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CR-134123

REFURBISHMENT OF SOLAR SIMULATOR

OPTICAL TRAIN MIRROR ASSEMBLIES

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National Aeronautics & Space Administration
Manned Spacecraft Center
Space Environment Simulation Section/ES6
Houston, Texas 77058

Attention: Jack Fuller

Contract NAS-9-11461

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Xerox Corp

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1.0 REFERENCE DOCUMENTATION

NASA/MSC Contract NAS-9-11461, dated January 15, 1971, and modifications to the contract:

MOD 1C	MOD 4S	MOD 7S
MOD 2S	MOD 5S	MOD 8S
MOD 3C	MOD 6S	MOD 9S

Contract includes complete refurbishment of the reflector surfaces on:

89 ea. No. 1 Solar Simulator Primary Collector Mirrors.
78 ea. No. 2 Solar Simulator Secondary Collector Mirrors
32 ea. No. 3 Solar Simulator Secondary Collimator Mirrors
52 ea. No. 4 Solar Simulator Primary Collimator Mirrors.

Reference Drawings and Specifications:

Drawings

Drawing Number	Mirror Number	Revision	Dated
614331	1	A	3/22/66
614805	1	C	2/15/69
614577	2	A	10/13/66
614806	2	C	2/15/69
614576	3	C	9/28/66
614807	3	C	2/15/69
614320	4	D	9/28/66
614808	4	C	2/15/69

NASA/MSC Statement of Work:

1. Specifications for MSC Solar Simulator Mirrors, Appendix "A", dated July 23, 1968.

2. Appendix "B" - Sections B-1 through B-4, Detailed Optical Test Procedures for No. 1, No. 2, No. 3, and No. 4 Solar Simulator Mirrors.

3. Rework Procedure 3312 for Water Ports - November 22, 1966.

4. Inspection - Marking/Packaging.

NASA/MSC Statement of Work (continued):

5. Process Specification 158, Rev. A, December 30, 1968, Test - Reflectance of Solar Simulator Reflector Coatings.

6. Process Specification - Directive 12-2, Pre-treatment of Aluminum Alloy 356 Prior to Adhesive Bond.

7. Process Specification - Directive 15-1, Torque Shear Adhesion Test.

8. Process Specification - Directive 15-2, Bonding Nickel Replicas to Aluminum Castings.

9. Process Specification - Directive 15-3, Void Repair Procedure for Repair of External Voids Only.

10. Process Specification - Directive 15-4, Spinning Delamination Repair Procedure for No. 4 Aluminum Sub-Assembly.

11. Process Specification - Directive 35-1, Analytical Control Manual.

12. O. T. 45-1, Rev. "A", Mirrors Front Surface Coatings.

13. Process Specification - Directive 12-1, Procedure for Bonding No. 1 Aluminum Spinning Assembly.

14. Process Specification 201, Bonding No. 4 Spinning to Casting.

2.0 SUMMARY

A total of 251 mirror assemblies were completely processed through the Mirror Refurbishment Program. All reflectors were removed from the mirror casting, replaced, and processed through the various states of processing and testing.

The processing of the mirror assemblies was completed on two different contract MOD requirements. The initial contract called for 145 (40 each No. 1, No. 2 and No. 4 and 25 each No. 3) mirror assemblies to be refurbished.

MOD 2S of the contract called for an additional 106 (49 each No. 1, 38 each No. 2, 7 each No. 3 and 12 each No. 4) mirror assemblies to be refurbished.

Processing of all 251 mirror assemblies through mirror refurbishment was not a problem, except for one group of 24 No. 2 mirror assemblies and eight other mirror (one each No. 1, No. 2 and No. 3 and five each No. 4) assemblies which were returned for figure and coating problems.

Thirteen of the 24 No. 2 mirrors were stripped and buffed, optical tested, then recoated. These mirrors were returned to NASA/MSC. The remaining eleven mirrors required more extensive rework and refurbishment prior to being returned to MSC. This rework was done on MOD 8S of the contract.

Three other mirrors, one each of No. 1, No. 2 and No. 3, which had been returned for problems with figure and coating were reworked

2.0 SUMMARY (continued):

and returned to MSC as proof plating mirrors on plating tools that were reworked on NAS-9-12960 contract. The No. 1 casting showed porosity on the contour surface, and this casting was replaced by another unit. The No. 2 unit was refurbished because of a delaminated replica. The No. 3 replica was replaced due to coating delamination (which also had optical deviation over 16.7 fringes per inch in this area).

Of the group of five No. 4 mirrors returned from MSC, one unit was recoated and the other four mirrors were completely refurbished. This was due to epoxy voids between the casting contour surface and the electroformed nickel replica. Also, delamination of the electroformed replica and optical display was not satisfactory, nor within tolerance when tested optically.

MOD 6S to the contract was issued to vacuum coat six No. 4 mirrors with aluminum. No quartz (SiO_2) protective layer was to be coated over the aluminum coating. One unit coated on MOD 6S, S/N T-4-015, was returned with the five No. 4 mirrors mentioned above, and was completely refurbished. The sensitivity of the aluminized surface only was damaged to the point of etching the nickel replica, and could not be recoated.

3.0 MIRROR REFURBISHMENT PROCESSING:

There are four types of mirror assemblies refurbished, all of which consist of a water-cooled aluminum casting and an electroformed nickel replica mirror. Electroforming is the process of building a structural part by electro-deposition on a master plating tool, and in this case, the tool is reusable. EOS used two types of tools to produce these mirrors, one of which is a reverse form of the electroformed mirror and is made from 17-4-PH stainless steel. The other unit is an electroformed nickel tool, made from a stainless plating master; the master has a curvature identical to the electroformed mirror.

