SOURCE: RCA	11 Z 13	P P	8.00 UNITS	.14	1.15	1.00	0.00	0.00	1.15	.02
2040405. CAPACITOR PER SPEC. SOURCE: RCA	0.1MF1400V	P P	8.00 UNITS	.29	2.30	1.00	0.00	0.00	2.30	.04
2040406. PRINTED CIRCUIT BD PER SPEC. TWO SIDED EPOX GLASS,1.1 X 5 SOURCE: HUGHE CONNECTORS	T107	P P	2.00 UNITS	6.22	12.44	1.00	0.00	0.00	12.44	.22

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   POS/LIM INDICATOR   4424

DESCRIPTION                                     QTY/HRS/      REF UNIT  SUB TOTAL     F A C T O R S        TOTAL
                                               ANN. FAIL        COST               CRC  OVERHEAD  G_A                $/SM

      2040407.
   COVER               T226
  PER SPEC., .1345 X 7 X 7           P P      2.00 UNITS        1.20       2.39   1.00    0.00    0.00        2.39     .04
  SOURCE: MDAC


   POS/LIM INDICATOR   4424                                                                                   84.     1.49
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PWR SPLY/DIST 4425

DESCRIPTION		QTY/HRS/ ANN. FAIL		REF UNIT COST	SUB TOTAL	FACTORS CRC	OVERHEAD	G_A	TOTAL	$/SM
2050201. FEEDER CABLE CLX 3,NO. 4 AWG,5KV,COPPER CABLE/GALITE 2000,WITH ALUMINUM SHEATH AND PVC JACKETS SUITABLE FOR DIRECT BURIAL/ SOURCE: OKONITE	P P	1.00	UNITS	8.46	8.46	1.00	0.00	0.00	8.46	.15
2050202. TRANSFORMER 225T(19)H PER SPEC. SOURCE: SQUARE D	P P	1.00	UNITS	17.25	17.25	1.00	0.00	0.00	17.25	.30
2050203. DIST PANEL SQ.D-H-4172-4M 480V THREE PHASE WITH 100 APM C/B. SOURCE: SQUARE D	P P	1.00	UNITS	1.79	1.79	1.00	0.00	0.00	1.79	.03
2050204. BRANCH CIR BKR SQD NO.FA-34040 480V, 3 POLE, 40 AMP SOURCE: SQUARE D	P P	15.00	UNITS	.31	4.58	1.00	0.00	0.00	4.58	.08
2050205. BRANCH CIR CABLE CLX-ALS 3,NO.8 AWG,600V,COPPER CABLE/GALITE 2000 WITH ALUMINUM SHEATH AND PVC JACKET, SUITABLE FOR DIRECT BURIAL. SOURCE: OKONITE	P P	1.00	UNITS	53.15	53.15	1.00	0.00	0.00	53.15	.93
205030101. CIR.BRKR-BOX ASSY 4425311 LABOR REQUIRED FOR ASEMBLY OF THE CIRCUIT BREAKER ONTO THE MOUNTING PANEL	LBR	.03	HRS	9.64	.25	1.00	5.96	1.26	1.87	.03
20503010201. WIRE HARNESS ASSY 44253121 LABOR REQUIRED FOR ASSEMBLY OF THE POWER/CONTROL CABLES INTO HARNESSES 44253122	LBR	.22	HRS	9.64	2.11	1.00	5.96	1.26	15.94	.28
20503010202. ATTACH PINS 44253122 ATTACHMENT OF CONNECTORS TO CABLES	LBR	.05	HRS	9.64	.47	1.00	5.96	1.26	3.57	.06

PWR SPLY/DIST 4425

DESCRIPTION		QTY/HRS/ ANN. FAIL	REF UNIT COST	SUB TOTAL	FACTORS CRC	 OVERHEAD	 G_A	TOTAL	$/SM
20503010301. FIBER OPTIC ASSY 44253131 LABOR REQUIRED TO CUT TO LENGTH,POLI CABLE ENDS, AND ATTACH TERMINATORS TO FIBER OPTIC CABLE.	LBR	.11 HRS	9.64	1.04	1.00	5.96	1.26	7.84	.14
205030104. HARN.-OPTIC ASSY 4425314 FINAL ASSEMBLY OF HARNESS WITH FIBER OPTIC CABLE.	LBR	.08 HRS	9.64	.79	1.00	5.96	1.26	5.96	.10
2050302. JUNCTION BOX BOX-2 DUST AND WATER PROOF 6" X 6" X 3"	P P	1.00 UNITS	14.90	14.90	1.00	0.00	0.00	14.90	.26
2050303. TERMINAL STRIP STRIP-1 FIVE CONNECTOR	P P	1.00 UNITS	.64	.64	1.00	0.00	0.00	.64	.01
2050304. MOUNTING PANEL MNT-1 5" X 5" X 3/16"	P P	1.00 UNITS	1.99	1.99	1.00	0.00	0.00	1.99	.03
2050305. TERMINATOR TERM-1 P/N ALSJ 650(TYP) SOURCE: CROUSE AND HINDS	P P	4.00 UNITS	5.51	22.06	1.00	0.00	0.00	22.06	.39
2050306. CABLE FITTING FIT-1 P/N 177(TYP) SOURCE: CROUSE AND HINDS	P P	5.00 UNITS	13.89	69.44	1.00	0.00	0.00	69.44	1.22
2050307. CIRCUIT BREAKER CB-3PH THREE PHASE , 15 AMP	P P	1.00 UNITS	32.83	32.83	1.00	0.00	0.00	32.83	.58
2050308. POWER CABLE H-1 STANDARD POWER CABLE (600 V) CU THREE WIRE CONDUCTOR 20 GAGE 165"	P P	1.00 UNITS	1.64	1.64	1.00	0.00	0.00	1.64	.03
2050309. CONTROL CABLE CC-1 STANDARD CONTROL CABLE (600 V) CU 24 GAGE 312"	P P	1.00 UNITS	3.28	3.28	1.00	0.00	0.00	3.28	.06

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SECOND GENERATION HELIOSTAT 50K/YR.                                                     13.11.34.      DATE 02/09/81

   PWR SPLY/DIST       4425

DESCRIPTION                                        QTY/HRS/      REF UNIT  SUB TOTAL     F A C T O R S         TOTAL
                                                  ANN. FAIL        COST              CRC  OVERHEAD  G_A                  $/SM

      2050310.
   FIBER OPTIC CABLE   FOCB-1
 CALLITE 2000 TYPE 200P                  P P      1.00 UNITS        2.96      2.96   1.00   0.00    0.00        2.96    .05
 108"

      2050311.
   FIBER OPTIC TERMIN  FOCN-1
 FIBER OPTIC TERMINATORS                 P P      4.00 UNITS        7.40     29.59   1.00   0.00    0.00       29.59    .52

      2050312.
   CONNECTOR           CON-2
 25 PIN CONNECTOR                        P P      1.00 UNITS         .48       .48   1.00   0.00    0.00         .48    .01
 MALE AND FEMALE

      2050313.
   CONNECTOR           CON-3
 10 PIN CONNECTOR                        P P      3.00 UNITS        7.58     22.74   1.00   0.00    0.00       22.74    .40
 MALE AND FEMALE

      2050321.
   INSPECT & TEST      4425321
 LABOR REQUIRED FOR TEST AND INSPECTILBR           .15  HRS         9.64      1.44   1.00   5.96    1.26       10.89    .19
 OF PEDESTAL ELECTRICAL ASSEMBLY.

      2050322.
   MAT'L HANDLING      4425322
 LABOR REQUIRED FOR MATERIAL HANDLINGLBR           .04  HRS         9.64       .39   1.00   5.96    1.26        2.98    .05
 OF PEDESTAL ELECTRICAL ASSEMBLY.

      2050323.
   PACKAGING           4425323
 LABOR REQUIRED FOR PACKAGING OF     LBR           .08  HRS         9.64       .79   1.00   5.96    1.26        5.95    .10
 PEDESTAL ELECTRICAL COMPONENTS.


   PWR SPLY/DIST       4425                                                                                 343.     6.03
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SECOND GENERATION HELIOSTAT 50K/YR.                                                        13.11.34.        DATE 02/09/81

   ASSY DR/PED/ELCT P  4426

DESCRIPTION                                      QTY/HRS/       REF UNIT  SUB TOTAL     F A C T O R S         TOTAL
                                                ANN. FAIL        COST               CRC  OVERHEAD  G_A                  $/SM

        20601.
   ASSY. LABOR          44261
  ASSEMBLE PEDESTAL TO DRIVE UNIT,    LBR       .11  HRS        9.64      1.07     1.00   5.96     1.26       8.05     .14
  RUN BOLTS,MAKE FINAL ELECTRICAL
  CONNECTIONS AT SINGLE STATION ASSY
  BENCH WITH 90 DEGREE ROLLER/BED'V'
  BLK FIXTURE AND AIR WRENCH
  CREW SIZE = 2             SOURCE: GM

      2060202.
   COVER-EL. SENSOR     ID22416
  PER SPEC., COST BASIS=WT. TIMES     R M     1.00 UNITS         .62       .62     1.00   0.00     0.00        .62     .01
  DOLLARS PER LB.
  SOURCE: MDAC

      2060203.
   MNT- EL. SENSOR      ID22417
  PER SPEC., COST BASIS = WT. TIMES   R M     2.00 UNITS         .16       .32     1.00   0.00     0.00        .32     .01
  DOLLARS PER LB.
  SOURCE: MDAC

      2060204.
   BRKT-MAGNET(EL.)     ID22418
  PER SPEC., COST BASIS = WT. TIMES   R M     1.00 UNITS         .10       .10     1.00   0.00     0.00        .10     .00
  DOLLARS PER LB.
  SOURCE: MDAC

    206020501.
   PLATE                ID22419
  PER SPEC., COST BASIS = WT. TIMES   R M     1.00 UNITS         .21       .21     1.00   0.00     0.00        .21     .00
  DOLLARS PER LB.
  SOURCE: MDAC

    206020502.
   BASE                 ID22419
  PER SPEC., COST BASIS = WT. TIMES   R M     1.00 UNITS         .20       .20     1.00   0.00     0.00        .20     .00
  DOLLARS PER LB.
  SOURCE: MDAC

      2060206.
   PIN-TRUNNION         ID22432
  PER SPEC., COST BASIS = WT. TIMES   R M     2.00 UNITS        2.52      5.04     1.00   0.00     0.00       5.04     .09
  DOLLARS PER LB.
  SOURCEL MDAC
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   ASSY DR/PED/ELCT P  4426

DESCRIPTION                                          QTY/HRS/     REF UNIT  SUB TOTAL     F A C T O R S        TOTAL
                                                    ANN. FAIL       COST              CRC  OVERHEAD  G_A                 $/SM

      2060207.
   MNT-SENSOR PTPT       ID22433
 PER SPEC., COST BASIS=WT. TIMES     R M      1.00 UNITS       .12        .12   1.00    0.00     0.00        .12      .00
 DOLLARS PER LB.
 SOURCE: MDAC

      2060208.
   CAP-ROD END PIN       ID22438
 PER SPEC., COST BASIS = WT. TIMES   R M      2.00 UNITS       .08        .16   1.00    0.00     0.00        .16      .00
 DOLLARS PER LB.
 SOURCE: MDAC

      2060209.
   PIN-HINGE             ID22455
 PER SPEC., COST BASIS = WT. TIMES   R M      1.00 UNITS      3.00       3.00   1.00    0.00     0.00       3.00      .05
 DOLLARS PER LB.
 SOURCE: MDAC

      2060210.
   PIN-ROD END           ID22478
                                     R M      1.00 UNITS      1.50       1.50   1.00    0.00     0.00       1.50      .03

      2060211.
   COVER-EL.DR.          ID22594
 PER SPEC., COST BASIS = WT. TIMES   R M      1.00 UNITS       .16        .16   1.00    0.00     0.00        .16      .00
 DOLLARS PER LB.
 SOURCE: MDAC

    206021202.
   ANGLE                 ID22405
 PER SPEC.                           P P      1.00 UNITS       .13        .13   1.00    0.00     0.00        .13      .00
 SOURCE: MDAC

    206021203.
   PIN                   ID22405
 PER SPEC.                           P P      1.00 UNITS       .03        .03   1.00    0.00     0.00        .03      .00
 SOURCE: MDAC

    206021302.
   ANGLE                 ID22405
 PER SPEC.                           P P      1.00 UNITS       .13        .13   1.00    0.00     0.00        .13      .00
 SOURCE: MDAC

    206021303.
   PIN                   ID22405
 PER SPEC.                           P P      1.00 UNITS       .03        .03   1.00    0.00     0.00        .03      .00
 SOURCE: MDAC
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SECOND GENERATION HELIOSTAT 50K/YR.                                                           13.11.34.        DATE 02/09/81

   ASSY DR/PED/ELCT P  4426

DESCRIPTION                                             QTY/HRS/       REF UNIT  SUB TOTAL    F A C T O R S         TOTAL
                                                       ANN. FAIL        COST               CRC  OVERHEAD  G_A                $/SM

      2060214.
   HINGE-HLF ASSY       ID22405
  PER SPEC.                                   P P      1.00 UNITS        .13        .13   1.00    0.00     0.00        .13    .00
  SOURCE: MDAC

      2060215.
   COTTER PIN          MS24665-374
  PER SPEC.                                   P P      1.00 UNITS        .03        .03   1.00    0.00     0.00        .03    .00
  SOURCE: LAMB

      2060216.
   COTTER PIN          MS24665-377
  PER SPEC.                                   P P      2.00 UNITS        .04        .07   1.00    0.00     0.00        .07    .00
  SOURCE: LAMB

      2060217.
   BOLT                NAS1314-16
  PER SPEC.                                   P P      4.00 UNITS        .88       3.52   1.00    0.00     0.00       3.52    .06
  SOURCE: LAMB

      2060218.
   BOLT                NAS1316-42D
  PER SPEC.                                   P P      1.00 UNITS       1.17       1.17   1.00    0.00     0.00       1.17    .02
  SOURCE: LAMB

      2060220.
   SET SCREW           NAS1081-4A12P
  PER SPEC.                                   P P      1.00 UNITS        .02        .02   1.00    0.00     0.00        .02    .00
  SOURCE: LAMB

      2060221.
   SET SCREW           NAS1081-4A12P
  PER SPEC.                                   P P      2.00 UNITS        .02        .04   1.00    0.00     0.00        .04    .00
  SOURCE: LAMB

      2060222.
   MAGNET              M2
  PER SPEC., CRC ADJUSTED                     P P      2.00 UNITS        .30        .59   1.00    0.00     0.00        .59    .01
  SOURCE: KESSLER-ELLIS PROD.

