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Quality Assurance Program for Solar Thermal Test Facility (STTF) Heliostat Production

F. Patrick Freeman, James T. Hillman

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QUALITY ASSURANCE PROGRAM FOR SOLAR THERMAL TEST FACILITY (STTF) HELIOSTAT PRODUCTION

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ABSTRACT

This document describes the Quality Assurance (QA) Program followed during heliostat production for the Solar Thermal Test Facility. Problems encountered as well as the corrective action taken are discussed. Brief descriptions of the validation of processes, the Martin-Marietta Quality Control Inspections, and the data package and computer storage of Record of Assembly data are included. The experience gained is typical of a QA program which may be applied to other projects under the new requirements imposed on Sandia Laboratories by DOE AL Manual, Chapter 08XA ALO Quality Program.

CONTENTS

QUALITY ASSURANCE PROGRAM FOR SOLAR THERMAL TEST FACILITY (STTF) HELIOSTAT PRODUCTION

Introduction

The Quality Assurance (QA) Program for the Solar Thermal Test Facility (STTF) included preproduction hardware evaluation, qualification of vendors and the prime contractor (Martin-Marietta of Denver, Colorado), a review of production methods, and an acceptance plan for manufacturing 222 heliostats. The heliostats were installed and formally accepted at the STTF site through a submission process to Quality Assurance Sandia Laboratories (QASL) by the Martin-Marietta (M-M) Quality Control (QC) Department. The production period lasted from April through December 1977.

Each STTF heliostat mirror module is about 7 metres square and is comprised of 25 facets, each facet containing a mirror 1.2 metres square. They are individually mounted on a steel rack which is attached to a yoke and azimuth fixture stabilized on a large concrete base. The azimuth drive unit rotates the mirror module at the heliostat base and an elevation drive unit on the rack turns the module on its horizontal axis. The two drive units, azimuth and elevation, are controlled by an encoder/commutator electronic system and a computer. The computer in the STTF control structure tracks the sun and focuses the beams from the heliostats onto a test receiver mounted atop a 61-metre tall tower. Two hundred and twenty-one heliostats are installed in five zones surrounding the receiver tower. An initial heliostat was used for feasibility and development studies at the original Sandia test site northeast of the tower and remains in place. As graphically shown in Figure 1, 218 heliostats are installed in the north field, 76 in Zone A and 142 in Zone B. The south field presently contains 3 heliostats (blackened in Figure 1), one each in Zones C, D, and E. The north field has 16 sun-present sensors installed on heliostats scattered throughout the zones to determine if there is sufficient intensity for proper operation. The sun-present sensors (SPS) are identified in Figure 1 by asterisks; included are 10 SPS units in the initial heliostat array control field (HAC-0) in Zone A, 3 in HAC-1 (Zone B West), and 3 in HAC-2 (Zone B East).