      2060223.
   WASHER              5710-67-10
  PER SPEC.                                   P P     30.00 UNITS        .02        .54   1.00    0.00     0.00        .54    .01
  SOURCE: LAMB

      2060224.
   WASHER              5710-245-90
  PER SPEC.                                   P P      2.00 UNITS        .02        .04   1.00    0.00     0.00        .04    .00
  SOURCE: LAMB
```

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   ASSY DR/PED/ELCT P  4426

DESCRIPTION                                    QTY/HRS/        REF UNIT  SUB TOTAL     F A C T O R S          TOTAL
                                              ANN. FAIL         COST                 CRC  OVERHEAD  G_A               $/SM

      2060225.
   SHAFT                A3-17
 PER SPEC.                            P P      2.00 UNITS         .35        .70   1.00    0.00     0.00          .70    .01
 CRC ADJUSTED
 SOURCE: PIC DESIGN

      2060226.
   F.H.BRASS SCREW      .190-32UNF-2AX.7
 PER SPEC.                            P P      2.00 UNITS         .02        .04   1.00    0.00     0.00          .04    .00
 SOURCE: LAMB

      2060227.
   SPLT LK. WASHER      .190
 PER SPEC.                            P P      2.00 UNITS         .14        .29   1.00    0.00     0.00          .29    .01
 SOURCE: LAMB

      2060228.
   HEXNUT               .190-32UNF-2B
 PER SPEC.                            P P      2.00 UNITS         .00        .01   1.00    0.00     0.00          .01    .00
 SOURCE: LAMB

      2060229.
   HEX CAP SCREW        .250-20UNC-2AX.5
 PER SPEC.                            P P     16.00 UNITS         .01        .13   1.00    0.00     0.00          .13    .00
 SOURCE: LAMB

      2060230.
   HEX CAP SCREW        .250-20UNC-2AX.7
 PER SPEC.                            P P      2.00 UNITS         .01        .02   1.00    0.00     0.00          .02    .00
 SOURCE: LAMB

      2060231.
   HEX CAP SCREW        .250-20UNC-2AX.8
 PER SPEC.                            P P      8.00 UNITS         .01        .09   1.00    0.00     0.00          .09    .00
 SOURCE: LAMB

      2060232.
   SPLT LK. WASHER      .250
 PER SPEC.                            P P     26.00 UNITS         .00        .07   1.00    0.00     0.00          .07    .00
 SOURCE: LAMB

      2060233.
   HEXNUT               .250-20UNC-2B
 PER.SPEC.                            P P      8.00 UNITS         .00        .04   1.00    0.00     0.00          .04    .00
 SOURCE: LAMB
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SECOND GENERATION HELIOSTAT 50K/YR.                                              13.11.34.        DATE 02/09/81

   ASSY DR/PED/ELCT P  4426

DESCRIPTION                                           QTY/HRS/       REF UNIT  SUB TOTAL     F A C T O R S        TOTAL
                                                     ANN. FAIL        COST                 CRC  OVERHEAD  G_A                $/SM

      2060234.
   SPLT LK. WASHER     .500
 PER SPEC.                               P P       8.00 UNITS          .02        .14    1.00    0.00     0.00         .14     .00
 SOURCE: LAMB

      2060235.
   SPLT LK. WASHER     .875
 PER SPEC.                               P P       4.00 UNITS          .06        .25    1.00    0.00     0.00         .25     .00
 SOURCE: LAMB

      2060236.
   WAHER               AN960-1616
 PER SPEC.                               P P       1.00 UNITS          .08        .08    1.00    0.00     0.00         .08     .00
 SOURCE: LAMB

      2060237.
   NUT                 AN130-15
 PER SPEC.                               P P       1.00 UNITS          .07        .07    1.00    0.00     0.00         .07     .00
 SOURCE: LAMB

      2060238.
   COTTER PIN          .062X.50
 PER SPEC/                               P P       1.00 UNITS          .01        .01    1.00    0.00     0.00         .01     .00
 SOURCE: LAMB

      2060239.
   HEX CAP SCREW       .250-28UNF-2AX.5
 PER SPEC.                               P P       1.00 UNITS          .01        .01    1.00    0.00     0.00         .01     .00
 SOURCE: LAMB

      2060240.
   JUMPER              ST268-09CC
 PER SPEC., CRC ADJUSTED                 P P       1.00 UNITS          .58        .58    1.00    0.00     0.00         .58     .01
 SOURCE: MDAC PROCUREMENT EST.

    206024101.
   CONN SW TO PIN      4426241
 ELECTRICAL ASSY OF CONN SW TO PIN       LBR        .03  HRS          9.64        .27    1.00    5.96     1.26        2.01     .04
                      SOURCE: GM

    206024102.
   CONNECTOR           120-1809-000
 PER SPEC.                               P P       1.00 UNITS          .33        .33    1.00    0.00     0.00         .33     .01
 SOURCE: ITT CANNON

    206024103.
   CONTACT-PIN         110238-0040
 PER SPEC., CRC ADJUSTED                 R M       2.00 UNITS          .04        .08    1.00    0.00     0.00         .08     .00
 SOURCE: ITT CANNON
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  ASSY DR/PED/ELCT P  4426

DESCRIPTION                                       QTY/HRS/        REF UNIT  SUB TOTAL      F A C T O R S         TOTAL
                                                 ANN. FAIL          COST                 CRC  OVERHEAD  G_A                 $/SM

   206024104.
  CONTACT-SOCKET       110238-0085
 PER SPEC., CRC ADJUSTED               P P      2.00 UNITS           .07       .14     1.00    0.00     0.00        .14     .00
 SOURCE: ITT CANNON

   206024105.
  TUBING               STM0069-13-A6-0
 PER SPEC.                             R M      1.00 UNITS           .09       .09     1.00    0.00     0.00        .09     .00
 SOURCE: MDAC PROCUREMENT EST.

   206024106.
  TUBING               DPM2617-15
 PER SPEC.                             R M      1.00 UNITS           .09       .09     1.00    0.00     0.00        .09     .00
 SOURCE: MDAC PROCUREMENT EST.

   206024107.
  PROXIMITY SWITCH     LC2P-1839-1A-60
 PER SPEC., CRC ADJUSTED               P P      2.00 UNITS           .55      1.11     1.00    0.00     0.00       1.11     .02
 SOURCE: MDAC PROCUREMENT EST.

   206024201.
  CONN SW TO PIN       44262442
 ELECTRICAL ASSY OF CONN SW TO PIN     LBR       .01  HRS           9.64       .09     1.00    5.96     1.26        .67     .01
                        SOURCE: GM

   206024202.
  CONNECTOR            120-1807-000
 PER SPEC.                             P P      1.00 UNITS           .33       .33     1.00    0.00     0.00        .33     .01
 SOURCE: ITT CANNON

   206024203.
  CONTACT-PIN          110238-0040
 PER SPEC., CRC ADJUSTED               R M      1.00 UNITS           .04       .04     1.00    0.00     0.00        .04     .00
 SOURCE: ITT CANNON

   206024204.
  CONTACT-SOCKET       110238-0085
 PER SPEC., CRC ADJUSTED               P P      1.00 UNITS           .07       .07     1.00    0.00     0.00        .07     .00
 SOURCE: ITT CANNON

   206024205.
  TUBING               STM0069-13-A6-0
 PER SPEC.                             R M      1.00 UNITS           .09       .09     1.00    0.00     0.00        .09     .00
 SOURCE: MDAC PROCUREMENT EST.

   206024206.
  TUBING               DPM2617-15
 PER SPEC.                             R M      1.00 UNITS           .09       .09     1.00    0.00     0.00        .09     .00
 SOURCE: MDAC PROCUREMENT EST.
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ASSY DR/PED/ELCT P 4426

DESCRIPTION		QTY/HRS/ ANN. FAIL	REF UNIT COST	SUB TOTAL	FACTORS CRC	OVERHEAD	G_A	TOTAL	$/SM
206024207. PROXIMITY SWITCH LC2P-1839-1A-60 PER SPEC., CRC ADJUSTED SOURCE: MDAC PROCUREMENT EST.	P P	1.00 UNITS	.55	.55	1.00	0.00	0.00	.55	.01
206024301. ASSY. SEN/CABLE 4426243 ELECTRICAL INSTALLATION (ASSY OF SENSOR CABLE) SOURCE: GM	LBR	.09 HRS	9.64	.89	1.00	5.96	1.26	6.73	.12
206024302. CLAMP ST253C6 PER SPEC. SOURCE: MDAC PROCUREMENT EST.	P P	1.00 UNITS	.09	.09	1.00	0.00	0.00	.09	.00
206024303. JUMPER ST263-16CC PER SPEC., CRC ADJUSTED SOURCE: MDAC PROCUREMENT EST.	P P	1.00 UNITS	.58	.58	1.00	0.00	0.00	.58	.01
206024304. RNDHEAD SCREW .190-32UNF-2AX.5 PER SPEC. SOURCE: LAMB	P P	1.00 UNITS	.01	.01	1.00	0.00	0.00	.01	.00
206024305. SPLT LK. WASHER .190 PER SPEC. SOURCE: LAMB	P P	1.00 UNITS	.01	.01	1.00	0.00	0.00	.01	.00
206024306. CABLE TIES PLT1M PER SPEC., CRC ADJUSTED SOURCE: PANDUIT	P P	2.00 UNITS	.01	.02	1.00	0.00	0.00	.02	.00
206024402. CONNECTOR 120-1869-000 PER SPEC/,CRC ADJUSTED SOURCE: ITT CANNON	P P	1.00 UNITS	.33	.33	1.00	0.00	0.00	.33	.01
206024403. CONTACT-PIN 110238-0040 PER SPEC., CRC ADJUSTED SOURCE: ITT CANNON	R M	3.00 UNITS	.04	.11	1.00	0.00	0.00	.11	.00

ASSY DR/PED/ELCT P 4426

DESCRIPTION		QTY/HRS/ ANN. FAIL		REF UNIT COST	SUB TOTAL	FACTORS CRC	OVERHEAD	G_A	TOTAL	$/SM
206024404. CONTACT-SOCKET 11238-0085 PER SPEC. SOURCE: MDAC PROCUREMENT EST.	P P	5.00	UNITS	.07	.36	1.00	0.00	0.00	.36	.01
206024405. PLUG FILLER 225-0072-000 PER SPEC., CRC ADJUSTED SOURCE: ITT CANNON	P P	2.00	UNITS	.01	.03	1.00	0.00	0.00	.03	.00
206024406. SPLICE A1A PER SPEC. SOURCE: T & B	P P	1.00	UNITS	.06	.06	1.00	0.00	0.00	.06	.00
206024407. WIRE 8918 PER SPEC., #18AWG SOURCE: BELDEN	R M	1.00	UNITS	3.21	3.21	1.00	0.00	0.00	3.21	.06
206024408. WIRE 8451 PER SPEC., #22-2SJ SOURCE: BELDEN	R M	1.00	UNITS	.57	.57	1.00	0.00	0.00	.57	.01
206024409. TUBING DPM2617-15 PER SPEC. SOURCE: MDAC PROCUREMENT EST.	R M	1.00	UNITS	.09	.09	1.00	0.00	0.00	.09	.00
206024410. TUBING STM0069-13-A6-0 PER SPEC. SOURCE: MDAC PROCUREMENT EST.	R M	1.00	UNITS	.09	.09	1.00	0.00	0.00	.09	.00
2060245. BOLT NAS1308-15 PER SPEC. SOURCE: LAMB	P P	8.00	UNITS	.93	7.46	1.00	0.00	0.00	7.46	.13
2062101. FINAL 4426211 FINAL FLOOR INSPECTION SOURCE: GM	LBR	.04	HRS	9.64	.34	1.00	5.96	1.26	2.58	.05
2062102. SENSOR 4426212 FLOOR INSPECTION OF SENSOR SOURCE: GM	LBR	.05	HRS	9.64	.51	1.00	5.96	1.26	3.86	.07

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SECOND GENERATION HELIOSTAT 50K/YR.                                                   13.11.34.        DATE 02/09/81

   ASSY DR/PED/ELCT P  4426

DESCRIPTION                                         QTY/HRS/       REF UNIT  SUB TOTAL      F A C T O R S        TOTAL
                                                   ANN. FAIL         COST                CRC  OVERHEAD  G_A                $/SM

      2062201.
   PACKAGE             4426221
 PACKAGING OF ELECTRONIC PARTS      LBR        .09  HRS        9.64       .85  1.00   5.96     1.26       6.44    .11
                    SOURCE: GM

      2062202.
   LOAD/UNLOAD         4426222
 LOAD/UNLOAD DRIVES AND PEDESTAL    LBR        .23  HRS        9.64      2.17  1.00   5.96     1.26      16.36    .29
 WITH OVERHEAD CRANE
                    SOURCE: GM

      2062203.
   SUPPLY              4426223
 SUPPLY FOR ELECTRICAL PARTS,PEDES- LBR        .10  HRS        9.64       .97  1.00   5.96     1.26       7.29    .13
 TAL AND DRIVES
                    SOURCE: GM


   ASSY DR/PED/ELCT P  4426                                                                             90.      1.59
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SECOND GENERATION HELIOSTAT 50K/YR.                                          13.11.34.        DATE 02/09/81

   SENSOR/CALIB EQUIP   4431

DESCRIPTION                                            QTY/HRS/      REF UNIT  SUB TOTAL     F A C T O R S        TOTAL
                                                       ANN. FAIL       COST               CRC  OVERHEAD  G_A                 $/SM

      3010101.
   CAMRA/CABLE/MOUNT   2850C-207
 INVESTMENT FOR 50KW ELECT PLANT     P P         9.24 UNITS        .43      3.98   1.00    0.00      0.00        3.98     .07
 MFG. COHU INC., SAN DIEGO, CALIF.
   CAMERA                  $4365
   IMAGE TUBE               1650
   UNIV CAMERA MOUNT          60
   REMOTE CONTRL RECVER      730
   CABLE REC TO CAMERA       230

      3010102.
   COMP CNTRL/TEST EQ  ER-8807
 COMPUTER CONTROL AND TEST EQUIPMENT P P         9.24 UNITS        .20      1.83   1.00    0.00      0.00        1.83     .03
 MFG. COHU INC., SAN DIEGO, CALIF.
   REMOTE CONTRL XMIT       $ 835
   MOD FOR DIRECT CONTRL     8500
   BAR DOT GENERATOR          560
   CAMERA TEST JIG              0

      3010103.
   MULTPLE CAMRA SWIT  VS504H
 MULTIPLE CAMERA SWITCH              P P         9.24 UNITS        .05       .45   1.00    0.00      0.00         .45     .01
 MFG. COHU INC., SAN DIEGO, CALIG.
 ONLY NEEDED IF MORE THAN ONE CAMERA

        30102.
   FACTORY TRAINING     44312
 FACTORY TRAINING OF 4 PEOPLE FOR    LBR          .01  HRS        9.64       .11   1.00    5.96      1.26         .84     .01
 4 DAYS BY COHU INC.


        30103.
   INSTL AND CHKOUT     44313
 INSTALLATION AND CHECKOUT OF BCS    LBR          .01  HRS        9.64       .09   1.00    5.96      1.26         .68     .01
 2MEN FOR 1 DAYWITH CABLES IN
 COMMON RUNS WITH HELIOSTAT CABLES
 APRX. 3000FT AT $.75/FT
 $2500 IS FOR WIRING, FOUNDATIONS AND
 GROUNDING


   SENSOR/CALIB EQUIP   4431                                                                            8.        .14
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SECOND GENERATION HELIOSTAT 50K/YR. 13.11.34. DATE 02/09/81

FIELD CONTROL 4432

DESCRIPTION		QTY/HRS/ ANN. FAIL	REF UNIT COST	SUB TOTAL	FACTORS CRC	FACTORS OVERHEAD	FACTORS G_A	TOTAL	$/SM
3020101. FINAL HC ASSY 443211 FINAL ASSEMBLY OF HELIOSTAT FIELD CONTROLLER.	LBR	.00 HRS	9.64	.00	1.00	5.96	1.26	.02	.00
3020102. PWB COMPONENT ASSY 443212 ASSEMBLY OF COMPONENTS ONTO THE PWB	LBR	.00 HRS	9.64	.00	1.00	5.96	1.26	.01	.00
3020201. TWO SIDED PWB PWB-2 2 SIDED EPOXY PWB 4" X 5" SOURCE: MDZC	P P	2.00 UNITS	.02	.05	1.00	0.00	0.00	.05	.00
3020202. CONNECTOR CON-25M 25 PINS (MALE) SOURCE: AMP INC.	P P	2.00 UNITS	.00	.01	1.00	0.00	0.00	.01	.00
3020203. LED SG-1010 SOURCE: RCA	P P	10.00 UNITS	.00	.03	1.00	0.00	0.00	.03	.00
3020204. OPT TRANSCEIVER SIM 75116 COMMUNICATION WITH HELIOSTAT ARRAY CONTROLLER SOURCE: T.I.	P P	2.00 UNITS	.13	.26	1.00	0.00	0.00	.26	.00
3020205. MICRO-COMPUTER SEMI 8748 SOURCE: NATL SEMICONDUCTOR	P P	2.00 UNITS	.16	.32	1.00	0.00	0.00	.32	.01
3020206. OPT TRANSCEIVER SIM 75116 COMMUNICATION WITH HELIOSTAT ARRAY CONTROLLER SOURCE: T.I.	P P	8.00 UNITS	.15	1.22	1.00	0.00	0.00	1.22	.02
3020207. RELAY R10E6-Y2V185 4PDT (5V) SOURCE: POTTER BRUMFIELD	P P	8.00 UNITS	.01	.10	1.00	0.00	0.00	.10	.00

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  FIELD CONTROL       4432

DESCRIPTION                                 QTY/HRS/      REF UNIT  SUB TOTAL    F A C T O R S        TOTAL
                                           ANN. FAIL        COST              CRC  OVERHEAD  G_A               $/SM

     3020208.
  CERAMIC CAPS        CCAP-1
 0.1 UF, 50V                       P P      8.00 UNITS        .00       .02  1.00    0.00   0.00        .02    .00
 SOURCE: BELL

     3020209.
  MODULAR PWR-SUPPLY  SIMI LOS-W5
 SOURCE: LAMBELA                   P P      2.00 UNITS        .16       .33  1.00    0.00   0.00        .33    .01

     3020210.
  FOAM PADS           FPAD-1
 1/2" X 1" X 5"                    P P      2.00 UNITS        .00       .00  1.00    0.00   0.00        .00    .00
 SOURCE: MDAC

     3020211.
  PHOTO DETECTOR      C30807
 OPTICAL FIBER                     P P      2.00 UNITS        .01       .03  1.00    0.00   0.00        .03    .00
 SOURCE: I.T.

     3020212.
  PHOTO TRANSISTORS   FPT100A
 OPTICAL FIBER                     P P      8.00 UNITS        .00       .02  1.00    0.00   0.00        .02    .00
 SOURCE: I.T.

     3020213.
  BOX                 BOX-1
 ONE PLASTIC MOLDED BOX W/ COVER   P P      1.00 UNITS        .00       .00  1.00    0.00   0.00        .00    .00
 5" X  6" X 3"
 SOURCE: NEWPORT PLASTIC

     3020214.
  CONNECTOR           CON-25F
 25 PIN (FEMALE)                   P P      2.00 UNITS        .00       .01  1.00    0.00   0.00        .01    .00
 SOURCE: AMP INC.

       30221.
  INSPECT/TEST        443221
 LABOR REQUIRED FOR TEST AND INSPECTILBR     .00  HRS        9.64       .00  1.00    5.96   1.26        .04    .00
 OF HFC ASSEMBLY.

       30222.
  MAT'L HANDLING      443222
 LABOR REQUIRED FOR MATERIAL HANDLINGLBR     .00  HRS        9.64       .00  1.00    5.96   1.26        .01    .00
 OF HFC ASSEMBLY.


  FIELD CONTROL       4432                                                                         2.      .04
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SECOND GENERATION HELIOSTAT 50K/YR. 13.11.34. DATE 02/09/81

CNTRL/SIG EQ 4433

DESCRIPTION		QTY/HRS/ ANN. FAIL	REF UNIT COST	SUB TOTAL	FACTORS CRC	OVERHEAD	G_A	TOTAL	$/SM
3030101. FINAL HC ASSY 443311 FINAL ASSEMBLY OF HELIOSTAT CONTROLL	LBR	.07 HRS	9.64	.68	1.00	5.96	1.26	5.14	.09
3030102. PWB COMPONENT ASSY 443312 ASSEMBLY OF COMPONENTS ONTO THE PWB	LBR	.03 HRS	9.64	.32	1.00	5.96	1.26	2.42	.04
3030201. PRINTED CIRCUIT BD T100 4" X 5" TWO SIDED EPOXY GLASS COPPER CIRCUITRY WITH THRU PLATED HOLES. .02 SOURCE: MDAC	P P	1.00 UNITS	6.89	6.89	1.00	0.00	0.00	6.89	.12
3030203. CONNECTOR 24-28P 24 PINS (MALE) SOURCE: AMP ICN.	P P	1.00 UNITS	1.82	1.82	1.00	0.00	0.00	1.82	.03
3030204. MU.COMPUTER SIMI 8748 SOURCE: NATIONAL SEMICONDUCTOR	P P	1.00 UNITS	45.60	45.60	1.00	0.00	0.00	45.60	.80
3030205. QUAD.DIFF. LINE DR SIMIDS1688 MOTOR DRIVER INTERFACE SOURCE: NATIONAL SEMICONDUCTOR	P P	2.00 UNITS	2.74	5.48	1.00	0.00	0.00	5.48	.10
3030206. QUAD.DIFF. LINE RE SIMI DS1689 ENCODER INTERFACE SOURCE: NATIONAL SEMICONDUCTOR	P P	2.00 UNITS	2.74	5.48	1.00	0.00	0.00	5.48	.10
3030207. HEX D-FLIP FLOP SN7474N ENCODER INTERFACE SOURCE: T. I.	P P	3.00 UNITS	1.82	5.47	1.00	0.00	0.00	5.47	.10
3030208. CAPACITOR 0.1MF-50V O.I.M.F. 50V SOURCE: BELL	P P	3.00 UNITS	.61	1.82	1.00	0.00	0.00	1.82	.03
3030209. POWER SUPPLY 3425-0000 5V MODULAR POWER SUPPLY SOURCE: SEMICONDUCTOR	P P	1.00 UNITS	46.00	46.00	1.00	0.00	0.00	46.00	.81

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SECOND GENERATION HELIOSTAT 50K/YR.                                                         13.11.34.         DATE 02/09/81

   CNTRL/SIG EQ        4433

DESCRIPTION                                           QTY/HRS/       REF UNIT  SUB TOTAL     F A C T O R S        TOTAL
                                                     ANN. FAIL        COST               CRC  OVERHEAD  G_A                $/SM

      3030210.
   BOX                 BOX-1
 ONE PLASTIC MOLDED BOX W/ COVER      P P      1.00 UNITS       .56       .56   1.00   0.00     0.00         .56    .01
 5" X  6" X 3"
 SOURCE: NEWPORT PLASTIC

      3030211.
   CONNECTOR           CON-1
 24 PINS (FEMALE)                     P P      1.00 UNITS      1.82      1.82   1.00   0.00     0.00        1.82    .03
 SOURCE: AMP INC.

      3030212.
   OPT TRANSCEIVER     SIM 75116
 COMMUNICATION WITH HELIOSTAT         P P      1.00 UNITS     37.49     37.49   1.00   0.00     0.00       37.49    .66
 ARRAY CONTROLLER
 SOURCE: T.I.

        30321.
   INSPECT/TEST        443321
 LABORREQUIRED FOR TEST AND INSPECTIOLBR        .16  HRS       9.64      1.55   1.00   5.96     1.26       11.72    .21
 OF HC ASSEMBLY.

        30322.
   MAT'L HANDLING      443322
 LABOR REQUIRED FOR MATERIAL HANDLINGLBR        .04  HRS       9.64       .38   1.00   5.96     1.26        2.88    .05
 OF HC ASSEMBLY.


   CNTRL/SIG EQ        4433                                                                          181.     3.18
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SECOND GENERATION HELIOSTAT 50K/YR.                                                                13.11.34.        DATE 02/09/81

   FOUNDATION         4441

DESCRIPTION                                             QTY/HRS/       REF UNIT  SUB TOTAL     F A C T O R S          TOTAL
                                                       ANN. FAIL        COST               CRC  OVERHEAD  G_A                   $/SM




      4010101.
   FORM, POUR/FINISH   444111
 LABOR TO POSITION TAPERED PIPE      LBR        2.29   HRS       15.12      34.66   1.00    1.70     1.00       58.92    1.04
 ,POUR CONCRETE AND VIBRATE.
 4 CREWS (9.4 WEEK BASE) EACH:
 5 LABORERS (INCL. LEAD)
 SOURCE: STEARNS-ROGER

      4010102.
   CAGES               444112
 LABOR TO SET UP AND PLACE CAGES     LBR        1.83   HRS       15.12      27.73   1.00    1.70     1.00       47.14     .83
 IN AUGERED HOLE.
 4 CREWS (9.4 WEEK BASE) EACH:
 2 RODMEN
 2 IRONWWRKERS
 SOURCE: STEARNS-ROGER

      4010103.
   EQUIP OPER _ DRIVR  444113
 EQUIPMENT OPERATORS AND TRUCK       LBR        2.29   HRS       15.12      34.66   1.00    1.70     1.00       58.92    1.04
 DRIVERS USED IN SUPPORT OF
 FOUNDATION INSTALLATION.
 4 CREWS (9.4 WEEK BASE) EACH:
 1 HYDRAULIC CRANE OPERATOR
 1 OILER
 3 TRUCK DRIVERS
 SOURCE: STEARNS-ROGER

         40102.
   CONCRETE            44412
 2.32 CUBIC YARDS OF CONCRETE (5%   P P       1.00 UNITS      111.08     111.08   1.00    0.00     0.00      111.08    1.95
 OVERPOUR) PRICED AT $ 44.4 PER YARD
 INCLUDING COST OF MATERIALS,
 MIXING AND DELIVERY TO FOUNDATION"S
 POSITION.
1
```

```
SECOND GENERATION HELIOSTAT 50K/YR.                                                    13.11.34.        DATE 02/09/81

   FOUNDATION          4441

DESCRIPTION                                          QTY/HRS/       REF UNIT  SUB TOTAL     F A C T O R S        TOTAL
                                                    ANN. FAIL        COST                CRC  OVERHEAD  G_A                  $/SM

       40103.
   CAGES               44413
 296 LBS. OF REBAR PRICED AT $ .24 PELBR            3.21  HRS        15.12      48.52    1.00    1.70    1.00        82.49   1.45
 LB. AND LABOR TO PREFABRICATE REBAR R M            1.00 UNITS       78.90      78.90    1.00    0.00    0.00        78.90   1.39
 CAGES WITH THE TAPERED PIPE.
 5 CREWS (9.4 WEEK BASE) EACH:
 2 RODMEN
 3 LABORERS (INCL. LEAD)
 1HYDRAULIC CRANE OPERATOR
 1 TRUCK DRIVER
 SOURCE: STEARNS-ROGER

       40104.
   TAPERED PIPE        44414
 86 LBS. PRICED AT $ .37 PER LB. BASEP P            1.00 UNITS       32.13      32.13    1.00    0.00    0.00        32.13    .57
 ON U.S. STEEL PRICE INFORMATION.

       40105.
   BRACING             44415
 BRACING---50 SETS AT $216 EACH       P P           1.00 UNITS        4.71       4.71    1.00    0.00    0.00         4.71    .08


   FOUNDATION          4441                                                                                         474.     8.34
1
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SECOND GENERATION HELIOSTAT 50K/YR. 13.11.34. DATE 02/09/81

SITE PREPARATION 4442

DESCRIPTION		QTY/HRS/ ANN. FAIL		REF UNIT COST	SUB TOTAL	FACTORS CRC	OVERHEAD	G_A	TOTAL	$/SM
40201.										
SURVEY 44421										
4 SURVEY CREWS(9.4 WEEK BASE)	LBR	.92	HRS	15.12	13.86	1.00	1.70	1.00	23.57	.41
2 SURVEYORS										
SOURCE: SEARNS-ROGER										
40202.										
DRILLING 44422										
DRILLING OPERATIONS, USING DRILL	LBR	2.75	HRS	15.12	41.59	1.00	1.70	1.00	70.70	1.24
SITE PREPARATION 4442									94.	1.66

SECOND GENERATION HELIOSTAT 50K/YR. 13.11.34. DATE 02/09/81

HELIO SUPP STRUCT 4451

DESCRIPTION		QTY/HRS/ ANN. FAIL	REF UNIT COST	SUB TOTAL	FACTORS CRC	OVERHEAD	G_A	TOTAL	$/SM
5010101. WELD 445111 WELD WITH DOLLAR WELD MACHINE EXPAND TAPER WITH GROTNES EXPAND MANDREL MILL AND DRILL WITH LAMB SPECIAL PURPOSE MACHINE CREW SIZE = 3.5 SOURCE: GM	LBR	.16 HRS	9.64	1.54	1.00	5.96	1.26	11.58	.20
5010102. PAINT 445112 SPRAY PAINT WITH BINKS PRIME AND PAINT SPRAYLINE CREW SIZE = 2 SOURCE: GM	LBR	.06 HRS	9.64	.59	1.00	5.96	1.26	4.43	.08
5010201. TUBE ID22461-3 TWIN TAPERED CIRCULAR TUBE LENGTH= 139 IN., SOURCE: LAMB	R M	1.00 UNITS	55.79	55.79	1.00	0.00	0.00	55.79	.98
5010202. PLATE ID22461 PER SPEC. SOURCE: LAMB	R M	1.00 UNITS	43.34	43.34	1.00	0.00	0.00	43.34	.76
5010203. CONE ID22461 PER SPEC. SOURCE: LAMB	R M	1.00 UNITS	19.37	19.37	1.00	0.00	0.00	19.37	.34
5010204. RING ID22461 PER SPEC. SOURCE: LAMB	R M	1.00 UNITS	6.55	6.55	1.00	0.00	0.00	6.55	.12
5010205. NUT 1.00-8 PER SPEC. SOURCE: LAMB	R M	4.00 UNITS	.26	1.04	1.00	0.00	0.00	1.04	.02
50121. MAT'L HANDLING 445121 HANDLING WITH CUSTOM PALLETS,MONORAIL HOISTS,TROLLEYS,HOOKS SOURCE: GM	LBR	.15 HRS	9.64	1.47	1.00	5.96	1.26	11.11	.20

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SECOND GENERATION HELIOSTAT 50K/YR.                                                       13.11.34.         DATE 02/09/81

   HELIO SUPP STRUCT   4451

DESCRIPTION                                 QTY/HRS/      REF UNIT  SUB TOTAL     F A C T O R S        TOTAL
                                           ANN. FAIL        COST               CRC  OVERHEAD  G_A               $/SM

        50122.
   INSPECTION          445122
 AUTOMATIC INSPECTION WITH SPECIAL   LBR       .07  HRS       9.64       .64   1.00   5.96    1.26       4.83    .08
 TOOL
 FLOOR INSPECTION
                       SOURCE: GM


   HELIO SUPP STRUCT   4451                                                                            158.     2.78
```