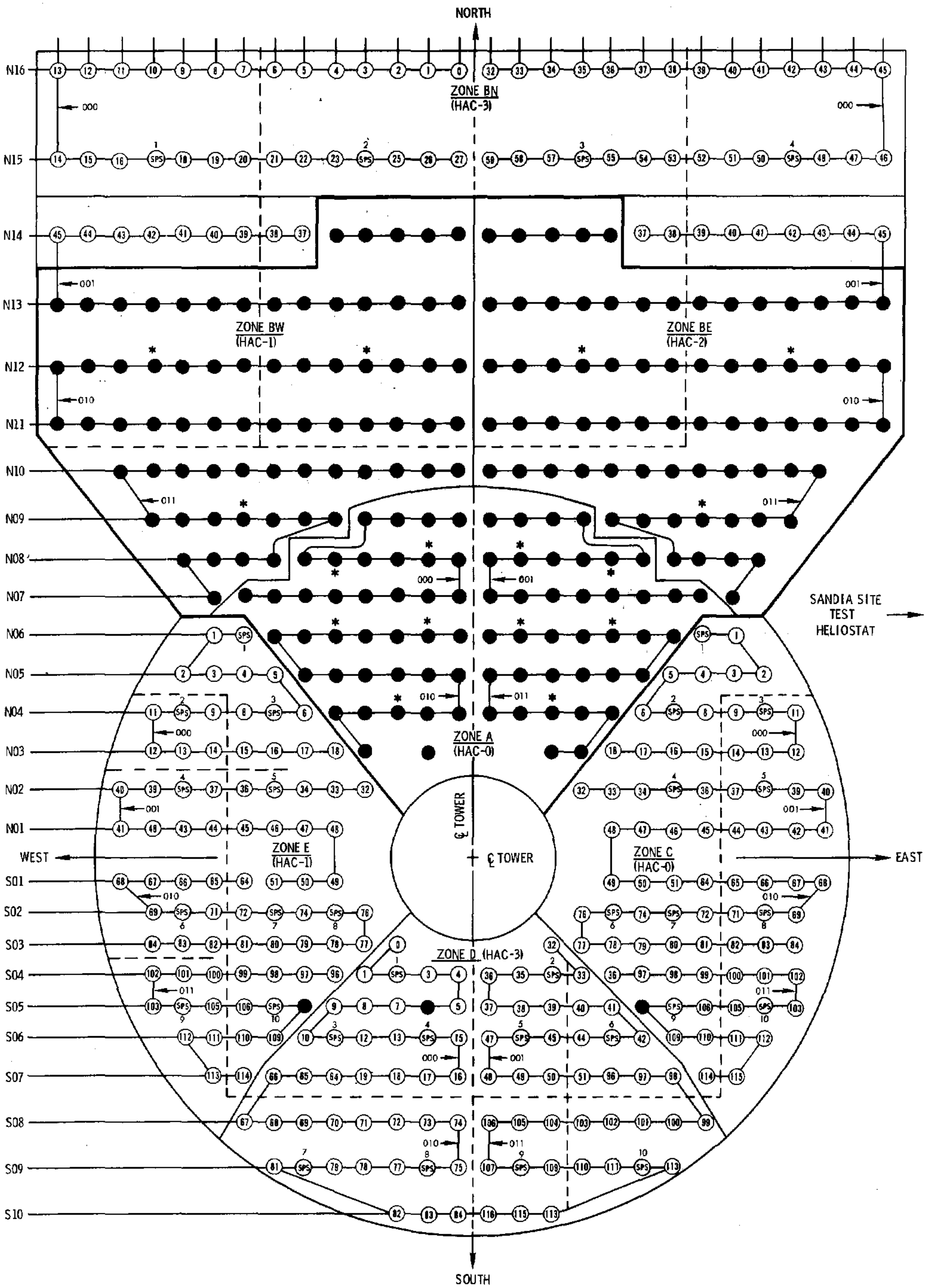

Figure 1. Graphic Overview of STTF Heliostat Field

Several vendors furnished components and assemblies: Litton Industries - encoder/commutators; Morse-Chain - drive units; Rio Grande Steel - rack assembly; Teledyne - mirror facet-support rings. Martin-Marietta Engineering and QC were responsible for assuring that only parts and assemblies meeting specifications were used. A deviation system was established to permit the use of deviating hardware (if approved by the design agency) in much the same manner as in the Department of Energy (DOE) War Reserve Acceptance System.

Sandia Laboratories Quality Assurance Program

When the STTF was originally proposed, minimum QA support was planned to work in conjunction with heliostat manufacture. However, as development progressed, it became obvious that a complete QA program was necessary. As a response, QASL developed the program described in Appendix A. The QASL responsibility was to evaluate development hardware and processes and to develop an overall QC plan for production of heliostats. QASL did not get involved in building the receiver tower and the heliostat bases, or in producing and accepting the computer which controls the heliostats.

Table I lists the hardware and processes found deficient in design, their cause and, in some cases, the corrective steps taken.

The Quality Assurance program provides definitions, controls, inspections, records, sampling plans, and reporting procedures for heliostat production. A Certificate of Inspection (COI) (Appendix A) was utilized to accept or reject at two levels of production. QA Verification Instructions (QAVI) were used with the COI to inspect the mirror module in the hangar and the completed heliostats at the STTF site. Martin-Marietta's QC System was periodically audited by Sandia Laboratories Explosive and Energy Devices Division 9515. The mirror module was produced at Kirtland Air Force Base (KAFB) and transported approximately 19 km (12 miles) to the STTF site on a trailer truck. There the module was positioned on the yoke/azimuth and attached to yoke brackets. The completed heliostat was inspected and functionally checked with a manual control box. In case future maintenance and retrofit would be required, a Record of Assembly/Disassembly form (Appendix A) was designed so that pertinent identification and site location could be entered.

TABLE I

Deficiencies in STTF Hardware and Processes and Their Causes

Deficiencies	Causes and Corrective Steps
1. Facet cracking	Internal stresses in glass
2. Inability of mirrors to hold focus	Deficient support ring and focus plate
3. Focus plate bonding	Insufficient cleaning
4. RTV108 relaxation	Characteristic of the material and had to be taken into account when focusing
5. Heliostat "hunting" while in the control mode	Dirty assembly area was restructured to provide a clean assembly and verification area
6. Contamination of drive units	Naval jelly, applied to prevent rust after fabrication, was not removed
7. Paint not adhering to back of facets	Poor quality paint
8. Beams on which mirror assemblies are mounted not in alignment	Improper jigging during the welding fabrication process
9. Poor welds in beam assembly	Unqualified welders

Martin-Marietta Quality Control Plan

Quality Control procedures implemented by Martin-Marietta to meet the requirements of the QA program designed by QASL called for internal verification of encoders/printed circuit boards (PCB), commutators, drive units, and mirror assemblies (Appendix B). Inspections required by the plan were performed by Martin-Marietta QC personnel and audited periodically by QASL. Quality status reports were issued monthly by QASL to the project group at Sandia Laboratories in Albuquerque (SLA). These provided a qualitative measurement of the effectiveness of the M-M QC program. For an example of the Status Reports, see Appendix A.

Qualification of Vendors and Contractors

Before starting heliostat production, 14 evaluations were conducted to qualify manufacturing methods or processes proposed by Martin-Marietta and some vendors. These processes and hardware along with supplier identification are listed below.

Proposed Methods and Hardware

1. Encoder/commutator - Litton Industries
2. Heliostat Control Electronics (HCE) - assembled at Denver by M-M
3. Support rings and focus plate - Teledyne, San Diego
4. Drive unit - Morse-Chain, Denver
5. Drive unit cleaning and oil fill - M-M, Bldg 481, SLA
6. Drive unit/encoder-commutator assembly - M-M, Bldg 481, SLA
7. Facet: bonding/curing and storage - M-M, Bldg 481, SLA
8. Facet (mirror assembly painting), Paint Shop, Bldg. 20679, KAFB East
9. Sandblasting of rings and focus plates for facet bonding - M-M, Bldg 481, SLA
10. Rack assembly: attaching elevation drive unit to beams and welding trusses to beams and studs to trusses - M-M, KAFB Bldg 481
11. Facet focusing: M-M, Bldg 481 (using bar gage with holding fixture so that adjustments can be made to center pull plate and corner set screws)
12. Drive unit azimuth/yoke installation at site on concrete base and roller mounting - M-M, STTF Site
13. Transferring mirror module to site and installing on yoke/drive unit assembly - M-M, Bldg 481/STTF Site
14. Final acceptance of heliostat and leveling procedure - M-M, STTF Site

Heliostat Production Problems or Deficiencies and Subsequent Corrective Action

During production of the 222 heliostats for Zones A and B, Martin-Marietta QC and QASL noted several deviations from specifications as well as deficiencies which may need attention to ensure proper heliostat function. Problems in azimuth and elevation drive units and in mirror assembly (facet) production are listed and include brief descriptions, identifying items judged significant with an asterisk.