HELIOSTAT 4461

DESCRIPTION		QTY/HRS/ ANN. FAIL		REF UNIT COST	SUB TOTAL	FACTORS CRC	FACTORS OVERHEAD	FACTORS G_A	TOTAL	$/SM
7010201. DRIVE/PED/ELTRONC 446121 REMOVE 1311 LBS. DPE UNIT FROM FLAT BED. ROTATE IT TO VERTICAL; POSITION THE PEDESTAL SECTION OVER TAPERED FOUNDATION CAP; ORIENT DRIVE UNIT RELATIVE TO TRUE NORTH; INSTALL ON FOUNDATION USING HYDRAULICS DIESEL CRANE MODIFIED TO ADD MANIPULATION. 3 CREWS (16 WK BASE) EACH: 1 EQUIPMENT OPERATOR 1 MILLWRIGHT 1 LABORER	LBR	.54	HRS	15.12	8.19	1.00	1.70	1.00	13.93	.24
7010202. REFLECTOR PANELS 446122 REMOVE PANELS FROM PALLETS, POSITIONING PANELS RELATIVE TO PEDESTAL/DRIVE UNIT USING SPECIALIZED EQUIPMENT; BOLT PANELS TO PEDESTAL/DRIVE UNIT 2 CRANE/MANIPULATORS 3 CREWS (16 WK BASE) EACH: 1 FORKLIFT OPERATOR 1 TRAVELIFT OPERATOR 2 MILLWRIGHTS 2 LABORERS	LBR	2.44	HRS	15.12	36.91	1.00	1.70	1.00	62.74	1.10
HELIOSTAT 4461									77.	1.35

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SECOND GENERATION HELIOSTAT 50K/YR.                                                  13.11.34.        DATE 02/09/81

   SENSOR/CALIB EQ     4462

DESCRIPTION                                       QTY/HRS/       REF UNIT  SUB TOTAL     F A C T O R S        TOTAL
                                                 ANN. FAIL         COST                CRC  OVERHEAD  G_A               $/SM

        70203.
   CALIBRATE           44622
  ONE VOLT-OHM METER AND ONE          LBR         .00  HRS       15.12         .06  1.00    1.70     1.00          .10     .00
  OSCILLOSCOPE TO CALIBRATE DIGITAL
  EYE UNITS.
  1 CREW (2 DAY BASE) EACH;
  1 FIELD ENGINEER
  EFFORT IS CONCURRENT AND IN ASSOC-
  CIATION WITH INSTALLATION.
  16.7 UNITS (2/FIELD)