Problems in Azimuth and Elevation Drive Units

1. Input shaft torque: Several drive units exhibited torque values which exceeded the high limit of 50 in. -lbs: however, oil fill and gear function reduced the torque to an acceptable level.
2. Oil over-fill: The first 20 drive units in Zone A were inadvertently overfilled with oil during installation. A few drive units may still be overfilled but field checks show no problems.
3. Loose drain plugs: Many loose plugs were noted during early production but field observations indicate that they are now uncommon.
4. Defective dowels (elevation): Five units had cracked, bent, or broken dowels. These units were shipped to Denver to be repaired and are now installed. No more dowel problems are anticipated except possibly when drive units are disassembled and reassembled.
5. Locked gears: Although gears in a few drive units were locked and were returned to Morse-Chain to be repaired, gear problems are not anticipated if adequate oil levels are maintained.
6. Backlash: Slack in gears (backlash) was measured on all Zone A drive units and on 25 in Zone B. When M-M issued a memo stating that backlash problems had been corrected by Morse-Chain and that measurements were no longer needed (Appendix C), QASL concurred. (SLA 5713/9515)

7. End flange bolt torque*: Flange bolts of 32 elevation drive units in Zone A may have insufficient torque applied to them. These units were accepted because of difficulty in removing mirror module beams.

8. Oil leaks: Six drive units in Zone A leaked oil. M-M disassembled one heliostat, repaired the oil leak, and sealed the remaining five units in situ with caulking and sealant.

9. Drive-unit cover seal*: The initial RTV seal was messy, difficult to apply, and worked poorly. After about 20 units had been assembled, foam-rubber gaskets were substituted and it was found that, when necessary, drive-unit disassembly was much easier. However, when gaskets were used, cover bolts became loose a few days after assembly. The RTV used as fix on the bolt threads was blamed; investigations were not made to determine if the gaskets were adequately compressed.

10. Encoders: Early production encoders had several defects, such as read-head misalignment, corrosion, bellows damage, or inadequately soldered PCBs. Many defects were corrected at the vendor location and few encoder problems are expected in the field.

11. Commutators: Because the commutators are made of glass and drive unit clamping is metal-to-glass, cracking and chipping were expected. However, only one has been returned from the field, suggesting that few commutator problems will be encountered.

<u>Problems in Mirror Assembly (Facet) Production</u>

1. Mirrors: During Zones A and B production, 6775 mirrors were received and 5868 were accepted (a 13.4% reject rate). The primary reasons for rejection were nonflatness, chips or cracks, and distortion (zebra board inspection).

2. Focusing discs: The primary reason for rejecting some focusing discs during inspection was that they were not flat enough and their center studs were not perpendicular. However, after observing the focusing of more than 5000 facets with satisfactory bond and proper assembly and support ring, QASL determined that a disc problem no longer exists.

3. Support rings: During early production, many rings could not be used because they were elliptical and were poorly welded. Corrective action by Teledyne, the vendor, at their site, reduced the rejection rate; no significant problems are anticipated now.

4. Drain holes: Only one facet was observed whose ring drain holes had not yet been machined. However, several rings had RTV bonding material blocking their drain holes and it was removed.

5. Bonding: Inconsistent application of RTV beads on disc and ring surfaces was noted during production of the first five facets. This was rectified by having the RTV dispenser retrack, thus assuring proper bond.

6. Bond strength: Two sample facets were taken from April 1977 production and subjected to a pull test at SLA Dept. 1540 environmental laboratory. Neither delamination nor separation occurred between the disc or ring and the mirror surface when the pull level exceeded 1360 kg, demonstrating that the bond strength was approximately ten times that required by Design Engineering Div. 5713 for heliostat use (Appendix C).

7. Bond strength (reworked discs and rings): Pull tests were conducted on two facets that had reprocessed discs and rings. Separation was noted at about 680 kg, indicating that the bond strength is well above that needed on heliostats.

Field Maintenance Computer Program

To identify deficiencies observed during heliostat performance, a computer routine system was developed to accumulate failures which may result in retrofit. The computer program lists identification and control number for any components not meeting specifications. The first listing includes integrated circuits (ICs), drive units, switches, capacitors, motors, and cables for which failure modes and quantities were collected. Data Planning Division 9625 coordinated data retrieval and periodically furnished data printouts to STTF Division 5713 for analysis.

Future Quality Assurance Support of Solar Energy Facilities

The fabrication and follow-on acceptance of the 222 heliostats now installed at the STTF site completes the Quality Assurance Division 9500 plan. Heliostat production for the 10-MW thermal facility in Barstow, California is expected to start in early 1979. A QA Plan has not been developed yet for that facility, but a plan similar to the STTF plan could be implemented.

APPENDIX A

1. Quality Assurance Program for Heliostat Array Control Subsystem 842C0000000 and Heliostat Assembly 842H1000000

2. Certificate of Inspection (sample)

3. Record of Assembly/Disassembly (sample)

4. Quality Status Report (sample)

QUALITY ASSURANCE PROGRAM

FOR HELIOSTAT ARRAY CONTROL SUBSYSTEM 842C0000000

AND

HELIOSTAT ASSEMBLY 842H1000000

1.0 PURPOSE

The Sandia Quality Assurance Program requirements for heliostat production is the governing document for Sandia Laboratories Quality Policy and Procedures to be used in assuring that heliostat assemblies and major subcomponents thereof conform to contract requirements.

2.0 SCOPE

This document delineates the respective contractor quality control and the procuring agency quality assurance responsibilities in the procurement of subcomponents and the production of heliostat assemblies.

3.0 REFERENCES

1. Heliostat Array and Control System Quality Assurance Plan (MMC).

2. Qualification Evaluation System for Commercial Suppliers EP401401 (SLA).

4.0 DEFINITIONS

4.1 Contractor. The seller of parts, components, or apparatus to the procuring agency; in this case, Martin-Marietta.

4.2 Procuring Agency. A prime contractor of the US ERDA, acting as the buyer of parts, components, or apparatus from the contractor. For this project, this refers to Sandia Laboratories.

4.3 Subcontractor. The seller of raw materials, parts, components, or apparatus to a contractor or another subcontractor.

4.4 Heliostat Assembly. The heliostat array subsystem shall consist of an array of heliostats and their associated controls, sensors, drive and positioning mechanisms, support structure, and the heliostat array control subsystem and its computer software. The design requirement is that this system will continuously reflect the solar rays to a specified elevated experiment located on the facility experiment tower per 84200000005.

The individual heliostats within this array shall be made up of 25 mirrors, four feet square and capable of being individually focused so as to concentrate a solar light beam on the tower experiment.

Each heliostat mirror array shall be capable of rotation about a vertical axis and about a horizontal axis and may be computer directed to follow the sun.

The heliostat shall be composed of:

a. Twenty-five facets each of which is a 4' x 4' mirror bonded on the back to a steel ring with a circular "pull plate" bonded in the center of the back of the mirror. A stud arrangement permits movement of the pull plate relative to the ring with consequent movement of the center of the mirror relative to the outer areas. The result is a concave surface that may be focused by changing the curvature.

b. A truss assembly which is a welded angle iron structure with studs welded to it in a fashion which allows the mounting of 25 facets in a 5 x 5 array. The center beam of the truss assembly contains the elevation drive and drive motor which provides for rotation of the mirror array around a horizontal axis.

c. The mirror array on the truss assembly is mounted on a large U-shaped channel steel yoke. The yoke is centered in an upright position on an azimuth drive unit which provides the capability for rotation around a vertical axis.

d. The azimuth drive is a heavy duty gear box with its associated drive motor to which is mounted the yoke and mirror array and which provides for rotation of the heliostat around a vertical axis.

5.0 PROGRAM

5.1 Operations. The contractor/supplier shall operate a quality program which will assure that product conforms to contract requirements, including product definition requirements.

5.2 Management. Quality program management shall be prescribed by the contractor in conjunction with other functions necessary to satisfy the contract requirements.

Heliostats shall be produced under an effective and economical quality control program. The program shall ensure that quality activities are identified and implemented throughout the applicable phases of contract performance, including development, procurement, fabrication, processing, assembly, inspection, testing, and data recording. The program shall provide for the early detection of deficiencies or marginal quality and for effective corrective action.

Product acceptance shall be by submission of product by the contractor with supporting specifications and inspection data to a duly designated inspector functioning in the interest of the procuring agency.

5.3 Documentation. The contractor/supplier shall have documented quality procedures (where possible, a compilation of working papers) to implement the quality program.

5.4 Audit. The contractor/supplier quality procedures, operations, and records are subject to evaluation, audit, and control by the procuring agency.

6.0 PRODUCT DEFINITION CONTROL.

The product definition (such as drawing, specifications, and standards) shall be maintained to assure that product is fabricated and inspected to authorized requirements. Changes to product definition shall be processed to assure their incorporation as specified, and a record of incorporation points (by date, batch, lot, unit, or other specific identification) shall be maintained. All product changes shall be approved by a Sandia Laboratory representative.

6.1 Data Control. The contractor shall provide accurate and complete data to the procurement agency, as required, to assure that applicable base line data is available for (1) heliostat configuration, (2) long-term studies, (3) technology sharing, and (4) reporting requirements.

7.0 CONTRACTOR QUALITY PROGRAM ELEMENTS

7.1 Source Control. The contractor shall control procurement sources to assure that purchased materials and services conform to authorized requirements. Purchase orders or subcontracts shall assure incorporation of technical and quality requirements, including authorized changes. The contractor shall either provide for inspection at source or require objective evidence that the subcontractor has complied with authorized requirements.

7.2 Raw Materials. Raw materials, purchased as such or as a part of a fabricated part, shall be inspected and tested to assure conformance with authorized requirements. Incoming raw materials shall be withheld from use until after inspection and testing, or after receipt and use of quality evidence.

7.3 Material Control. The contractor shall have procedures and facilities for controlling the identification, handling, storage, and use (on a first-in, first-out basis) of raw and fabricated material, including presentation and disposition of reworked or repaired items. The system shall include a means of identifying the inspection status of items. These controls shall be maintained from the time of receipt of the material until delivery of the finished product, to protect the material from damage, deterioration, loss, or substitution.

7.4 Process Control. Controls, including in-process inspections and tests, shall be established and maintained at appropriately located points to assure continuous quality throughout the manufacturing process.

7.5 Inspection Equipment. The contractor/supplier shall provide accurate measuring and testing equipment to inspect and test the product. At intervals to assure continued accuracy, such equipment shall be calibrated against certified standards that have a known valid relationship to National Bureau of Standards equipment. If production tools (such as jigs, fixtures, and patterns) are used as media of inspection, such devices shall also be proved for accuracy at established intervals. Equipment so verified shall bear an indication attesting to the current status and showing the date (or other basis) on which inspection or calibration is next required.

7.6 Inspection. The contractor/supplier shall operate an inspection program which will verify that product conforms to contract requirements, including product definition requirements.

The inspection program shall also provide for submission of material with supporting documents to the procuring agency inspector. Supporting documents will partially consist of recording and submitting data that is to be retained by the procuring agency in formats provided by the procuring agency.

7.7 Records. The contractor/supplier shall maintain records of inspections and tests, including data on both conforming and nonconforming product.

7.8 Corrective Action. The contractor/supplier shall systematically use quality records and information from control areas described above to prevent, detect, and correct deficiencies that affect quality. Use of deviated material must be approved by a Sandia Laboratory representative.

7.9 Records of Assembly. A record of all serially numbered subcomponents of each heliostat array subassembly will be initiated and submitted with that assembly at time of verification inspection. Record of assembly data will be provided on formats specified and furnished by the procuring agency.

8.0 PROCURING AGENCY QUALITY PROGRAM ELEMENTS

8.1 Product Qualification Evaluation

8.1.1 Objective. The objective of qualification evaluation is to provide evidence to be used by the procuring agency to predict production capability and the degree to which production units will perform the functions for which they were designed. Qualification evaluation provides such evidence and determines the degree to which:

a. the sample conforms to the drawings and specifications, and

b. the facilities, tools, manufacturing and assembly processes, quality controls, inspection and test processes and equipment, and type of personnel used by the contractor and subcontractors are adequate to furnish product of the quality and quantity required.

8.1.2 Qualification Evaluation Approval. Qualification evaluation approval is procuring agency acceptance of evidence that the manufacturer's capabilities are adequate to supply product of the quality and quantity required. Qualification evaluation approval does not waive any requirements in the drawings and specifications and does not imply acceptance of subsequent nonconforming product.