   SENSOR/CALIB EQ     4462                                                                                 0.       .00
```

ELECTRICAL/DISTRIB 4463

DESCRIPTION		QTY/HRS/ ANN. FAIL		REF UNIT COST	SUB TOTAL	FACTORS CRC	FACTORS OVERHEAD	FACTORS G_A	TOTAL	$/SM
70302. INSTALL CABLE 44631 EMPLOY VIBRATORY DIESEL PLOW TO BURY ONE POWER/FIBEROPTICS CABLE. 3 CREWS (16 WK BASE) EACH; 1 CABLE PLOW OPERATOR 2 LABORERS	LBR	.98	HRS	15.12	14.76	1.00	1.70	1.00	25.10	.44
70303. PWR TR/DISTRIB PNL 44632 INSTALL POWER TRANSFORMER/ DISTRIBUTION PANELS USING 1 TRUCK AND 1 FORKLIFT 1 CREW (3 DAY BASE) EACH; 1 TRUCK DRIVER 1 FORKLIFT OPERATOR 1 MILLWRIGHT 2 LABORERS	LBR	.03	HRS	15.12	.43	1.00	1.70	1.00	.73	.01
70304. CONN.C/O&CLOSE OUT 44633 USE 1 SPECIAL TEST SET AND STANDARD ELECTRICIAN TOOLS TO CONNECT, CHECK AND CLOSE OUT POWER/FIBEROPTICS CABLE, POWER/ TRANSFORMER/DISTRIBUTION PANELS AND HELIOSTAT ELECTRONICS. C/O INCLUDES VERIFICATION OF PROPER DATA AT VARIOUS LEVELS. 2 CREWS (16 WK BASE) EACH; 1 ELECTRICIAN 1 LABORER	LBR	.65	HRS	15.12	9.84	1.00	1.70	1.00	16.73	.29
ELECTRICAL/DISTRIB 4463									43.	.75

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SECOND GENERATION HELIOSTAT 50K/YR.                                              13.11.34.      DATE 02/09/81

   ALIGN HELIOSTATS    4464

DESCRIPTION                                        QTY/HRS/      REF UNIT  SUB TOTAL    F A C T O R S        TOTAL
                                                   ANN. FAIL       COST               CRC  OVERHEAD  G_A                $/SM


   ALIGN HELIOSTATS    4464                             .74  HRS     15.12     11.18   1.00   1.70     1.00     19.00     .33
1
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   FIELD SUPPORT       4465

DESCRIPTION                                 QTY/HRS/     REF UNIT  SUB TOTAL    F A C T O R S        TOTAL
                                           ANN. FAIL       COST              CRC  OVERHEAD  G_A                $/SM

          70501.
   INSTALLATION MGMT   44651
 OVERALL MANAGEMENT OF FIELD EFF-   LBR        .11  HRS      15.12       1.62  1.00   1.70    1.00        2.75   .05
 ORT. 1 FIELD MANAGER (18 WK BASE)

        7050201.
   SUPERVISION         446521
 1 LOGISTICS SUPERVISOR             LBR        .11  HRS      15.12       1.62  1.00   1.70    1.00        2.75   .05
 (18 WK BASE)

        7050202.
   RECORDS             446522
 KEEP ACCOUNTABLE RECORDS FOR       LBR        .11  HRS      15.12       1.62  1.00   1.70    1.00        2.75   .05
 FIELD MATERIALS , COMPLETIONS
 TO SPECIFICATIONS, RECORDS, ETC.
 1 RECORDS CLERK (18 WK BASE)

        7050203.
   FIELD COORDINATION  446523
 COORDINATE MATERIAL HANDLING,      LBR        .43  HRS      15.12       6.46  1.00   1.70    1.00       10.99   .19
 MOVEMENT, AND SCHEDULES.
 1 FIELD COORDINATOR (18 WK BASE)

        7050204.
   PERSONNEL           446524
 KEEPS PERSONNEL FILES, ADMINIS-    LBR        .11  HRS      15.12       1.62  1.00   1.70    1.00        2.75   .05
 TERS HOUSING AND BENEFITS FOR
 FIELD PERSONNEL, TIME RECORDS,ETC
 1 PERSONNEL CLERK (18 WK BASE)

          70503.
   QUALITY CONTROL     44653
 OVERSEE AND ASSURE QUALITY OF      LBR        .15  HRS      15.12       2.33  1.00   1.70    1.00        3.96   .07
 INSTALLATIONS THROUGH FIELD
 INSPECTION, PRACTICES REVIEW,
 AND DECREPANT MATERIAL, FAILURE
 AND CORRECTIVE ACTION REPORTS.
 1 QUAL.ASSUR. REP.
 (16 WK BASE)

          70504.
   FIELD ENGINEERING   44654
 PROVIDE ENGINEERING SUPPORT DUR-   LBR        .15  HRS      15.12       2.33  1.00   1.70    1.00        3.96   .07
 ING INSTALLATION AND CHECKOUT.
 1 STAFF (16 WK BASE)
 1 MECHANICAL/SAFETY ENGINEER
 1 ELECTRONICS/CONTROL ENGINEER


   FIELD SUPPORT       4465                                                                       30.
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SECOND GENERATION HELIOSTAT 50K/YR.                                      13.11.34.       DATE 02/09/81

   PACK & TRANS        4466

DESCRIPTION                                  QTY/HRS/      REF UNIT  SUB TOTAL     F A C T O R S        TOTAL
                                            ANN. FAIL       COST                CRC  OVERHEAD  G_A               $/SM

      7060101.
   DRIVE                 44661-1
 SPECIALIZED PALLET FOR HOLDING      P P      1.00 UNITS       3.56       3.56   1.00    0.00     0.00       3.56    .06
 THE PEDESTAL/DRIVE/MAIN BEAM
 ASSEMBLY    QTY PER REUSABLE
 PALLET = 4   QTY OF PALLETS PER
 TRAILER BER = 3
 ASSUME A 10 YR LIFE FOR PALLETS
 QTY OF PALLETS NEEDED FOR 50000
 PROD/YR = 910

      7060102.
   REFLECTOR             44661-2
 SPECIALIZED PALLET FOR HOLDING      P P      1.00 UNITS      11.13      11.13   1.00    0.00     0.00      11.13    .20
 MIRROR MODULES VERTICALLY,HELD
 IN PLACE BY SHIPPING BANDS AT 2
 POINTS   QTY OF PANELS PER PAL-
 LET = 4(2 HELIOS WORTH)
 REUSABLE PALLETS - ASSUME A 10
 YEAR LIFE FOR PALLETS  QUANTITY
 NEEDED FOR 50000 PROD/YR = 1820

      7060103.
   DISTRIB ELECT         44661-3
 TRANSFORMERS STRAPPED TO REUSABLE   P P      1.00 UNITS        .05        .05   1.00    0.00     0.00        .05    .00
 PALLETS

      7060201.
   DRIVE                 44662-1
 SPECIALIZED TRAILER BEDS REMAIN AT  LBR       .90  HRS        9.90       8.91   1.00    2.95     1.15      30.16    .53
 SITE UNTIL UNLOADED
 WT PER DRIVE ASSY= 1311 LBS
 12 DRIVE ASSYS PER TRAILER BED
 WEIGHTED MEAN ROUND TRIP
 DISTANCE = 288 MILES
 FLEET TRANSPORTATION   DAC RATES
1
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```
SECOND GENERATION HELIOSTAT 50K/YR.                                                    13.11.34.       DATE 02/09/81

   PACK & TRANS        4466

DESCRIPTION                                    QTY/HRS/        REF UNIT   SUB TOTAL        F A C T O R S         TOTAL
                                              ANN. FAIL          COST                  CRC  OVERHEAD  G_A                  $/SM

      7060202.
   REFLECTOR             44662-2
 ONE LOWBOY PULLED BY ONE TRUCK CAB  LBR       5.40  HRS          9.90      53.46   1.00    2.95    1.15       181.01     3.18
 ONE PALLET PER LOWBOY,PALLET LIFT-
 ED FROM LOWBOY WITH FORKTRUCK
 QTY: 4 PANELS(TWO HELIOSTATS WORTH
 OF MIRROR MODULES
 FLEET TRANSPORTATION
 DAC RATES
 WEIGHT: 2216 LBS EACH PLUS WT OF
 PALLET
 WEIGHTED MEAN ROUND TRIP
 DISTANCE = 288 MILES

    706020201.
   PERMITS               44662-2-1
 PERMITS REQUIRED FOR OVERSIZED      P P       1.00 UNITS         6.50       6.50   1.00    0.00    0.00         6.50      .11
 LOAD: CALIF-$ 3.00
       ARIZ -$10.00
            -----
           $13.00 PER LOAD OF 2
                  HELIOS WORTH OF
                  MIRROR MODULES

      7060203.
   DISTRIB ELECT         44662-3
 TRANSFORMER WEIGHT = 2600 LBS       LBR        .00  HRS          9.90        .04   1.00    2.95    1.15          .13      .00
 12 PER TRUCK LOAD        DAC TRANSPT

      7060204.
   REBAR CAGE/CONE       44662-4
 28 PER LOAD  ASSUME DAC TRANSPORTA  LBR        .13  HRS          9.90       1.27   1.00    2.95    1.15         4.31      .08
 TION FROM ASSY LOCATION (CLOSER TO
 SITE THAN FACTORY)    382 LBS EACH

      7060205.
   CABLING               44662-5
 CABLING WT. PER HELIO = 34.75 LBS   LBR        .01  HRS          9.90        .09   1.00    2.95    1.15          .32      .01
 THEREFORE,CABLING FOR 1151 HELIOS
 TRANSPORTED PER TRUCKLOAD


   PACK & TRANS        4466                                                                              237.17     4.17
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SECOND GENERATION HELIOSTAT INVESTMENT COSTS - (50K/YEAR, 11TH YEAR)                14.22.07.        DATE 02/06/81

   PLANT CONTROL        4350

DESCRIPTION                                        QTY/HRS/       REF UNIT   SUB TOTAL      F A C T O R S          TOTAL
                                                  ANN. FAIL        COST                 CRC  OVERHEAD  G_A               $/SM

   4305030101.
   COMPUTER-PERH        KDF11-HF
 MFG. DIGITAL EQUIPMENT CO. (DEC)    P P      9.24 UNITS        .35       3.24   1.00    0.00     0.00       3.24    .06
   LSI11 MICROCOMPUTER          $4190
   FLOATING POINT HARDWARE        390
   SERIAL INTERFACE               465
   KEYBOARD PRINTER              1600
   4X4 BACKPLANE/PWR SUPPLY      1300

   4305030102.
   MASS STORAGE         RXV21-BA
 MFG. DIGITAL                        P P      9.24 UNITS        .16       1.51   1.00    0.00     0.00       1.51    .03
   FLOPPY DISC

   4305030103.
   DISPLAY CONSOLE      ISC-8001G
 MFG. ISC                            P P      9.24 UNITS        .11        .98   1.00    0.00     0.00        .98    .02
   COLOR CRT DISPLAY STATION

   4305030104.
   HARD COPY/LOGGER     LA180
 MFG. DIGITAL                        P P      9.24 UNITS        .09        .82   1.00    0.00     0.00        .82    .01
   150 CHARACTER/SEC (CPS) DATA LOGGER
   $1000 EACH, QUOTE IS FOR 4

   4305030105.
   CONSOLE RACKS        2-42B-1-A-2Y-30
 MFG. AMCO                           P P      9.24 UNITS        .02        .20   1.00    0.00     0.00        .20    .00
   2 BAY CONSOLE

   4305030106.
   WWV UPDATED CLOCK    60-DC
 MFG. TRUTIME                        P P      9.24 UNITS        .03        .31   1.00    0.00     0.00        .31    .01
   TIME OF DAY CLOCK THAT IS
   SYNCHRONIZED BY WWV

   4305030107.
   RSX11-M SYS SFTWRE   RSV11-S
 MFG. DIGITAL                        P P      9.24 UNITS        .02        .17   1.00    0.00     0.00        .17    .00
   RUN ONLY VERSION OF RSX11-M
   OPERATING SYSTEM

   4305030108.
   DATA ACQTIN PKG      ADK11-KT
 MFG. DIGITAL                        P P      9.24 UNITS        .08        .74   1.00    0.00     0.00        .74    .01
   REAL TIME DATA ACQUISITION PACKAGE
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SECOND GENERATION HELIOSTAT INVESTMENT COSTS - (50K/YEAR, 11TH YEAR)                    14.22.07.        DATE 02/06/81

   PLANT CONTROL       4350

DESCRIPTION                                           QTY/HRS/      REF UNIT  SUB TOTAL      F A C T O R S       TOTAL
                                                     ANN. FAIL        COST               CRC  OVERHEAD  G_A              $/SM

     43050302.
   HRDWARE DESGN ENG    43532
 HAC HARDWARE DESIGN                         LBR         .099 HRS      16.46       1.63   1.00    2.14     1.35       4.72     .08

     43050303.
   SFTWARE DESGN ENG    43533
 HAC SOFTWARE DESIGN                         LBR         .116 HRS      16.50       1.91   1.00    2.14     1.35       5.53     .10

     43050304.
   INSTL AND CHKOUT     43534
 HARDWARE COSTS                              LBR         .113 HRS      10.66       1.20   1.00    2.14     1.35       3.48     .06
 SOFTWARE AND HARDWARE ENGIN.
 SETUP, TEST HARDWARE/SFTWARE FUNCTIONS
 RING OUT WIRING.


   PLANT CONTROL       4350                                                                                        22.       .38
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Appendix D-4
OPERATIONS AND MAINTENANCE COSTS

The costs presented in the tables contained in Appendix D-4 indicates the total cost to operate a field of 5412 heliostats during the first year of operations. Costs for each non-labor item or activity have been collected by the major categories of Spares, Repair parts, Other, Corrective Maintenance, and Scheduled Maintenance. The sum of the costs for a given category tie directly to column totals shown in the summary of costs at the beginning of Appendix D-4, and in Table 27.

Costs have been developed in accordance with the costing approach described in Section 6.4.3 and presented in terms of annual operations costs. In exception, the costs for initial spares and miscellaneous equipment at the end of this appendix are presented in terms of cost per heliostat and the description for Appendix D-3 is more appropriate.

The following provides a further description of the contents of each column in the Tables.

1. Cost Element, CBS or PN and Technical Cost Drivers. This column provides the description and reference numbers for each costed line item. The first line of the description gives the reference number used by the LEADER system to logically orient the various cost elements within a WBS hierarchy. The next line gives cost element title and the Sandia CBS number down to the required CBS reporting level. For lower levels, the vendor part number, MDAC drawing or part number, standard specification number, or description index number is provided. Following lines provide a description of the element which may include: technical cost drivers, activity descriptions, and for important cost elements, the source of the estimate.
2. Cost Classification (no heading). This column indicates whether the line refers to L--labor or N--non-labor.

3. Quantity/Hours/Annual Failures. Annual failures indicate the total number of failures in the first year of operation in terms of spare or repair part end items, rather than heliostats. Hours indicate the base maintenance hours required in the first year before adjustment for efficiency and rework.

4. Reference Unit Cost. The meaning of the value shown as the reference unit cost depends on the type of cost as follows:

SPARES -- the unit cost of a spare

Repair Parts -- the unit cost of the end item spare part. The repair part cost is calculated as a percentage of this value.

OTHER -- the cost to transport and package a spare or repair part the unit cost of a commodity such as fuel (e.g., $/G), or the monthly cost of a service contract. Where transportative costs are involved, the values occur in pairs for transport and packaging. Where four numbers are shown, the first pair is for spares transport and packaging and the second pair for repair parts.

Corrective Maintenance -- the hourly labor rate including fringe and other allocations at the power plant. This cost is shown in pairs with the first line relating to remove and replace labor and the second relating to bench labor.

Schedule Maintenance -- the hourly labor rate including fringe and other allocations.

5. Subtotal. The subtotal is the product of the value in the Hours/Annual failures column and the value in the Reference unit column.