8.1.3 Evaluation Sample. The evaluation sample is one or more units of product produced from the same facilities, tools, manufacturing and assembly processes, quality controls, inspection and test processes and equipment, type of personnel, and location planned for use during production. The product to be subjected to inspections and/or tests of this qualification evaluation will be Heliostat Assembly (842H1000000), Heliostat Array Control Subsystem (842C0000000), Heliostat Array Controller Assembly (842C1100000), Mirror Assembly (842H1110027), Elevation Drive Mechanisms - Final Assembly (842H1300000), Drive Assembly - Azimuth (842H1300000), Mirror Module Truss Assembly (842H1110028), Yoke Module Assembly (842H1200000), Sun Present Sensor Assembly (842C3100000), and Heliostat Control Electronic Assembly (842C1600000).

8.2 Subcontractor Surveys. The procuring agency shall have the right to perform inspection activities in subcontractor plants to assure conformance to contractor contract requirements and to assure qualification of subcontractor through inspection and approval of first production units.

Investigation may include material control, production control, calibration, drawing and specifications, production processes, inspection, and records.

Such inspection shall normally include a quality representative from the procuring agency and a contractor quality representative.

8.3 Verification Inspection

8.3.1 The procuring agency will accept material at specified levels via Quality Assurance Verification Instructions (QAVI). These Instructions are inspections and tests based upon contractual requirements defined in the contractor's product drawings and specifications. The levels to be included are the same as those defined under paragraph 8.1.3.

8.3.2 It is required that the above units be submitted with a certificate of inspection, the associated inspection data required by the procuring agency, and manufacturing specifications (drawings) to the procuring agency's designated inspector for sampling, inspection, and acceptance/rejection by that inspector. No higher level of assembly is permitted until each unit by serial number has been accepted.

8.3.3 Acceptance of lots of material are granted after successful completion of all tests and inspections specified in the QAVI. Signature of the procuring agency inspector on the certificate of inspection denotes acceptance.

8.3.3.1 Material deviations and reject disposition may be approved only by the procuring agency project representative.

8.4 Contractor Quality Program Review and Approval. The contractor shall design and implement a quality control program to assure delivery of a quality product. Sandia Laboratories shall audit and approve the contractor's quality program prior to implementation and periodically during production.

8.5 Process Control Audits. Periodic audits will be performed to ascertain conformance to specified contractor procedures. Candidates for these audits include such items as welding and welding inspections, mirror to ring bonding, mirror painting and paint testing, encoder testing, and drive unit and drive assembly processing and testing. Deviations from defined procedures may be cause for cessation of the process until corrective action is taken by the contractor.

8.6 Quality Reports. Periodic and final quality reports assessing the quality of product submitted to the procuring agency as measured by verification inspections will be published by the procuring agency.

CERTIFICATE OF INSPECTION;
HELIOSTAT PRODUCTION

SOLAR THERMAL TEST FACILITY

roduct Definition and Identification

COI No.

. Mirror Module 842H1100000 (Hangar)
. Heliostat 842H1000000 (Site)

Lot No.

Disp	Serial Number	Deviations and Comments

marks

Sandia Quality Assurance			Martin-Marietta
Sampled	Accepted	Withheld	The listed material meets applicable specifications and quality requirement of the contract.

QOI No.

ithorized Signature Date
LA Quality Assurance

Authorized Signature Date
M-M Quality Control

STTF **RECORD OF ASSEMBLY/DISASSEMBLY** STTF

A or D	ROA DWG	OP 131 COMPLETION MO / DAY / YR	ASSY / DISASSY AGENCY		CARD COUNT	69
A	RF1000000			1	35	L

For Agency Enter:
MGR- for Martin Marietta
SLA- for Sandia Labs.

LINE	ITEM	PART NO.	PN SUFF	REV.	SERIAL NUMBER	S/N ENTRY EXAMPLES
2	Heliostat Assembly	H1000000				078
3	Elevation Drive	H1300000				
	Encoder	H1110600				
	Mirror Assembly (FACET) 1	H1100000				1100 or 0075
	2					or 0009
	3					
	4					
	5					
	6					
	7					
	8					
	9					
	10					
	11					
	12					
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	18					
	19					
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	22					
	23					
	24					
	Mirror Assembly (FACET) 25	H1100000				
	Azimuth Drive	H1310000				010 or 110
	Encoder	H1110600				
	Motor Drive Module (Azimuth)	H1310110				
	Heliostat Control Elec. (HCE)	C1600000				
	Motor Drive Module (Elevation)	H1310110				
	Sun Present Sensor	C3100000				
	Location in Field	L1000000	0 0 0	A		41N32W

REMARKS:

DISTRIBUTION:
Send originals to
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NOTE: Right justify all entries

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UNCLASSIFIED

AUTHORIZED SIGNATURE

RF1000000

October 18, 1977
Report No. 003

QUALITY STATUS REPORT
SOLAR THERMAL TEST FACILITY

Section I (Hangar Operation)

Reporting Period - 9/1/77 thru 9/30/77

1. Sand Blast Operation

   Remarks: No problems encountered.

2. Drive Unit Cleaning

   a. Torque

   b. Oil Fill (leaks)

   c. Dowels (broken, cracked, bent, etc.)

   Remarks: (a) One EL drive unit lock gear train.

   (b) No problem.

   (c) Five drive units (EL) with broken dowels reworked and placed back in production flow.

3. Drive Unit Assembly

   a. Commutators

   b. Encoders

   c. Seal (gaskets)

   Drive Unit Production

   Totals: Azimuth - 42
   Elevation - 37

   Remarks: (a) 81 commutators inspected - two rejected.

   (b) 96 encoders inspected - 17 rejected

   (c) Two AZ units returned from field were improperly installed - gaskets were replaced on drive units for reuse.

4. Mirror Assembly (Facet)

   a. Mirrors (distortion, chips, cracks, etc.)

   b. Focusing Discs

   c. Support Rings

d. Bonding Operation

e. Temperature and Humidity (curing)

Facet Production Total: 647 (4561)

Remarks: (a) 968 mirrors received in September - 742 inspected - 8% reject, 2% of facets were rejected due to in house handling damage.

(b,c,d&e) No problems.

5. Paint Shop

a. Paint Samples

b. Temperature and Humidity

Remarks: No problems encountered.

6. Focusing

Remarks: Of the 647 facets produced in September 1977, four percent would not focus properly. However, a proposed M-M rework procedure (non-flatness shim correction) is expected to recover almost the entire group.

7. Rack Assembly

a. Trusses

b. Beams

c. Welding

d. Alignment (string test)

Remarks: (a) No problems.

(b) One main beam returned to vender - mislocated holes of flange.

(c&d) No problems.

8. Mirror Module

a. Alignment (mirrors installed)

b. Paint touch-up

c. Mirror Damage (chips or cracks)

Remarks: No problems.

9. Summary of Hangar Operations

The high reject rates on encoders and mirrors have continued through September. The encoders are being returned to Litton for rework although it appears that functional verification methods differ between M-M and Litton. R. England (M-M) has been investigating rework procedures and functional verification at Litton to possibly reduce reject rate. The high reject rate during basic mirror inspection is mainly due to inability to meet flatness requirements. However, M-M has initiated a plan to correct non-flatness condition by placing mirror on flat surface and installing shims between mirror and flat surface. Considerable difficulty has been encountered in the focusing operation because the 640 ft. focus requirements or adjustments are very slight and facet focus is more dependent on mirror flatness at 640 ft. than the closer zones.

The production and acceptance of 24 mirror modules during September are less than that produced in August when 36 modules were assembled primarily due to mirror delivery delays. An overall assessment of the hangar operation indicates that mirror module production is continuing at a satisfactory rate with only minor quality problems experienced and corrected.

Carl W. Shunk
M-M Authorized Signature

J. S. Dueman
Sandia Quality Assurance

APPENDIX B

1. Martin-Marietta Quality Control Program

2. Heliostat Data Package/Computer Storage

Martin-Marietta Quality Control Program

The Martin-Marietta Quality Control Inspection Program was implemented to provide conformance with the QASL designed Quality Assurance Program. The details of that Inspection Program are given in the following pages.

Martin-Marietta Quality Control Program

Inspection Levels

1.0 Encoder

1.1 Electronics/Read Heads

Bellows Condition

- Corrosion
- Cracks
- Dents
- Alignment

1.2 PC Board

- Chipped, Cracked, Damaged PP
- Solder
- Flux Corrosion
- Epoxy on Adjustments

1.3 Commutators

- Clean Code
- Index Mark Location
- Damaged Glass

1.4 Clamp Plates

- Smooth Surfaces (Molded)
- Hole Restriction

1.5 Data for each Unit

2.0 Mirror Rings & Discs (Typical Production min. 50 ea/8 hrs)

2.1 Rings

2.1.1 Flatness (.030 max)

2.1.2 Roundness (46" ± .200)

2.1.3 Welds

Ring seam weld 100% penetration

Other Welds

Penetration requirements on drawing

Splatter - center hole sensitive

Ring seam weld - outer surface

No more than 1/32 high

Drain holes properly oriented

PEM Nuts Seated

2.2 Discs (focus pull plates)

Flat to .030

Stud centered

Stud perpendicularity ± 0.5°

Look for Rust - can sandblast off masked area

2.3 Rings and Discs Sand Blasted Surfaces Must be Protected

Discs on clean craft paper only

3.0 Bonded Mirrors

3.1 Glass

3.1.1 No nicks or cracks

3.1.2 Shell/spall damage permissible

3.1.3 Each 10th mirror measured for flatness front and back

Front} * Avg of 4 corners not to exceed .025"

Back} *

3.2 Bond Tool

3.2.1 Dispense RTV on center of sandblast area of rings and discs

3.2.2 Squeeze out evident on both sides of ring to glass. Evidence of bond with lack of squeeze out not to exceed 4"

3.2.3 .400 - .800" squeeze on discs - exposed squeeze comparable to rings.

NOTE: Rework or major adjustment of tool requires a clear glass sample be run to determine squeeze in disc bond.

NOTE: Slide on contact of ring to glass is cause for rejection.

3.2.4 Data = Assy S/N
= Pallet No.
= Any MRB rings or discs used

3.3 Cure

3.3.1 Cure time is 48 hours at controlled humidity

NOTE: Inspection limited to exposed edges - Tag suspect assemblies (chips - cracks - Bond suspects) for inspection prior to paint.

3.4 Post Cure

3.4.1 Drain holes cut open

3.4.2 Check for Mirror Damage

3.4.3 Check for improper bonds

4.0 Painted Facets (mirror assembly)

4.1 Pre-Focus

4.1.1 Handling Damage to Glass

4.1.2 Paint coverage (bottom usually light)

4.1.3 When primer shows through - reject

5.0 Focused Facets (mirror assembly)

5.1 Handling Damage

5.2 Screw (focus each corner)

5.2.1 End Caps

5.2.2 Jamb Nuts

5.2.3 Stencil Part Number and S/N

5.3 Date on Record of Assembly Forms (see 6.0)

Mirror Assembly configuration

Mirror Assembly S/N

Remarks Col = Unusual Conditions, i.e., unpainted, white

6.0 Drive Units - elevation or azimuth

6.1 Pre-clean room operation

6.1.1 Initiate Data Sheet (MMC Quality Data)

6.1.2 Fill, Lubricate

6.1.3 Clean

6.2 Clean Room Operations

6.2.1 Initiate Record of Assembly Form

6.2.2 Install Limit Switches

6.2.3 Install Commutator - adjust runout

6.2.4 Install Read Head and Electronics

6.2.5 Test (cover off) System (witness)

6.2.6 Clean

6.2.7 Test (cover on) system (witness)

6.3 Complete Data

6.3.1 MMC Quality Data Sheet - buy

Record of Assembly and deliver to focus crew

NOTE: Assure no units failing backlash get to assembly area.

NOTE: Units may develop leaks during or after assembly/test acceptance.

7.0 Mirror Module Rack (lots of attention)

7.1 Initiate MMC Quality Data Sheet

7.2 Quality identify weld rework required at junction of -001 and -002 assemblies.

7.3 Quality verify completed assembly trusses are ± 3/8 parallel to each other.

7.4 Data Sheet

8.0 Mirror Module Assembly

8.1 Focused Mirrors Installed

8.1.1 Complete record of assembly (ROA)

(Data sheet from 7 provides information on el drive S/N used to this step).

By entering mirror data, deliver to quality.

8.1.2 Quality Obtain el Drive

MMC Quality Date:

Encoder Data Sheet

Drive Unit Data Sheet

MMC Test Data

8.1.3 Quality reproduce one copy of the Record of Assembly and retain. Combine the original ROA with the MMC Quality Data into a package. Package to move to site with completed mirror module assembly.