6. Factors. The factors columns are subheaded Adjustment, Overhead and G and A. The Overhead and G and A columns are not used since all operations and maintenance items at the collector field are assumed costed directly or covered in other accounts. The adjustment factor is determined as the following products

Spares -- % discarded and refix factor
Repair Parts -- % repaired and refix factor
Other -- refix factor and % spared or repaired
Corrective Maintenance -- the efficiency factor and refix factor
Scheduled Maintenance -- the efficiency factor

7. Total. The total column is the product of the value in the subtotal column and the value in the adjustment factor column.

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"SECOND GENERATION HELIOSTAT INVESTMENT AND FIRST YEAR O&M COST - (50K/YEAR)          14.50.13.        DATE:  81/02/10.

 WBS NUMBER AND TITLE                       +--OPERATIONS AND MAINTENANCE------------+
                                            +---NON-LABOR-------+ +---LABOR----+
                                             SPARES REP PT OTHER CORRECT SCHED  TOTAL

                    GRAND TOTAL                 37.      9.  105.    173.   84.   407.
4410                  REFLECTOR ASMBLY           3.      0.    1.      7.    0.    11.
4411                    REFLECTIVE SURFACE       3.      0.    1.      6.    0.    10.
4412                    MIRROR BACK STRU         0.      0.    0.      1.    0.     1.
4420                  DRIVE UNIT                21.      9.    4.    156.    0.   190.
4421                    AZIMUTH DRIVE            1.      5.    0.     55.    0.    61.
4422                    ELEVATION                1.      3.    0.     14.    0.    18.
4423                    MOTOR TOTAL             15.      0.    2.     82.    0.    99.
4424                    POS/LIMIT INDICATO       4.      0.    1.      2.    0.     7.
4425                    PWR SPLY/DIST            1.      0.    0.      3.    0.     4.
4430                  CONTROL/INSTRMT EQ        13.      0.    0.      7.    0.    20.
4432                    FIELD CONTROL            0.      0.    0.      0.    0.     0.
4433                    CNTRL/SIG EQ            13.      0.    0.      7.    0.    20.
4450                  HELIO SPT ST/PR EN         0.      0.    0.      3.    0.     3.
4451                    PEDESTAL                 0.      0.    0.      3.    0.     3.
OM000                 COMMON O&M                 0.      0.   79.      0.   84.   164.
OM200                   MAINT.MATERIAL           0.      0.   79.      0.    0.    79.
OM300                   MAINTENANCE LABOR        0.      0.    0.      0.   84.    84.
4100                  SITE/STRU/MISC EQ          0.      0.   17.      0.    0.    17.
4130                    MISC.EQUIP               0.      0.   17.      0.    0.    17.
4300                  ELECT PLT EQ               0.      0.    2.      0.    0.     2.
4350                    PLANT CONTROL            0.      0.    2.      0.    0.     2.




4100                  SITE/STRU/MISC EQ          0.      0.   64.      0.    0.    65.
4130                    MISC.EQUIP               0.      0.   64.      0.    0.    65.


4800                  INITIAL SPARES             8.      0.    0.      0.    0.     8.
4841                    HELIO INIT SPARES        8.      0.    0.      0.    0.     8.
1
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OPERATIONS AND MAINTENANCE FIRST YEAR COSTS, 5412 HELIOSTATS - (50K/YEAR)            14.17.13.          DATE 02/06/81

   SPARES

DESCRIPTION                                         QTY/HRS/      REF UNIT  SUB TOTAL     F A C T O R S          TOTAL
                                                   ANN. FAIL        COST              ADJ  OVERHEAD  G_A                  $/SM

          101.
   REFLECTIVE SURFACE  4411
  PART NO. ID22462-501                         N     59.86 FAIL      40.47   2422.40   1.05    0.00     0.00     2543.52   .01
  REMOVE AND REPLACE THE MIRROR MODULE
  PANELS WITH A MOBILE CRANE AND SLING.
  NO REPAIRS MADE, ALWAYS DISCARDED.
  MINOR CRACKS MAY BE REPAIRED BY
  ADHESIVE BOND.
  FAILURE RATE/YR/PANEL  -  .00079

  WOOD CRATE SHIPPING          6.93/CWT

          102.
   MIRROR BACK STRU    4412
  PART NO. ID22463-1                           N       .95 FAIL       0.00      0.00   1.05    0.00     0.00        0.00  0.00
  REFLECTOR SUPPORT STRUCTURE ALWAYS
  REPAIRED IN PLACE.
  FAILURE RATE/YR/PANEL  -  .00095

  REPAIR PARTS SHIPPED IN CARDBOARD BOX
                               5.55/CWT

          201.
   AZIMUTH DRIVE       4421
  PART NO. ID22494-1                           N     52.93 FAIL     352.00  18631.13    .03    0.00     0.00      614.83   .00
  COMPLETE AZIMUTH DRIVE ASSEMBLY IS
  REPLACED UPON FAILURE.
  BENCH REPAIR:
    REPLACE DEFECT GEAR TRAIN COMPONENTS,
    LUBRICATE HARMONIC SECTION WITH
    HEAVY DUTY OIL AND PACK GEAR TRAIN
    WITH GREASE
  FAILURE RATE/YR/DRIVE  -  .00978

  SPARES TRANSPORTED IN COVERED WOODEN
  SKID                         6.18/CWT

      2020202.
    JACK-ELEVATION      ID22497-1
  REPLACE ELEVATION DRIVE MOTOR                N     49.14 FAIL     260.44  12798.35    .08    0.00     0.00      985.47   .00
  UPON COMPONENT FAILURE
  BENCH REPAIR:
    REPLACEMENT OF DEFECTIVE COMPONENTS.
  ANNUAL FAILURE RATE/JACK  -  .00908

  SPARES STRAPPED TO PALLET   6.18/CWT
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OPERATIONS AND MAINTENANCE FIRST YEAR COSTS, 5412 HELIOSTATS - (50K/YEAR)            14.17.13.        DATE 02/06/81

   SPARES

DESCRIPTION                                          QTY/HRS/      REF UNIT  SUB TOTAL     F A C T O R S        TOTAL
                                                    ANN. FAIL       COST               ADJ  OVERHEAD  G_A                $/SM

        20302.
   AZ.DRIVE MOTOR      40ID22487-501
  AZIMUTH DRIVE MOTOR IS REPLACED UPON    N   120.21 FAIL      58.16   6991.23   1.10   0.00    0.00     7690.35    .02
  COMPONENT FAILURE
  BENCH REPAIR:
    REPLACE INC. ENCODER, MOTOR CONTROLLER
    FAILED MOTORS ARE DISCARDED
  ANNUAL FAILURE RATE/MOTOR UNIT - .0065
  MEAN TIME TO REPAIR - 1.7HRS

  SHIPPED IN CARDBOARD BOX    6.18/CWT

        20303.
   EL.DRIVE MOTOR      40ID22487-1
  ELEVATION DRIVE MOTOR IS REPLACED UPON  N   120.21 FAIL      58.16   6991.23   1.10   0.00    0.00     7690.35    .02
  COMPONENT FAILURE
  BENCH REPAIR:
    REPLACE INC. ENCODER, MOTOR CONTROLLER
    FAILED MOTORS ARE DISCARDED
  ANNUAL FAILURE RATE/MOTOR UNIT - .0065
  MEAN TIME TO REPAIR - 1.9HRS

  SHIPPED IN CARDBOARD BOX    6.18/CWT

      2040201.
   INCR.ENCODER        40ID22571-501
  INCREMENTAL ENCODER IS REPLACED AT      N    24.30 FAIL      23.23    564.57   1.10   0.00    0.00      621.03    .00
  BENCH UPON FAILURE.
  ANNUAL FAILURE RATE/ENCODER  -  .0049

  SHIPPED IN CARDBOARD BOX    6.18/CWT

      2040202.
   INCR.ENCODER        40ID22571-1
  INCREMENTAL ENCODER IS REPLACED AT      N    24.30 FAIL      23.23    564.57   1.10   0.00    0.00      621.03    .00
  BENCH UPON FAILURE.
  ANNUAL FAILURE RATE/ENCODER  -  .0049

  SHIPPED IN CARDBOARD BOX    6.18/CWT

        20404.
   MOTOR CONTROL       40T619
  MOTOR CONTROL IS REPLACED AND THEN      N    49.68 FAIL      47.45   2357.42   1.10   0.00    0.00     2593.16    .01
  REPAIRED ON SITE.
  ANNUAL FAILURE RATE/CONTROL  -  .00459

  SHIPPED IN WOODEN BOX       6.18/CWT
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OPERATIONS AND MAINTENANCE FIRST YEAR COSTS, 5412 HELIOSTATS - (50K/YEAR) 14.17.13. DATE 02/06/81

SPARES

DESCRIPTION		QTY/HRS/ ANN. FAIL	REF UNIT COST	SUB TOTAL	FACTORS ADJ	OVERHEAD	G_A	TOTAL	$/SM
2050201. FLD.PWR/DATA CABLE 40CLX ALL FIELD POWER/DATA CABLES ARE REPAIRD IN PLACE BY STD. ELECTRICAL METHODS INCLUDING REPLACEMENT OF TERMINALS AND CONNECTORS ANNUAL FAILURE RATE/CABLE - .00073 SHIPPED IN FIBERBOARD BOX 5.55/CWT	N	.73 FAIL	0.00	0.00	1.00	0.00	0.00	0.00	0.00
2050202. POWER TRANSFORMER 40225T(19)H POWER TRANSFORMERS ARE REPLACED UPON INTERNAL COMPONENT FAILURE WITH A FORKLIFT OR MOBILE CRANE AND SLING. ANNUAL FAILURE RATE/TRANSFORMER - .00665 SHIPPED TO OFFSITE REPAIR FACILITY STRAPPED TO PALLET 3.97/CWT	N	6.65 FAIL	0.00	0.00	1.05	0.00	0.00	0.00	0.00
2050203. PWR.DISTRIB PANEL 40SQ.DH-4172-4N ALL POWER DIST. PANELS ARE REPAIRED IN PLACE. ANNUAL FAILURE RATE/PANEL - .00499 SHIPPED IN WOOD BOX 6.18/CWT	N	4.99 FAIL	0.00	0.00	1.00	0.00	0.00	0.00	0.00
2050205. HEL.PWR/DATA CABLE CLX-ALS HELIOSTAT POWER/DATA CABLES ARE REPLACED UPON FAILURE ANNUAL FAILURE RATE/CABLE - .00037 ASSUMES SHIPMENT IN ECONOMIC QUANTITY 5.55/CWT	N	10.01 FAIL	58.10	581.71	1.05	0.00	0.00	610.79	.00
30202. DATA DIST.INTERFAC 443202 DDI IS ALWAYS REPAIRED. BENCH REPAIR CONSISTS OF REPLACING THE DDI CIRCUIT CARDS AND DEFECTIVE COMPONENTS. ANNUAL FAILURE RATE/INTERFACE - .0131 SHIPPED IN CARDBOARD CONTAINER 6.18/CWT	N	26.21 FAIL	0.00	0.00	1.05	0.00	0.00	0.00	0.00

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OPERATIONS AND MAINTENANCE FIRST YEAR COSTS, 5412 HELIOSTATS - (50K/YEAR)              14.17.13.        DATE 02/06/81

   SPARES

DESCRIPTION                                      QTY/HRS/      REF UNIT  SUB TOTAL     F A C T O R S         TOTAL
                                                ANN. FAIL        COST                ADJ  OVERHEAD  G_A                  $/SM

        30302.
   HELIO CONTROLLER    443302
  HELIOSTAT CONTROLLER IS ALWAYS REPLACED N    59.45 FAIL     205.00  12187.96   1.05    0.00     0.00   12797.36     .04
  UPON FAILURE DETECTED BY THE MOBIL TEST
  VAN AND OPERATIONAL INDICATIONS OF
  SOFTWARE PROBLEMS.
  ANNUAL FAILURE RATE/CONTROLLER - .00549

  SHIPPED IN CARDBOARD CONTAINER
                              6.18/CWT

      5010201.
   TUBE-CAP-COVER      ID22461-1
  ALL PEDESTAL REPAIRS ARE MADE IN PLACE  N      .87 FAIL       0.00      0.00   1.00    0.00     0.00       0.00    0.00
  USING STD REPAIR PRACTICES
  ANNUAL FAILURE RATE/PED  -  .00087

  REPAIR PARTS SHIPPED IN CARDBOARD BOX
                              5.55/CWT

      5010204.
   J BOX               40ID40046-9
  J-BOXES ARE ALL REPAIRED IN PLACE       N     3.33 FAIL       0.00      0.00   1.00    0.00     0.00       0.00    0.00
  ANNUAL FAILURE RATE/BOX  -  .00333

  REPAIR PARTS SHIPPED IN CARDBOARD BOX
                              6.18/CWT

   SPARES                                                                                          36768.       .11
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REPAIR PTS

DESCRIPTION		QTY/HRS/	REF UNIT	SUB TOTAL	FACTORS			TOTAL	
		ANN. FAIL	COST		ADJ	OVERHEAD	G_A		$/SM
101. REFLECTIVE SURFACE 4411 PART NO. ID22462-501 REMOVE AND REPLACE THE MIRROR MODULE PANELS WITH A MOBILE CRANE AND SLING. NO REPAIRS MADE, ALWAYS DISCARDED. MINOR CRACKS MAY BE REPAIRED BY ADHESIVE BOND. FAILURE RATE/YR/PANEL - .00079 WOOD CRATE SHIPPING 6.93/CWT	N	11.06 FAIL	0.00	0.00	1.00	0.00	0.00	0.00	0.00
102. MIRROR BACK STRU 4412 PART NO. ID22463-1 REFLECTOR SUPPORT STRUCTURE ALWAYS REPAIRED IN PLACE. FAILURE RATE/YR/PANEL - .00095 REPAIR PARTS SHIPPED IN CARDBOARD BOX 5.55/CWT	N	1.90 FAIL	0.00	0.00	1.00	0.00	0.00	0.00	0.00
201. AZIMUTH DRIVE 4421 PART NO. ID22494-1 COMPLETE AZIMUTH DRIVE ASSEMBLY IS REPLACED UPON FAILURE. BENCH REPAIR: REPLACE DEFECT GEAR TRAIN COMPONENTS, LUBRICATE HARMONIC SECTION WITH HEAVY DUTY OIL AND PACK GEAR TRAIN WITH GREASE FAILURE RATE/YR/DRIVE - .00978 SPARES TRANSPORTED IN COVERED WOODEN SKID 6.18/CWT	N	52.93 FAIL	387.68	20519.87	.25	0.00	0.00	5129.97	.02
2020202. JACK-ELEVATION ID22497-1 REPLACE ELEVATION DRIVE MOTOR UPON COMPONENT FAILURE BENCH REPAIR: REPLACEMENT OF DEFECTIVE COMPONENTS. ANNUAL FAILURE RATE/JACK - .00908 SPARES STRAPPED TO PALLET 6.18/CWT	N	49.14 FAIL	277.50	13636.81	.25	0.00	0.00	3409.20	.01

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OPERATIONS AND MAINTENANCE FIRST YEAR COSTS, 5412 HELIOSTATS - (50K/YEAR)          14.17.13.          DATE 02/06/81

   REPAIR PTS

DESCRIPTION                                          QTY/HRS/       REF UNIT  SUB TOTAL      F A C T O R S         TOTAL
                                                    ANN. FAIL        COST                  ADJ  OVERHEAD  G_A                  $/SM

         20302.
   AZ.DRIVE MOTOR      40ID22487-501
  AZIMUTH DRIVE MOTOR IS REPLACED UPON     N     22.21 FAIL        0.00        0.00   1.00    0.00     0.00         0.00     0.00
  COMPONENT FAILURE
  BENCH REPAIR:
    REPLACE INC. ENCODER, MOTOR CONTROLLER
    FAILED MOTORS ARE DISCARDED
  ANNUAL FAILURE RATE/MOTOR UNIT - .0065
  MEAN TIME TO REPAIR - 1.7HRS

  SHIPPED IN CARDBOARD BOX    6.18/CWT

         20303.
   EL.DRIVE MOTOR      40ID22487-1
  ELEVATION DRIVE MOTOR IS REPLACED UPON   N     22.21 FAIL        0.00        0.00   1.00    0.00     0.00         0.00     0.00
  COMPONENT FAILURE
  BENCH REPAIR:
    REPLACE INC. ENCODER, MOTOR CONTROLLER
    FAILED MOTORS ARE DISCARDED
  ANNUAL FAILURE RATE/MOTOR UNIT - .0065
  MEAN TIME TO REPAIR - 1.9HRS

  SHIPPED IN CARDBOARD BOX    6.18/CWT

       2040201.
   INCR.ENCODER        40ID22571-501
  INCREMENTAL ENCODER IS REPLACED AT       N      4.49 FAIL        0.00        0.00   1.00    0.00     0.00         0.00     0.00
  BENCH UPON FAILURE.
  ANNUAL FAILURE RATE/ENCODER  -  .0049

  SHIPPED IN CARDBOARD BOX    6.18/CWT

       2040202.
   INCR.ENCODER        40ID22571-1
  INCREMENTAL ENCODER IS REPLACED AT       N      4.49 FAIL        0.00        0.00   1.00    0.00     0.00         0.00     0.00
  BENCH UPON FAILURE.
  ANNUAL FAILURE RATE/ENCODER  -  .0049

  SHIPPED IN CARDBOARD BOX    6.18/CWT

         20404.
   MOTOR CONTROL       40T619
  MOTOR CONTROL IS REPLACED AND THEN       N      9.18 FAIL        0.00        0.00   1.00    0.00     0.00         0.00     0.00
  REPAIRED ON SITE.
  ANNUAL FAILURE RATE/CONTROL  -  .00459

  SHIPPED IN WOODEN BOX       6.18/CWT
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OPERATIONS AND MAINTENANCE FIRST YEAR COSTS, 5412 HELIOSTATS - (50K/YEAR)              14.17.13.        DATE 02/06/81

   REPAIR PTS

DESCRIPTION                                         QTY/HRS/     REF UNIT  SUB TOTAL     F A C T O R S         TOTAL
                                                   ANN. FAIL       COST                ADJ  OVERHEAD  G_A                 $/SM

      2050201.
   FLD.PWR/DATA CABLE  40CLX
 ALL FIELD POWER/DATA CABLES ARE REPAIRD N       .73 FAIL        0.00       0.00   1.00    0.00     0.00        0.00    0.00
 IN PLACE BY STD. ELECTRICAL METHODS
 INCLUDING REPLACEMENT OF TERMINALS AND
 CONNECTORS
 ANNUAL FAILURE RATE/CABLE  -  .00073

 SHIPPED IN FIBERBOARD BOX   5.55/CWT

      2050202.
   POWER TRANSFORMER   40225T(19)H
 POWER TRANSFORMERS ARE REPLACED UPON    N       .12 FAIL     7938.43     950.23    .25    0.00     0.00      237.56     .00
 INTERNAL COMPONENT FAILURE WITH
 A FORKLIFT OR MOBILE CRANE AND SLING.
 ANNUAL FAILURE RATE/TRANSFORMER - .00665

 SHIPPED TO OFFSITE REPAIR FACILITY
 STRAPPED TO PALLET           3.97/CWT

      2050203.
   PWR.DISTRIB PANEL   40SQ.DH-4172-4N
 ALL POWER DIST. PANELS ARE REPAIRED IN  N      4.99 FAIL        0.00       0.00   1.00    0.00     0.00        0.00    0.00
 PLACE.
 ANNUAL FAILURE RATE/PANEL  -  .00499

 SHIPPED IN WOOD BOX     6.18/CWT

      2050205.
   HEL.PWR/DATA CABLE  CLX-ALS
 HELIOSTAT POWER/DATA CABLES ARE         N      1.85 FAIL        0.00       0.00   1.00    0.00     0.00        0.00    0.00
 REPLACED UPON FAILURE
 ANNUAL FAILURE RATE/CABLE  -  .00037

 ASSUMES SHIPMENT IN ECONOMIC QUANTITY
                             5.55/CWT

        30202.
   DATA DIST.INTERFAC  443202
 DDI IS ALWAYS REPAIRED. BENCH REPAIR    N     26.21 FAIL        0.00       0.00   1.05    0.00     0.00        0.00    0.00
 CONSISTS OF REPLACING THE DDI CIRCUIT
 CARDS AND DEFECTIVE COMPONENTS.
 ANNUAL FAILURE RATE/INTERFACE  -  .0131

 SHIPPED IN CARDBOARD CONTAINER
                             6.18/CWT
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OPERATIONS AND MAINTENANCE FIRST YEAR COSTS, 5412 HELIOSTATS - (50K/YEAR)            14.17.13.          DATE 02/06/81

   REPAIR PTS

DESCRIPTION                                         QTY/HRS/      REF UNIT  SUB TOTAL      F A C T O R S         TOTAL
                                                   ANN. FAIL       COST                  ADJ  OVERHEAD  G_A                $/SM

        30302.
   HELIO CONTROLLER    443302
 HELIOSTAT CONTROLLER IS ALWAYS REPLACED N     10.99 FAIL        0.00       0.00   1.00    0.00     0.00        0.00    0.00
 UPON FAILURE DETECTED BY THE MOBIL TEST
 VAN AND OPERATIONAL INDICATIONS OF
 SOFTWARE PROBLEMS.
 ANNUAL FAILURE RATE/CONTROLLER - .00549

 SHIPPED IN CARDBOARD CONTAINER
                            6.18/CWT

      5010201.
   TUBE-CAP-COVER      ID22461-1
 ALL PEDESTAL REPAIRS ARE MADE IN PLACE  N       .87 FAIL        0.00       0.00   1.00    0.00     0.00        0.00    0.00
 USING STD REPAIR PRACTICES
 ANNUAL FAILURE RATE/PED   -   .00087

 REPAIR PARTS SHIPPED IN CARDBOARD BOX
                            5.55/CWT

      5010204.
   J BOX               40ID40046-9
 J-BOXES ARE ALL REPAIRED IN PLACE       N      3.33 FAIL        0.00       0.00   1.00    0.00     0.00        0.00    0.00
 ANNUAL FAILURE RATE/BOX   -   .00333

 REPAIR PARTS SHIPPED IN CARDBOARD BOX
                            6.18/CWT


   REPAIR PTS                                                                                                   8777.      .03
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OPERATIONS AND MAINTENANCE FIRST YEAR COSTS, 5412 HELIOSTATS - (50K/YEAR) 14.17.13. DATE 02/06/81

OTHER

DESCRIPTION		QTY/HRS/ ANN. FAIL	REF UNIT COST	SUB TOTAL	FACTORS ADJ	OVERHEAD	G_A	TOTAL	$/SM
101.									
REFLECTIVE SURFACE 4411									
PART NO. ID22462-501	N	59.71 FAIL	15.03	897.44	1.11	0.00	0.00	991.67	.00
REMOVE AND REPLACE THE MIRROR MODULE PANELS WITH A MOBILE CRANE AND SLING. NO REPAIRS MADE, ALWAYS DISCARDED. MINOR CRACKS MAY BE REPAIRED BY ADHESIVE BOND.	N	59.71 FAIL	2.00	119.41	1.11	0.00	0.00	131.95	.00
FAILURE RATE/YR/PANEL - .00079									
WOOD CRATE SHIPPING 6.93/CWT									
102.									
MIRROR BACK STRU 4412									
PART NO. ID22463-1	N	10.24 FAIL	.39	3.96	.95	0.00	0.00	3.77	.00
REFLECTOR SUPPORT STRUCTURE ALWAYS REPAIRED IN PLACE.	N	10.24 FAIL	.15	1.54	.95	0.00	0.00	1.46	.00
FAILURE RATE/YR/PANEL - .00095									
REPAIR PARTS SHIPPED IN CARDBOARD BOX 5.55/CWT									
201.									
AZIMUTH DRIVE 4421									
PART NO. ID22494-1	N	52.92 FAIL	39.08	2068.18	.03	0.00	0.00	68.56	.00
COMPLETE AZIMUTH DRIVE ASSEMBLY IS	N	52.92 FAIL	6.00	317.51	.03	0.00	0.00	10.53	.00
REPLACED UPON FAILURE.	N	52.92 FAIL	1.95	103.34	1.07	0.00	0.00	110.77	.00
BENCH REPAIR: REPLACE DEFECT GEAR TRAIN COMPONENTS, LUBRICATE HARMONIC SECTION WITH HEAVY DUTY OIL AND PACK GEAR TRAIN WITH GREASE	N	52.92 FAIL	1.50	79.38	1.07	0.00	0.00	85.08	.00
FAILURE RATE/YR/DRIVE - .00978									
SPARES TRANSPORTED IN COVERED WOODEN SKID 6.18/CWT									
2020202.									
JACK-ELEVATION ID22497-1									
REPLACE ELEVATION DRIVE MOTOR	N	49.14 FAIL	10.01	491.98	.08	0.00	0.00	38.05	.00
UPON COMPONENT FAILURE	N	49.14 FAIL	7.00	343.99	.08	0.00	0.00	26.61	.00
BENCH REPAIR:	N	49.14 FAIL	.50	24.60	1.03	0.00	0.00	25.28	.00
REPLACEMENT OF DEFECTIVE COMPONENTS.	N	49.14 FAIL	1.75	86.00	1.03	0.00	0.00	88.37	.00
ANNUAL FAILURE RATE/JACK - .00908									
SPARES STRAPPED TO PALLET 6.18/CWT									

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OPERATIONS AND MAINTENANCE FIRST YEAR COSTS, 5412 HELIOSTATS - (50K/YEAR)            14.17.13.        DATE 02/06/81

   OTHER

DESCRIPTION                                             QTY/HRS/         REF UNIT  SUB TOTAL      F A C T O R S          TOTAL
                                                       ANN. FAIL           COST                  ADJ  OVERHEAD  G_A                  $/SM

        20302.
   AZ.DRIVE MOTOR      40ID22487-501
 AZIMUTH DRIVE MOTOR IS REPLACED UPON    N    120.24 FAIL         2.47     297.24   1.11    0.00     0.00        328.45     .00
 COMPONENT FAILURE                       N    120.24 FAIL         6.00     721.45   1.11    0.00     0.00        797.21     .00
 BENCH REPAIR:
   REPLACE INC. ENCODER, MOTOR CONTROLLER
   FAILED MOTORS ARE DISCARDED
 ANNUAL FAILURE RATE/MOTOR UNIT - .0065
 MEAN TIME TO REPAIR - 1.7HRS

 SHIPPED IN CARDBOARD BOX    6.18/CWT

        20303.
   EL.DRIVE MOTOR      40ID22487-1
 ELEVATION DRIVE MOTOR IS REPLACED UPON  N    120.24 FAIL         2.47     297.24   1.11    0.00     0.00        328.45     .00
 COMPONENT FAILURE                       N    120.24 FAIL         6.00     721.45   1.11    0.00     0.00        797.21     .00
 BENCH REPAIR:
   REPLACE INC. ENCODER, MOTOR CONTROLLER
   FAILED MOTORS ARE DISCARDED
 ANNUAL FAILURE RATE/MOTOR UNIT - .0065
 MEAN TIME TO REPAIR - 1.9HRS

 SHIPPED IN CARDBOARD BOX    6.18/CWT

      2040201.
   INCR.ENCODER        40ID22571-501
 INCREMENTAL ENCODER IS REPLACED AT      N     24.30 FAIL          .05       1.20   1.25    0.00     0.00          1.50     .00
 BENCH UPON FAILURE.                     N     24.30 FAIL         6.00     145.80   1.25    0.00     0.00        181.96     .00
 ANNUAL FAILURE RATE/ENCODER   -  .0049

 SHIPPED IN CARDBOARD BOX    6.18/CWT

      2040202.
   INCR.ENCODER        40ID22571-1
 INCREMENTAL ENCODER IS REPLACED AT      N     24.30 FAIL          .05       1.20   1.25    0.00     0.00          1.50     .00
 BENCH UPON FAILURE.                     N     24.30 FAIL         6.00     145.80   1.25    0.00     0.00        181.96     .00
 ANNUAL FAILURE RATE/ENCODER   -  .0049

 SHIPPED IN CARDBOARD BOX    6.18/CWT

        20404.
   MOTOR CONTROL       40T619
 MOTOR CONTROL IS REPLACED AND THEN      N     48.60 FAIL          .04       2.10   1.25    0.00     0.00          2.62     .00
 REPAIRED ON SITE.                       N     48.60 FAIL        12.00     583.20   1.25    0.00     0.00        727.83     .00
 ANNUAL FAILURE RATE/CONTROL   -  .00459

 SHIPPED IN WOODEN BOX       6.18/CWT
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OPERATIONS AND MAINTENANCE FIRST YEAR COSTS, 5412 HELIOSTATS - (50K/YEAR)              14.17.13.         DATE 02/06/81

   OTHER

DESCRIPTION                                       QTY/HRS/       REF UNIT  SUB TOTAL     F A C T O R S        TOTAL
                                                  ANN. FAIL       COST                 ADJ  OVERHEAD  G_A              $/SM

      2050201.
   FLD.PWR/DATA CABLE   40CLX
 ALL FIELD POWER/DATA CABLES ARE REPAIRD N      3.97 FAIL        .03       .13     .95   0.00     0.00         .13     .00
 IN PLACE BY STD. ELECTRICAL METHODS     N      3.97 FAIL        .75      2.98     .95   0.00     0.00        2.84     .00
 INCLUDING REPLACEMENT OF TERMINALS AND
 CONNECTORS
 ANNUAL FAILURE RATE/CABLE   -  .00073

 SHIPPED IN FIBERBOARD BOX   5.55/CWT

      2050202.
   POWER TRANSFORMER   40225T(19)H
 POWER TRANSFORMERS ARE REPLACED UPON    N       .12 FAIL     206.44     24.72    1.11   0.00     0.00       27.31     .00
 INTERNAL COMPONENT FAILURE WITH         N       .12 FAIL      12.00      1.44    1.11   0.00     0.00        1.59     .00
 A FORKLIFT OR MOBILE CRANE AND SLING.
 ANNUAL FAILURE RATE/TRANSFORMER - .00665

 SHIPPED TO OFFSITE REPAIR FACILITY
 STRAPPED TO PALLET           3.97/CWT

      2050203.
   PWR.DISTRIB.PANEL   40SQ.DH-4172-4N
 ALL POWER DIST. PANELS ARE REPAIRED IN  N       .09 FAIL        .62       .06     .95   0.00     0.00         .05     .00
 PLACE.                                  N       .09 FAIL       1.20       .11     .95   0.00     0.00         .10     .00
 ANNUAL FAILURE RATE/PANEL   -  .00499

 SHIPPED IN WOOD BOX     6.18/CWT

      2050205.
   HEL.PWR/DATA CABLE  CLX-ALS
 HELIOSTAT POWER/DATA CABLES ARE         N      9.90 FAIL       1.62     16.05     .95   0.00     0.00       15.28     .00
 REPLACED UPON FAILURE                   N      9.90 FAIL       3.00     29.71     .95   0.00     0.00       28.29     .00
 ANNUAL FAILURE RATE/CABLE   -  .00037

 ASSUMES SHIPMENT IN ECONOMIC QUANTITY
                             5.55/CWT

        30202.
   DATA DIST.INTERFAC  443202
 DDI IS ALWAYS REPAIRED. BENCH REPAIR    N       .47 FAIL        .01       .01    1.25   0.00     0.00         .01     .00
 CONSISTS OF REPLACING THE DDI CIRCUIT   N       .47 FAIL        .60       .28    1.25   0.00     0.00         .35     .00
 CARDS AND DEFECTIVE COMPONENTS.
 ANNUAL FAILURE RATE/INTERFACE  -  .0131

 SHIPPED IN CARDBOARD CONTAINER
                             6.18/CWT
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OPERATIONS AND MAINTENANCE FIRST YEAR COSTS, 5412 HELIOSTATS - (50K/YEAR)                 14.17.13.        DATE 02/06/81

   OTHER

DESCRIPTION                                           QTY/HRS/       REF UNIT  SUB TOTAL      F A C T O R S          TOTAL
                                                     ANN. FAIL         COST                ADJ  OVERHEAD  G_A                     $/SM

        30302.
   HELIO CONTROLLER     443302
 HELIOSTAT CONTROLLER IS ALWAYS REPLACED N     59.43 FAIL          .25     14.69   1.25     0.00     0.00        18.34     .00
 UPON FAILURE DETECTED BY THE MOBIL TEST N     59.43 FAIL         6.00    356.59   1.25     0.00     0.00       445.03     .00
 VAN AND OPERATIONAL INDICATIONS OF
 SOFTWARE PROBLEMS.
 ANNUAL FAILURE RATE/CONTROLLER - .00549

 SHIPPED IN CARDBOARD CONTAINER
                              6.18/CWT

      5010201.
   TUBE-CAP-COVER       ID22461-1
 ALL PEDESTAL REPAIRS ARE MADE IN PLACE  N      4.69 FAIL        48.43    227.24   1.11     0.00     0.00       251.10     .00
 USING STD REPAIR PRACTICES              N      4.69 FAIL          .17       .82   1.11     0.00     0.00          .90     .00
 ANNUAL FAILURE RATE/PED   -   .00087

 REPAIR PARTS SHIPPED IN CARDBOARD BOX
                              5.55/CWT

      5010204.
   J BOX                40ID40046-9
 J-BOXES ARE ALL REPAIRED IN PLACE       N     18.00 FAIL          .03       .56    .95     0.00     0.00          .53     .00
 ANNUAL FAILURE RATE/BOX   -   .00333    N     18.00 FAIL          .60     10.80    .95     0.00     0.00        10.28     .00

 REPAIR PARTS SHIPPED IN CARDBOARD BOX
                              6.18/CWT

      9020301.
   WASHING SOLUTION     OM231
 MC GEAN CHEM.CO.DOWNY,CA.               N  5715.07 FAIL          3.91  22345.93   1.00     0.00     0.00     22345.93     .07
 CB120D BIO-DEGRADABLE
 USED IN 5 PERCENT SOLUTION

      9020302.
   DEIONIZED WASH WAT   OM232
 ARROWHEAD WATER                         N108001.87 FAIL           .05   5832.10   1.00     0.00     0.00      5832.10     .02
 USED AS BALANCE OF WASHING SOLUTION

      9020303.
   DEIONIZED RNSE WAT   OM233
 ARROWHEAD WATER TO RINSE MIRRORS        N454608.00 FAIL           .05  24548.83   1.00     0.00     0.00     24548.83     .08

      9020304.
   DIESEL FUEL          OM234
 FOR WASH TRUCKS AT $.90/GAL EST.        N 19418.26 FAIL           .90  17476.43   1.00     0.00     0.00     17476.43     .06

      9020305.
   OTHER FUEL           OM235
 FOR PICK-UP TRUCKS, CRANE, FORK-LIFT    N  3896.64 FAIL          1.35   5260.46   1.00     0.00     0.00      5260.46     .02

      9020306.
   LUBRICANT-AZ DRIV    OM236
 MOBIL OIL SCH 626 FOR AZIMUTH DRIVE     N   270.60 FAIL          9.75   2638.35   1.00     0.00     0.00      2638.35     .01
 .1 GAL/HELIO/YR
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OPERATIONS AND MAINTENANCE FIRST YEAR COSTS, 5412 HELIOSTATS - (50K/YEAR)   14.17.13.   DATE 02/06/81

OTHER

DESCRIPTION		QTY/HRS/ ANN. FAIL	REF UNIT COST	SUB TOTAL	FACTORS ADJ	OVERHEAD	G_A	TOTAL	$/SM
9020307. LUBRICANT-JACK OM237 MOBIL OIL SCH 630 FOR ELEVATION DRIVE (JACK) .02 GAL/HELIO/YR QUOTE GOOD TIL 11-28-80 $10.57/GAL	N	108.24 FAIL	10.57	1144.10	1.00	0.00	0.00	1144.10	.00
9020308. ELECT POWER REQMTS OM238 ELECT POWER REQUIRED FOR HELIOSTAT FIELD AND MASTER CONTROL FOR SUCH $.05 PER KWHR	N	0.00 FAIL	.05	0.00	1.00	0.00	0.00	0.00	0.00
413001. MAINT.SUPP./EQ. 4131 MAINTENANCE AT 5 PERCENT OF EQUIPMENT COST	N	.11 FAIL	161036.97	17391.99	1.00	0.00	0.00	17391.99	.06
430503. HELIO ARRAY CONTRL 4353 OPERATIONS AND MAINTENANCE FOR THE HAC	N	12.00 FAIL	200.00	2400.00	1.00	0.00	0.00	2400.00	.01
OTHER								104771.	.34

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OPERATIONS AND MAINTENANCE FIRST YEAR COSTS, 5412 HELIOSTATS - (50K/YEAR)              14.17.13.        DATE 02/06/81

   CORRECT

DESCRIPTION                                         QTY/HRS/        REF UNIT  SUB TOTAL     F A C T O R S        TOTAL