8.1.4 Annotate the date of completion of mirror module assembly on the ROA.

Heliostat Data Package/ Computer Storage

The STTF Heliostat Data Package is comprised of the following completed data forms:

Quality Data Forms (4 each)

Encoder Acceptance Sheets (2 each)

Record of Assembly (1 each)

Heliostat Control Electronics (HCE) Form (1 each)

Leveling Forms (1 each)

Focusing Data (25 sheets)

Drive Unit Acceptance (2 each)

Quality Control Work Sheet (if necessary)

Data Planning Division (SLA 9625) provided the Record of Assembly form to use in computer storage program. The Record of Assembly form lists major component, i.e., encoder, drive units, sun-present-sensors, mirror assemblies, and heliostat control electronics, serial numbers and part number identifications, plus other pertinent information or deviations observed during heliostat fabrication. A log of mirror assembly (facet) serial numbers, manufacture dates, and pad control numbers was maintained throughout the heliostat production.

APPENDIX C

1. Drive Mechanism Backlash Measurement

2. Mirror Assembly Bond Strength Pull Test

MEMO

TO: J. Otts 5713

D. Kuehl 5713

CC: P. R. Brown

Attachment: Two Tables - Backlash Measurement Comparison, MMC vs. Morse Chain, Elevation and Azimuth Drive Mechanisms

Subject: Drive Mechanism Backlash Measurement

Measurement of backlash has now been performed on a total of 308 azimuth and elevation drive mechanisms: 258 by Sandia and 50 by MMC. As a result of the measurements by Sandia, 29 units were returned to Morse Borg Warner (MBW) for rework to reduce their backlash to 3.0 arc minutes or less at the tight point of the mesh. An additional 6 units which had backlash less than 3.0 at the tight point of the mesh, but slightly greater than 4.5 arc minutes at the loose point of the mesh have been returned to stock for assembly in heliostats.

Prior to the return of the 29 units to MBW, the method used by MBW to establish backlash was a two-stage measurement in the gear mesh, the sum of which was intended to establish the true backlash. Subsequently, MBW changed their procedure to measure backlash directly at the output shaft. The measurements made by MMC were on units that MBW had checked by the direct method. A comparison of MMC's and MBW's measurements is shown in the attached tables. Admittedly, there is not a direct correlation. This is understandable because, although for both MMC and MBW, measurements are made at eight (roughly) equidistant locations of the output shaft, there are literally an infinite number of positions of the output shaft that could be affected by the engagement relationship of the gears, bearings, carriers, etc., in the entire train, from output shaft to input worm. The correlation that does exist, however, is that of the 50 units rechecked by MMC, all meet the acceptance criteria which has been established as:

1) Backlash at tightest point of mesh (as measured) equal 3.0 arc minutes or less.

2) Backlash at loosest point of mesh (as measured) equal 4.5 arc minutes or less.

As can be seen on the attached tables, all of MMC's measurements verify that this criteria is met; on the units where 3.0 arc minutes is exceeded at the loosest point, it is well below 4.5 arc minutes.

Based on the fact that MBW has made the backlash check on all delivered units, and a recheck of a large sample of these units has disclosed that 100% of the sample meets the criteria, it is MMC's contention that a continuation of the recheck here at Albuquerque is not productive. It is felt that the manpower required to make this check could be utilized more productively. Therefore, MMC, unless specifically directed to the contrary by Sandia, will (has) discontinue(d) the backlash test on drive mechanisms. However, the MBW data sheet on all units will be checked to (1) assure that MBW did perform the backlash test and (2) that the criteria (as stated above) has been met.

R. A. Englund
R. A. Englund
Project Engineer
HAACS

Backlash Measurement Comparison
MMC Vs Morse-Chain
25 Elevation Drive Mechanisms

Drive S/N	MMC Tightest	MMC Loosest	Morse-Chain Tightest	Morse-Chain Loosest	Δ(MMC - M-C) Tightest	Δ(MMC - M-C) Loosest
77-270	0.28	2.10	2.29	3.15	-2.01	-1.05
77-245	0.29	1.23	1.15	2.29	-0.86	-1.06
77-143	1.34	3.14	1.43	2.58	-0.09	+0.56
77-145	0.98	2.07	1.15	2.01	-0.17	+0.06
77-189	0.53	2.13	2.01	3.43	-1.48	-1.30
77-190	1.70	2.47	2.29	3.43	-0.59	-0.96
77-144	2.41	2.88	2.29	3.43	-0.15	-0.55
77-142	0.47	1.07	0.86	1.43	-0.39	-0.36
77-139	1.54	2.03	1.72	2.86	-0.18	-0.83
77-146	1.03	1.72	1.15	2.01	-0.12	-0.29
77-241	1.59	2.39	1.43	2.01	+0.15	+0.38
77-239	0.97	1.47	1.43	2.01	-0.46	-0.54
77-195	1.78	2.20	2.29	3.44	-0.51	-1.24
77-216	1.98	2.50	0.86	1.15	+1.12	+1.35
77-220	2.75	3.66	1.15	2.01	+1.60	+1.65
77-219	1.43	2.07	1.43	2.24	-0-	-0.17
77-222	1.56	2.56	0.86	1.43	+0.70	+1.13
77-221	2.41	4.13	1.15	2.01	+1.26	+2.03
77-218	2.22	3.26	2.01	3.44	+0.21	-0.18
77-212	1.55	2.32	1.15	2.24	+0.40	+0.08
77-217	1.19	2.13	2.24	2.86	-1.05	-0.73
77-214	1.99	2.67	0.86	2.01	+1.13	+0.66
77-215	2.01	3.25	1.72	2.58	+0.29	+0.67
77-197	1.59	2.28	2.01	5.15	-0.42	-2.87
77-147	1.75	2.60	1.72	2.86	+0.03	-0.26

NOTES:
1. All values are in arc-minutes.