                                                   ANN. FAIL         COST                 ADJ  OVERHEAD  G_A                $/SM

          101.
   REFLECTIVE SURFACE  4411
 PART NO. ID22462-501                        L   155.63  HRS        18.05   2809.08   2.21    1.00     1.00     6208.06    .02
 REMOVE AND REPLACE THE MIRROR MODULE        L     0.00  HRS        18.18      0.00   1.29    1.00     1.00        0.00   0.00
 PANELS WITH A MOBILE CRANE AND SLING.
 NO REPAIRS MADE, ALWAYS DISCARDED.
 MINOR CRACKS MAY BE REPAIRED BY
 ADHESIVE BOND.
 FAILURE RATE/YR/PANEL   -  .00079

 WOOD CRATE SHIPPING         6.93/CWT

          102.
   MIRROR BACK STRU    4412
 PART NO. ID22463-1                          L    30.85  HRS        18.05    556.81   2.21    1.00     1.00     1230.56    .00
 REFLECTOR SUPPORT STRUCTURE ALWAYS          L     0.00  HRS        18.18      0.00   1.29    1.00     1.00        0.00   0.00
 REPAIRED IN PLACE.
 FAILURE RATE/YR/PANEL   -  .00095

 REPAIR PARTS SHIPPED IN CARDBOARD BOX
                             5.55/CWT

          201.
   AZIMUTH DRIVE       4421
 PART NO. ID22494-1                          L  1058.59  HRS        18.05  19107.50   2.20    1.00     1.00    42036.50    .14
 COMPLETE AZIMUTH DRIVE ASSEMBLY IS          L   564.76  HRS        18.18  10267.27   1.30    1.00     1.00    13347.45    .04
 REPLACED UPON FAILURE.
 BENCH REPAIR:
   REPLACE DEFECT GEAR TRAIN COMPONENTS,
   LUBRICATE HARMONIC SECTION WITH
   HEAVY DUTY OIL AND PACK GEAR TRAIN
   WITH GREASE
 FAILURE RATE/YR/DRIVE   -  .00978

 SPARES TRANSPORTED IN COVERED WOODEN
 SKID                        6.18/CWT

      2020202.
   JACK-ELEVATION      ID22497-1
 REPLACE ELEVATION DRIVE MOTOR               L   216.22  HRS        18.05   3902.78   2.21    1.00     1.00     8625.13    .03
 UPON COMPONENT FAILURE                      L   221.13  HRS        18.18   4020.22   1.30    1.00     1.00     5226.29    .02
 BENCH REPAIR:
   REPLACEMENT OF DEFECTIVE COMPONENTS.
 ANNUAL FAILURE RATE/JACK   -  .00908

 SPARES STRAPPED TO PALLET   6.18/CWT
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OPERATIONS AND MAINTENANCE FIRST YEAR COSTS, 5412 HELIOSTATS - (50K/YEAR)              14.17.13.         DATE 02/06/81

   CORRECT

DESCRIPTION                                         QTY/HRS/          REF UNIT  SUB TOTAL     F A C T O R S        TOTAL
                                                   ANN. FAIL           COST                 ADJ  OVERHEAD  G_A                $/SM

          20302.
   AZ.DRIVE MOTOR      40ID22487-501
 AZIMUTH DRIVE MOTOR IS REPLACED UPON     L    964.90  HRS        18.05  17416.47    2.21    1.00    1.00   38490.39    .13
 COMPONENT FAILURE                        L      0.00  HRS        18.18      0.00    1.00    1.00    1.00       0.00   0.00
 BENCH REPAIR:
   REPLACE INC. ENCODER, MOTOR CONTROLLER
   FAILED MOTORS ARE DISCARDED
 ANNUAL FAILURE RATE/MOTOR UNIT - .0065
 MEAN TIME TO REPAIR - 1.7HRS

 SHIPPED IN CARDBOARD BOX    6.18/CWT

          20303.
   EL.DRIVE MOTOR      40ID22487-1
 ELEVATION DRIVE MOTOR IS REPLACED UPON   L   1078.42  HRS        18.05  19465.46    2.21    1.00    1.00   43018.67    .14
 COMPONENT FAILURE                        L      0.00  HRS        18.18      0.00    1.00    1.00    1.00       0.00   0.00
 BENCH REPAIR:
   REPLACE INC. ENCODER, MOTOR CONTROLLER
   FAILED MOTORS ARE DISCARDED
 ANNUAL FAILURE RATE/MOTOR UNIT - .0065
 MEAN TIME TO REPAIR - 1.9HRS

 SHIPPED IN CARDBOARD BOX    6.18/CWT

        2040201.
   INCR.ENCODER        40ID22571-501
 INCREMENTAL ENCODER IS REPLACED AT       L      0.00  HRS        18.05      0.00    1.00    1.00    1.00       0.00   0.00
 BENCH UPON FAILURE.                      L     23.08  HRS        18.18    419.68    1.30    1.00    1.00     545.59    .00
 ANNUAL FAILURE RATE/ENCODER   -  .0049

 SHIPPED IN CARDBOARD BOX    6.18/CWT

        2040202.
   INCR.ENCODER        40ID22571-1
 INCREMENTAL ENCODER IS REPLACED AT       L      0.00  HRS        18.05      0.00    1.00    1.00    1.00       0.00   0.00
 BENCH UPON FAILURE.                      L     23.08  HRS        18.18    419.68    1.30    1.00    1.00     545.59    .00
 ANNUAL FAILURE RATE/ENCODER   -  .0049

 SHIPPED IN CARDBOARD BOX    6.18/CWT

          20404.
   MOTOR CONTROL       40T619
 MOTOR CONTROL IS REPLACED AND THEN       L      0.00  HRS        18.05      0.00    1.00    1.00    1.00       0.00   0.00
 REPAIRED ON SITE.                        L     34.78  HRS        18.18    632.26    1.30    1.00    1.00     821.93    .00
 ANNUAL FAILURE RATE/CONTROL   -  .00459

 SHIPPED IN WOODEN BOX       6.18/CWT
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OPERATIONS AND MAINTENANCE FIRST YEAR COSTS, 5412 HELIOSTATS - (50K/YEAR)            14.17.13.        DATE 02/06/81

   CORRECT

DESCRIPTION                                         QTY/HRS/        REF UNIT  SUB TOTAL     F A C T O R S          TOTAL
                                                   ANN. FAIL          COST                ADJ  OVERHEAD  G_A                $/SM

      2050201.
   FLD.PWR/DATA CABLE  40CLX
 ALL FIELD POWER/DATA CABLES ARE REPAIRD L      27.75  HRS        18.05     500.84    2.50     1.00      1.00     1252.10    .00
 IN PLACE BY STD. ELECTRICAL METHODS     L       0.00  HRS        18.18       0.00    1.00     1.00      1.00        0.00   0.00
 INCLUDING REPLACEMENT OF TERMINALS AND
 CONNECTORS
 ANNUAL FAILURE RATE/CABLE  -  .00073

 SHIPPED IN FIBERBOARD BOX   5.55/CWT

      2050202.
   POWER TRANSFORMER   40225T(19)H
 POWER TRANSFORMERS ARE REPLACED UPON    L       1.01  HRS        18.05      18.15    2.21     1.00      1.00       40.11    .00
 INTERNAL COMPONENT FAILURE WITH         L       1.20  HRS        18.18      21.76    1.30     1.00      1.00       28.29    .00
 A FORKLIFT OR MOBILE CRANE AND SLING.
 ANNUAL FAILURE RATE/TRANSFORMER - .00665

 SHIPPED TO OFFSITE REPAIR FACILITY
 STRAPPED TO PALLET           3.97/CWT

      2050203.
   PWR.DISTRIB PANEL   40SQ.DH-4172-4N
 ALL POWER DIST. PANELS ARE REPAIRED IN  L        .29  HRS        18.05       5.19    2.21     1.00      1.00       11.47    .00
 PLACE.                                  L       0.00  HRS        18.18       0.00    1.00     1.00      1.00        0.00   0.00
 ANNUAL FAILURE RATE/PANEL  -  .00499

 SHIPPED IN WOOD BOX     6.18/CWT

      2050205.
   HEL.PWR/DATA CABLE  40CLX-ALS
 HELIOSTAT POWER/DATA CABLES ARE         L      36.04  HRS        18.05     650.59    2.50     1.00      1.00     1626.48    .01
 REPLACED UPON FAILURE                   L       0.00  HRS        18.18       0.00    1.00     1.00      1.00        0.00   0.00
 ANNUAL FAILURE RATE/CABLE  -  .00037

 ASSUMES SHIPMENT IN ECONOMIC QUANTITY
                              5.55/CWT

        30202.
   DATA DIST.INTERFAC  443202
 DDI IS ALWAYS REPAIRED. BENCH REPAIR    L       1.51  HRS        18.05      27.25    2.50     1.00      1.00       68.13    .00
 CONSISTS OF REPLACING THE DDI CIRCUIT   L       0.00  HRS        99.00       0.00    1.00     1.00      1.00        0.00   0.00
 CARDS AND DEFECTIVE COMPONENTS.
 ANNUAL FAILURE RATE/INTERFACE  -  .0131

 SHIPPED IN CARDBOARD CONTAINER
                              6.18/CWT
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OPERATIONS AND MAINTENANCE FIRST YEAR COSTS, 5412 HELIOSTATS - (50K/YEAR)              14.17.13.        DATE 02/06/81

   CORRECT

DESCRIPTION                                          QTY/HRS/        REF UNIT  SUB TOTAL     F A C T O R S          TOTAL
                                                    ANN. FAIL         COST                 ADJ  OVERHEAD  G_A                 $/SM

        30302.
   HELIO CONTROLLER    443302
 HELIOSTAT CONTROLLER IS ALWAYS REPLACED L   154.58  HRS        18.05   2790.15   2.50    1.00     1.00    6975.38    .02
 UPON FAILURE DETECTED BY THE MOBIL TEST L     0.00  HRS        18.18      0.00   1.00    1.00     1.00       0.00   0.00
 VAN AND OPERATIONAL INDICATIONS OF
 SOFTWARE PROBLEMS.
 ANNUAL FAILURE RATE/CONTROLLER - .00549

 SHIPPED IN CARDBOARD CONTAINER
                            6.18/CWT

      5010201.
   TUBE-CAP-COVER      ID22461-1
 ALL PEDESTAL REPAIRS ARE MADE IN PLACE  L     9.42  HRS        18.05    169.97   2.20    1.00     1.00     373.94    .00
 USING STD REPAIR PRACTICES              L     0.00  HRS        18.18      0.00   2.20    1.00     1.00       0.00   0.00
 ANNUAL FAILURE RATE/PED  -  .00087

 REPAIR PARTS SHIPPED IN CARDBOARD BOX
                            5.55/CWT

      5010204.
   J BOX               40ID40046-9
 J-BOXES ARE ALL REPAIRED IN PLACE       L    57.67  HRS        18.05   1040.95   2.20    1.00     1.00    2290.09    .01
 ANNUAL FAILURE RATE/BOX  -  .00333      L     0.00  HRS        18.18      0.00   1.00    1.00     1.00       0.00   0.00

 REPAIR PARTS SHIPPED IN CARDBOARD BOX
                            6.18/CWT

   CORRECT                                                                                          172762.      .56
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"OPERATIONS AND MAINTENANCE FIRST YEAR COSTS, 5412 HELIOSTATS - (50K/YEAR)           14.17.13.        DATE 02/06/81

  SCHED

DESCRIPTION                                   QTY/HRS/          REF UNIT  SUB TOTAL      F A C T O R S         TOTAL
                                             ANN. FAIL           COST               ADJ  OVERHEAD  G_A                 $/SM

      9030101.
   WASHING LABOR       OM311
 MONTHLY WASH REFLECTOR PANELS WITH       L  3117.32  HRS       18.05  56267.63   1.17    1.00     1.00   65833.12     .21
 SPRAY SOAK METHOD USING ONE TRUCK
 CARRYING WASH SOLUTION IN 5PERCENT
 SOLUTION AND DEIONIZED WATER.
 LABOR IS TIME NEEDED TO DRIVE TRUCK
 PAST EACH REFLECTOR PANEL AND
 TO FILL TRUCK WITH WASH AND RINSE
 SOLUTIONS.

      9030102.
   OILING DRIVES       OM312
 OILING DRIVES                            L   435.12  HRS       18.05   7854.00   1.17    1.00     1.00    9189.18     .03
 FILLING AZIMUTH DRIVE WITH 0.05GAL
 MOBIL OIL    626 AND ELEVATION JACK
 WITH .02GAL MOBIL OIL SHC630 AS
 NEEDED FOR OPERATION.

      9030103.
   CORROSION CONTRL    OM313
 CHECK DRIVES AND JACKS TO VERIFY THAT    L   435.12  HRS       18.05   7854.00   1.17    1.00     1.00    9189.18     .03
 OIL SEALS ARE NOT LEAKING.

   SCHED                                                                                                  84211.       .27
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SECOND GENERATION HELIOSTAT INVESTMENT COSTS - (50K/YEAR, 11TH YEAR)                14.22.07.         DATE 02/06/81

   MISC.EQUIP          4130

DESCRIPTION                                         QTY/HRS/       REF UNIT  SUB TOTAL      F A C T O R S        TOTAL
                                                   ANN. FAIL        COST                CRC  OVERHEAD  G_A                $/SM

   4130010101.
   MOBILE CRANE        ME-1
  GROVE MODEL 68 INDUSTRIAL CRANE      P P      9.24 UNITS        1.70      15.71     1.00    0.00     0.00        15.71    .28
  10 TON WITH STANDARD RIGGING
  TO REMOVE AND HOLD HELIOSTAT
  REFLECTOR DURING REMOVAL AND
  REPLACEMENT OF AZIMUTH DRIVE.

   4130010102.
   FORKLIFT            ME-2
  JOHN DEERE AND CO.                   P P      9.24 UNITS         .39       3.56     1.00    0.00     0.00         3.56    .06
  MODEL JD 380 WITH 7FT. 8IN. MAST.
  LIFTING CAPACITY OF 4000LBS.
  WILL BE USED TO REMOVE AND REPLACE
  AZIMUTH DRIVE.

   4130010103.
   HYDRASET            ME-3
  MODEL B (2.5 TON)                    P P      9.24 UNITS         .09        .81     1.00    0.00     0.00          .81    .01
  SUPPLIER: DEL MAR AVIONICS
            IRVINE, CALIF.
  FOR PRECISE POSITIONING OF THE
  REFLECTOR DURING REINSTALLATION OF
  THE AZIMUTH DRIVE.

   4130010104.
   PICK-UP TRUCK       ME-4
  3/4 TON                              P P      9.24 UNITS         .43       4.01     1.00    0.00     0.00         4.01    .07
  LOW PRESSURE TIRES FOR
  GENERAL USE.

   4130010105.
   WYLER MINILEVEL     ME-5
  ELECTRONIC WYLER MINILEVEL MEASURES  P P      9.24 UNITS         .12       1.11     1.00    0.00     0.00         1.11    .02
  MIRROR CANT ANGLE

   4130010106.
   OIL INJECTOR        ME-6
  TO FILL AZIMUTH DRIVE HOUSING        P P      9.24 UNITS         .02        .18     1.00    0.00     0.00          .18    .00
  WITH OIL.

   4130010107.
   PORTBLE CNTRL UNIT  ME-7
  FOR FAULT ISOLATION AND CONTROL      P P      9.24 UNITS         .09        .81     1.00    0.00     0.00          .81    .01
  OF AN INDIVIDUAL HELIOSTAT.
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SECOND GENERATION HELIOSTAT INVESTMENT COSTS - (50K/YEAR, 11TH YEAR) 14.22.07. DATE 02/06/81

MISC.EQUIP 4130

DESCRIPTION		QTY/HRS/ ANN. FAIL	REF UNIT COST	SUB TOTAL	FACTORS CRC	OVERHEAD	G_A	TOTAL	$/SM
4130010108. SERVICE LINK KIT ME-8 TO STABILIZE HELIO RELECTOR DURING REMOVAL AND REPLACEMENT OF ELEVATION JACK.	P P	9.24 UNITS	.16	1.48	1.00	0.00	0.00	1.48	.03
4130010109. JACK ADJSTMNT TOOL ME-9 SET ELEVATION JACK EXTENSION TO A DESIGN POINT FOR INITIAL TRACK CALIBRATION.	P P	9.24 UNITS	.08	.74	1.00	0.00	0.00	.74	.01
4130010110. CLINOMETER MOUNT ME-10 PROVIDE INTERFACE BETWEEN CLINOMETER OR MINILEVEL AND MAIN BEAM REFERENCE POINT.	P P	9.24 UNITS	.08	.74	1.00	0.00	0.00	.74	.01
4130010111. HOISTING TOOL ME-11 HOISTING TOOL TO REMOVE AND REPLACE AZIMUTH DRIVE.	P P	9.24 UNITS	.08	.74	1.00	0.00	0.00	.74	.01
4130010112. HOISTING TOOL ME-12 HOISTING TOOL TO REMOVE AND REPLACE REFLECTOR SUPPORT ASSEMBLY DURING AZIMUTH DRIVE CHANGE.	P P	9.24 UNITS	.08	.74	1.00	0.00	0.00	.74	.01
4130010113. PANEL LEVELING TOO ME-13 TOOL FOR PANEL LEVELING TO MEASURE MIRROR MODULE CANT ANGLE. USED IN CONJUNCTION WITH WYLER MINILEVEL.	P P	9.24 UNITS	.02	.18	1.00	0.00	0.00	.18	.00
4130010114. SLING ME-14 MIRROR MODULE LIFTING SLING TO REMOVE AND REPLACE MIRROR MODULE.	LBR	.022 HRS	5.97	.13	1.00	2.14	1.35	.38	.00
	P P	9.24 UNITS	.01	.14	1.00	0.00	0.00	.14	.00
	R M	9.24 UNITS	.00	.02	1.00	0.00	0.00	.02	.00
4130010115. REPAIR EQUIP. ME-15 ADDITIONAL STD. REPAIR EQUIPMENT NEEDED SUCH AS NEEDLE NOSE PLIERS, SCREW DRIVERS, WRENCHES, SOLDER GUNS, OHM METER, ETC.	P P	9.24 UNITS	.12	1.11	1.00	0.00	0.00	1.11	.02

```
SECOND GENERATION HELIOSTAT INVESTMENT COSTS - (50K/YEAR, 11TH YEAR)                     14.22.07.         DATE 02/06/81

   MISC.EQUIP          4130

DESCRIPTION                                 QTY/HRS/      REF UNIT  SUB TOTAL     F A C T O R S         TOTAL
                                           ANN. FAIL        COST                CRC  OVERHEAD  G_A                $/SM

   4130010116.
   WASHING EQUIP.      ME-16
 TWO WASH TRUCKS IN TANDEM, ONE TO   P P      9.24 UNITS      3.50      32.34   1.00   0.00    0.00      32.34    .57
 WASH WITH THE WASHING SOLUTION,
 ONE TO RINSE WITH DEIONIZED WATER.
 TRUCKS WILL HAVE PNEUMATIC TIRES.


   MISC.EQUIP          4130                                                              65.     1.14
```

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SECOND GENERATION HELIOSTAT INVESTMENT COSTS - (50K/YEAR, 11TH YEAR)              14.22.07.        DATE 02/06/81

   HELIO INIT SPARES    4841

DESCRIPTION                                           QTY/HRS/       REF UNIT   SUB TOTAL      F A C T O R S          TOTAL
                                                      ANN. FAIL        COST                  CRC   OVERHEAD   G_A               $/SM

     48010101.
   REFLECTIVE SURFACE  48ID22462-501
  (REFLECTIVE SURFACE)                    P P        9.24 UNITS        .06         .52     1.00    0.00      0.00          .52    .01
  A 1YEAR SUPPLY
  BASED ON:
  ANNUAL FAILUERS/HR/MODULE = 0.1E-6
  PLUS PIPELINE QUANTITY OF 10

     48010102.
   MIRROR BACK STRU    48ID22463-1
  SUPPLY BASED ON:                        P P        9.24 UNITS        .06         .56     1.00    0.00      0.00          .56    .01
  ANNUAL FAILURES/HR/STRUCTURE OF 0.12E-6
  PLUS PIPELINE QUANTITY OF 4

     48010201.
   AZIMUTH DRIVE       48ID22494-1
  30 DAY CONTINGENCY SUPPLY DUE TO ON P P    9.24 UNITS        .05         .47     1.00    0.00      0.00          .47    .01
  SITE REPAIR OF THIS ITEM
  BASED ON:
  ANNUAL FAILURES/HR/DRIVE OF 2.94E-6
  PLUS PIPELINE QUANTITY OF 2

     48010202.
   JACK-ELEVATION      48ID22497-1
  30DAY CONTINGENCY DUE TO ON SITE REPP P    9.24 UNITS        .03         .30     1.00    0.00      0.00          .30    .01
  BASES ON:
  ANNUAL FAILURES/HR/JACK OF 2.73E-6
  PLUS PIPE LINE QTY OF 2

   4801020302.
   AZIMUTH DRIVE MOTO  48ID22487-501
  SUPPLY BASED ON:                        P P        9.24 UNITS        .05         .50     1.00    0.00      0.00          .50    .01
  ANNUAL FAILURES/HR/MOTOR OF 2.0E-6
  PLUS PIPELINE QUANTITY OF 8

   4801020303.
   EL.DRIVE MOTOR      48ID22487-1
  SAME AS AZ. DRIVE MOTOR - 48ID22487-P P    9.24 UNITS        .05         .50     1.00    0.00      0.00          .50    .01

  480102040201.
    INCR.ENCODER       48ID22571-1
  INC. ENCODER SUPPLY BASED ON:           P P        9.24 UNITS        .02         .14     1.00    0.00      0.00          .14    .00
  ANNUAL FAILURES/HR/ENCODER OF 1.35E-6
  PLUS PIPELINE QUANTITY OF 7

  480102040202.
    INCR.ENCODER       48ID22571-501
  SAME AS ENCODER NO. 48ID22571-1         P P        9.24 UNITS        .02         .14     1.00    0.00      0.00          .14    .00
```

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SECOND GENERATION HELIOSTAT INVESTMENT COSTS - (50K/YEAR, 11TH YEAR)             14.22.07.        DATE 02/06/81

   HELIO INIT SPARES   4841

DESCRIPTION                                          QTY/HRS/      REF UNIT   SUB TOTAL      F A C T O R S         TOTAL
                                                    ANN. FAIL        COST                 CRC  OVERHEAD  G_A                 $/SM

   4801020403.
   MOTOR CONTORL         48T619
 MOTOR CONTROL SUPPLY BASED ON:       P P      9.24 UNITS         .06         .52    1.00    0.00     0.00          .52    .01
 ANNUAL FAILURES/HR/CONTROL OF 1.38E-6
 PLUS PIPELINE QUANTITY OF 9

 480102050201.
   FLD.PWR/DATA CABLE   48CLX
 FLD PWR/DATA CABLE SUPPLY BASED ON:  P P      9.24 UNITS         .00         .01    1.00    0.00     0.00          .01    .00
 ANNUAL FAILURES/HR/CABLE OF 0.22E-6
 PLUS A PIPELINE QUANTITY OF 3

 480102050202.
   POWER TRANSFORMER   48225T(19)H
 ANNUAL FAILURES/HR/TRANSFORMER OF    P P      9.24 UNITS         .14        1.27    1.00    0.00     0.00         1.27    .02
    2.0E-6
 PLUS A PIPELINE QUANTITY OF 1
 MAINTENANCE ACTIONS ARE NEGLIGIBLE
 FOR THIS ITEM.

 480102050203.
   PWR.DITRIB.PANEL    SQ.DH-4172-4N
 PWR DIST PANEL SUPPLY BASED ON:      P P      9.24 UNITS         .11        1.05    1.00    0.00     0.00         1.05    .02
 ANNUAL FAILURES/HR/PANEL OF 1.5E-6
 PLUS A PIPELINE QUANTITY OF 8
 MAINTENANCE ACTIONS ARE NEGLIGIBLE
 FOR THIS ITEM.

 480102050205.
   HEL.PWR/DATA CABLE  48CLX-ALS
 HELIO PWR/DATA CABLE SUPPLY BASED ONP P       9.24 UNITS         .02         .15    1.00    0.00     0.00          .15    .00
 ANNUAL FAILURES/HR/CABLE OF 0.11E-6
 PLUS PIPELINE QUANTITY OF 5

     48010302.
   DATA DIST.INTERFAC  484432
 DATA DIST INTER. SUPPLY BASED ON:    P P      9.24 UNITS         .01         .08    1.00    0.00     0.00          .08    .00
 ANNUAL FAILURES/HR/INTERFACE OF
 3.95E-6
 PLUS A PIPELINE QUANTITY OF 1
 THIS ITEM HAS NEG MAINT ACTIONS/YEAR

     48010303.
   HELIO CONTROLLER    484433
 HELIO CONTROLLER SUPPLY BASED ON:    P P      9.24 UNITS         .15        1.40    1.00    0.00     0.00         1.40    .02
 ANNUAL FAILURES/HR/CONTROLLER OF
    1.65E-6
 PLUS A PIPELINE QUANTITY OF 8
```

```
SECOND GENERATION HELIOSTAT INVESTMENT COSTS - (50K/YEAR, 11TH YEAR)                   14.22.07.         DATE 02/06/81

   HELIO INIT SPARES   4841

DESCRIPTION                                           QTY/HRS/      REF UNIT  SUB TOTAL     F A C T O R S        TOTAL
                                                     ANN. FAIL       COST              CRC  OVERHEAD  G_A                 $/SM

 480105010201.
   TUBE-CAP-COVER      48ID22461-1
 SUPPLY BASED ON:                           P P       9.24 UNITS        .03       .24   1.00   0.00     0.00          .24    .00
 ANNUAL FAILURES/HR/PED OF 0.11E-6
 PLUS PIPELINE QUANTITY OF 5

 480105010204.
   J BOX               48ID40046-9
 SUPPLY BASED ON:                           P P       9.24 UNITS        .01       .07   1.00   0.00     0.00          .07    .00
 ANNUAL FAILURES/HR/CABLE OF 1.0E-6
 PLUS PIPELINE QUANTITY OF 6
```

Appendix D-5

ADJUSTMENTS TO GM COST DATA FOR INSTALLED HELIOSTATS

Except for the table on page D5-3, all of the tables shown in Appendix D-5 have been taken directly from the General Motors volume. The table on page D5-3 starts with costs taken directly from a table in the GM volume. The purpose is to show in the most direct manner possible how the GM results have been adjusted for use in the final cost presentation. The impact of these adjustments is transmitted through the applied labor and overhead rates. The only adjustment to direct labor and material shown in the General Motors volume has been to add labor and materials cost for electronics, electrical field effort and other items not covered in GM's scope of work.

TABLE 8-9. LABOR RATE (DOLLARS PER HOUR)*

	March 1979	March 1980	September 1980 (est.)
California	$6.79	$7.44	$7.77
Nevada	6.88	7.36	7.60
Utah	6.03	6.88	7.31
Arizona	6.40	7.14	7.51
Colorado	6.60	7.13	7.40
New Mexico	5.12	5.72	6.02
Texas	6.27	6.96	7.31
AVERAGE	$6.30	$6.96	$7.27
Labor efficiency factor - 92 percent			$ .63 7.90
Industry factor = 115 percent			1.19
Labor rate used			$9.09

*U.S. Department of Labor

Adjustment:	March Rate	$6.96	$6.96
	Inflation Factor	(1 mo.)	1.007
	April rate		$7.01
	Industry Factor		1.15
	Applied Rate		$8.06

Note: Efficiency factor applied on hours (rather than dollars) as follows:

Factory - hours per heliostat - GM	9.989 hrs
Efficiencies factor (1/.92)	1.087
Factory - hours per heliostat - MDAC	10.86 hrs

Installed Heliostat Factory Burden Rates

Item	GM	Adj. Depr. & Outside Capital	Factor[(A)]	Installed Heliostat
Vari Burden	$187.06	$187.06	1.12	$209.50
Fix Burden	92.96	92.96	1.12	104.10
Depreciation	206.09	99.44(B)	1.12	111.40
Fix Fringe	36.93	36.93	1.12	41.40
Vari Fringe	63.30	63.30	1.12	70.90
Overtime	4.39	4.39	1.0	4.40
Night Shift	3.60	3.60	1.0	3.60
Cola	10.03	10.03	1.12	11.20
Spec Tools	28.68	28.68	1.0	28.70
Prod. Engr	12.17	12.17	1.12	13.60
Outside Tools	29.09	1.37(C)	1.12	1.50
Subtotal	$674.30	$539.90		$600.30
Labor	87.53	87.53	N/A	97.90
Subtotal				$698.20
G&A	165.00	165.00	1.12	184.80
Total				$883.00

Rates

Labor $= \dfrac{97.90 + 4.40 + 3.60 + 11.20}{10.86 + 1.29} =$ $9.64

Burden $= \dfrac{698.20}{97.90 + 4.40 + 3.60 + 11.20} = 5.962$

G&A $= \dfrac{883.00}{698.20} = 1.265$

(A) Factor $\dfrac{\text{GM hours} + \text{E\&E hours}}{\text{GM hours}} = \dfrac{10.86 + 1.29}{10.86} = 1.12$

(B) Exclude racks that are costed as CBS line item, and adjust to straightline dep.

(C) Exclude glass and mirror line equipment.

TABLE 8-8. REFLECTOR ASSEMBLY (1D22456-1) SHIPPING RACK ANALYSIS

Production Volume: 50,000 Heliostats per year

Assemblies per day: 416

Assemblies per rack: 3 → 4

Number of Racks	
At plant	693
In plant for loading	277
In repair	69
In route	693
At site	693
TOTAL	2,425 → 1,820

Estimated Cost: $7,420,375/2425 =	$3,060 each
factor to handle 4 assemblies	1.10
Adjusted cost/rack	$3,366 each
Adjusted Cost for 1820 racks	$6.13M

Table 8-12

MDC SECOND GENERATION HELIOSTAT TOOLS AND EQUIPMENT (DOLLARS)

PRODUCTION VOLUME: 50,000 PER YEAR

	Tools					
	Special	Durable	Nondurable	Total	Equipment	Total
Drive/Pedestal/Main Beam Assembly (1D22475-1)						
Pedestal, Paint	--	--	--	--	622,167	622,167
Pedestal, Weld	282,594	39,968	17,459	340,021	838,326	1,178,347
Azimuth Drive Housing, Weld	70,168	25,060	5,012	100,240	612,910	713,150
Azimuth Drive Housing, Machine	1,452,100	58,220	19,407	1,529,727	4,171,963	5,701,690
Main Beam, Weld	125,370	44,775	8,955	179,100	867.180	1,046.280
Main Beam, Machine	1,870,000	70,500	23,500	1,964,000	3,662,400	5,626,400
Elevation Drive Support, Machine	1,899,000	147,200	23,900	2,070,100	3,734,000	5,804,100
Flex Spline	46,700	7,700	87,920	142,320	370,645	512,965 ✓
Circular Spline	81,200	23,100	50,450	154,750	2,085,740	2,240,490 ✓
Wave Generator	50,600	12,650	6,050	69,300	1,661,930	1,731,230 ✓
Drive Shaft, Azimuth	102,405	48,783	13,522	164,710	552,580	717,290
Bearing Retainer, Azimuth	190,300	77,000	13,200	280,500	1,124,875	1,405,375
Cover and Retainer, Paint	--	--	--	--	393,740	393,740
Azimuth/Elevation Drive, Assembly	120,000	35,000	10,000	165,000	2,382,500	2,547,500
Azimuth/Elevation Drive, Paint	--	--	--	--	216,500	216,500
Incremental Encoder	--	--	--	--	73,750	73,750
Sensor/Controller Cables	--	--	--	--	3,000	3,000
Motor/Controller Cable	--	--	--	--	1,200	1,200
Encoder Cable	--	--	--	--	44,300	44,300
Sensor Cables	--	--	--	--	1,000	1,000
Motor Cable	--	--	--	--	400	400
Encoder/Controller Cable	--	--	--	--	1,200	1,200
Elec. Installation, Az/El Drive	--	--	--	--	119,750	119,750
Final Assembly	--	--	--	--	45,508	45,508
Shipping Racks	--	--	--	---	1,327,690	1,327,690
TOTAL	6,290,437	589,956	279,375	7,159,768	24,915,254	32,075,022
Reflector Assembly (1D22456-1)						
Mirror Module	371,675	--	--	371,765	7,245,931	7,617,696
Reflector Support Structure	508,125	101,720	13,079	622,924	4,072,691	4,695,615
Final Assembly	--	--	--	--	559,475	559,475
Shipping Racks	--	--	--	--	7,420,375 →	7,420,375 → 6,126,01
TOTAL	--	--	--	--	19,293,472	20,293,161
Heliostat Total	7,170,237	691,676	292,454	8,154,367	44,213,726	52,368,133
					18,004,114	18,998,803
					42,919,368	51,073,825

TABLE 8-5. OUTSIDE TOOLING AND PLANT COSTS

Rolling Mill Tools and Scotchbrite Equipment (Van Huffel)	$ 132,000	$132,000
Mirroring Line (Binswanger)	750,000	--
Stamping Tools and Dies (Bossert)	508,800	508,800
Corning Glass Works		
Fusion glass line	9,750,000	--
Precious metals	2,443,000*	--
Total Investment	$13,583,800	$640,800

*Included as a cost per unit of $6.84 (14 percent per year).

Note: Adjustment assumes that current glass and
mirror prices already consider such plant
cost allocations and need not be increased
further to allow recovery of plant costs

TABLE 8-6. MDC SECOND GENERATION HELIOSTAT REQUIRED INVESTMENT (DOLLARS)
PRODUCTION VOLUME: 50,000 PER YEAR

Plant	$ 36,000,000	$36.00M
Land and Improvements	800,000	.80
Machinery and Equipment	41,250,000	39.95*
Tools	8,150,000	8.15
Operations	2,970,000	2.97
Total	$ 89,170,000	→ $87.87M

*Adjusted for reduction in rack costs of $1.3M

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