2. Negative values under "Δ(MMC-MC)" indicate MMC measurements were lower than Morese-Chains' and vice versa.

Backlash Measurement Comparison
MMC Vs Morse-Chain
25 Azimuth Drive Mechanisms

Drive	MMC		Morse-Chain		Δ(MMC - M-C)	
S/N	Tightest	Loosest	Tightest	Loosest	Tightest	Loosest
77-223	1.93	3.69	0.26	1.72	+1.07	+1.97
77-230	2.29	4.26	1.15	2.86	+1.14	+1.40
77-228	0.17	1.86	1.43	1.72	-1.26	+0.14
77-232	0.27	2.04	0.86	1.72	-0.59	+0.32
77-136	2.09	3.06	2.24	2.86	-0.15	+0.20
77-127	2.36	3.96	2.01	2.86	-0.50	+1.10
77-135	2.29	3.22	0.86	2.01	+1.43	+1.21
77-130	0.80	1.37	0.86	1.43	-0.06	-0.06
77-137	1.88	3.11	2.29	2.58	-0.41	+0.53
77-128	1.39	2.17	1.43	2.29	-0.04	-0.12
77-132	2.34	2.82	2.29	2.58	+0.05	+0.24
77-129	1.17	2.08	0.86	1.15	+0.31	+0.93
77-114	1.59	2.14	1.15	1.72	+0.44	+0.42
77-084	2.00	2.60	0.86	1.43	+1.14	+1.17
77-257	2.98	3.38	1.72	2.58	+1.26	+0.80
77-258	1.50	2.36	1.72	2.24	-0.22	+0.12
77-207	1.98	2.52	0.86	1.43	+1.12	+0.55
77-203	2.28	3.11	1.72	2.26	+0.56	+0.25
77-086	1.55	2.67	- NO	DATA -	-	-
77-251	2.17	2.65	1.15	2.86	+1.02	-0.21
77-080	2.73	3.46	- NO	DATA -	-	-
77-202	2.41	2.75	1.72	2.24	+0.69	+0.51
77-252	2.03	2.49	2.01	2.58	+0.02	-0.10
77-199	2.80	3.21	2.24	3.44	+0.56	-0.23
77-210	2.82	2.27	1.72	2.24	+1.10	+0.03

Sandia Laboratories

date: May 16, 1977

to: J. V. Otts - 5713

from: F. P. Freeman - 9515

subject: Mirror Assembly Bond Strength Pull Test

Due to sandblasting residue observed on bonding surfaces of focus discs and ring supports, the strength of the disc and ring support/mirror bonds had been questioned. Martin-Marietta's calculations indicated that both disc and support bonds would withstand a 1500 lb. pull test.

Two mirror assemblies (183 and 184) were selected from a group of assemblies not acceptable for use because of mirror damage (cracks and chips) but were judged to be representative of bonding methods employed since 4/18/77. The two mirror assemblies were subjected to a concentrated pull test to evaluate the strength of the bonds as described below.

Focusing Disc Test.

The mirror assemblies were placed face down on a support table with wooden blocks positioned on the back of the mirror about two inches outside the disc so that the bond strength could be evaluated without interacting with mirror or glass durability. Initially, a pull test of 1500 lbs. was conducted on both mirror assemblies in which force was applied to the focus adjustment screw (see Figure 1) in the center of the disc. There were no bond separations or deficiencies detected at the 1500 lb. test. An additional test of 3000 lbs. was performed on the disc/mirror bond in which no bond faults were noted.

Ring (Frame) Support Test.

The same two mirror assemblies were then used to monitor the ring/mirror bond. The mirror assemblies were mounted on the support table (face up) with the wooden blocks away from the disc adjacent to the ring bond (see Figure 2). The pulling apparatus was then connected to the center of the ring support at the strut intersection of the frame. The pulling device was first adjusted to 1500 lbs and when no problems were experienced, the level was raised to 3000 lbs. At the 3000 lb. pull test, no bond delaminations were observed.

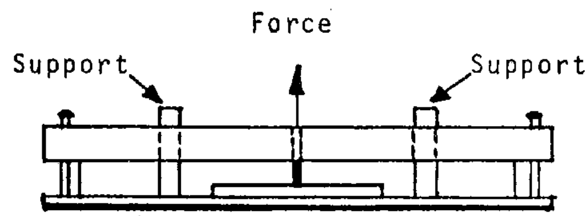
It is assumed that the samples subjected to the pull test are representative of the entire mirror assembly bonding operation. If this assumption is correct and sandblast residue could be found on bonding surfaces of all discs and ring supports during the bonding operation, the residue apparently does not affect the strength of either bond.

Also, the disc and ring support pull test showed that the bonds will withstand a stress many times the level expected during fabrication, handling, focusing, and ultimate heliostat use.

FPF:9515:hm

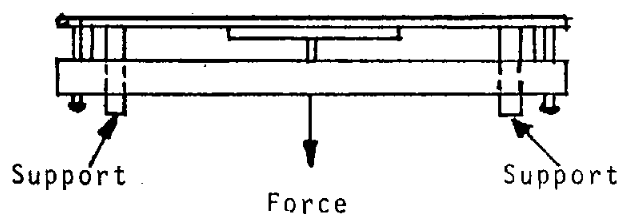
Copy to:
M-M Paul Brown
5713 H. J. Gerwin
9515 J. T. Hillman

Mirror Assembly (Facet)



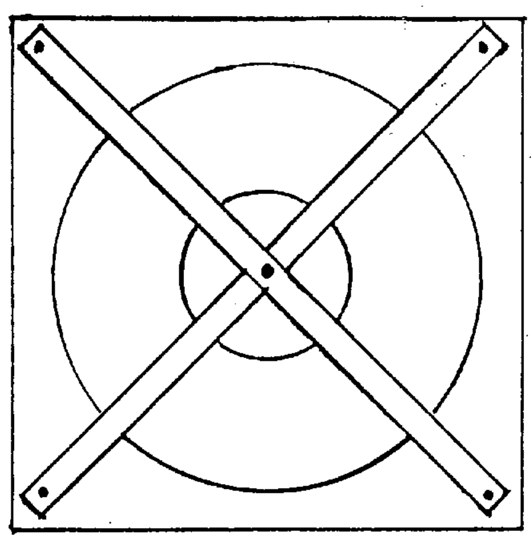
Focusing Disc Test

Figure 1



Ring (Frame) Support Test

Figure 2



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