There are several basic steps in the sequence of production, with the first step being fabrication of the replica tooling. Stainless steel has proven to be superior to any other metal and has produced large numbers of replications for these mirror configurations. NOTE: The above-mentioned tooling was manufactured on previous NASA/MSC contracts, and maintained in usable condition on subsequent contracts as well as this contract.

Once a master is available, the replica is electroformed directly on the master. After the proper thickness is achieved, the replica is parted from the master and is epoxy-bonded to an aluminum casting which has a contour machined to match the electroformed replica contour. After bonding and cure, the assembly is given a preliminary optical test; if it is within specification limits, it is sent to electric discharge machining (EDM). The EDM is used to cut the electroformed mirror to the proper inner and outer shapes.

3.0 MIRROR REFURBISHMENT PROCESSING (continued):

After washing, deburring, and mechanical inspection, the mirror assembly is ready for final optical tests. The mirror optics, surface quality and cosmetics are rechecked to verify the preliminary optical test data. If the mirror is accepted, final inspection buy-off is completed.

From optical testing, the mirror assembly is sent to the vacuum coating area. The vacuum coating which is applied protects the surface and improves the reflectivity of the mirror assembly. After final inspection, the mirror, with its paper work, is boxed and shipped to NASA/MSC, Houston.

3.1 Examination of Returned Mirror Assembly:

Each mirror assembly was unpackaged and examined for shipping damage. Also, at this time, the assembly serial number and replica degradation were verified with the NASA/MSC discrepancy list. After all paper work was completed, the mirror assembly was prepared for rework.

3.2 Nickel Mirror and Epoxy Removal:

After initial examination was completed, the mirror replica was heated with a large plumed torch, and removed from the casting assembly. Immediately after the replica was removed, Pittsburg Paint & Varnish Remover was applied to the epoxy which retained the replica. After many applications of this remover, the epoxy softened up and was scraped from the contour surface. Care was exercised so as not to damage the casting during removal of the epoxy,

3.0 MIRROR REFURBISHMENT PROCESSING (Continued):

3.3 Mirror Plating - Electroforming of Replica:

No. 1 Collector - Primary Mirror Plating:

One master was used to electroform all of the replicas for the No. 1 Collector Mirror replicas. This master was sent out twice during this contract for repolishing of the contour optical surface. Due to normal use and cleaning operations, the optical surface became sleeked and scratched. Also, this master has a small inclusion in one area which leaves a slight nodule on each replica. This nodule does not affect the optics of the replica, and is covered with SR-82 edge seal after vacuum coating to eliminate the possibility of coating decay in this area.

The plating life of this master appears to be doing very well considering the number of replicas plated from this tool. Present condition of this master can produce optically acceptable replicas if needed on any additional contracts.

No. 2 Collector - Secondary Mirror Plating Tool:

One master was used to electroform replicas for these secondary mirrors; however, the second plating tool was reworked on Contract NAS-9-12960. This master was proof plated on this contract, using No. 2 Mirror Casting S/N T-2-53 as the proof plating casting.

Repolishing of the main plating tool was done twice as milky stains and sleeks appeared on the surface, and normal cleaning and use required the master be polished to achieve better cosmetics on the end product replicas.

3.0 MIRROR REFURBISHMENT PROCESSING (continued):

3.3 Mirror Plating - Electroforming of Replica (continued):

No. 2 Collector - Secondary Mirror Plating Tool (continued):

There were no significant problems with the master. The flat "S" curve on this master makes initial set-up platings difficult; however, once these parameters are met, electroformed replicas can be produced at the rate of one per day.

The master tooling is in acceptable condition, and can be used to electroform any required units.

No. 3 Collimator - Secondary Mirror Plating:

During this contract, there was one master tool used to electroform all of the No. 3 Secondary Collimator replicas. A second tool was reworked on Contract NAS-9-12960, but a No. 3 mirror casting (S/N 3246) from this contract was used to proof plate the master.

Platings used for the Secondary Collimator Mirrors were very good, and the plating master held up very well. Here again, repolishing was required twice during the contract due to normal use and cleaning sleeks. The master tooling is also available for use if required. One unit is available for plating replicas, and the second unit is being reworked under Contract NAS-9-12960.

No. 4 Collimator Mirror Plating:

The master plating tool used to make No. 4 Submaster tools has been reworked and is in a Government bonded area. This tool was reworked as required, and will be used to make new submasters on Contract NAS-9-12960.

3.0 MIRROR REFURBISHMENT PROCESSING (continued):

3.3 Mirror Plating - Electroforming of Replica (continued):

No. 4 Collimator Submaster Plating Tools:

During this contract, Submasters MM-4 and MM-5 (used on previous contracts) were removed from storage and placed into service to electroform replicas for the required Collimator Mirrors. After two or three parts were produced from these submasters, it was noted that the submaster surfaces were decaying. The chrome layer was delaminating, and the cosmetics of the replicas were getting bad. Submaster MM-5 was sent out to be optically polished; however, this repolish did not improve the surface condition.

Both submasters were stripped of the chrome barrier layer, and buffed and rechromed. These efforts did not improve the surface, because the nickel areas below the initial chrome delamination area were etched, thus decaying the nickel surface. These submasters were removed from service, and new submasters fabricated.

Submasters MM-14, MM-16, MM-17 and MM-19 were fabricated and proof plated on Collimator castings on this contract.

Submaster MM-14's yield of electroformed mirrors was very good; however, the hex tips of the replicas decayed optically with continued use.

Submaster MM-16, though producing acceptable replicas, gradually decayed to 9 minutes of arc deviation at the TOP (or 12:00 o'clock position) of the mirror.

3.0 MIRROR REFURBISHMENT PROCESSING (continued):

3.3 Mirror Plating - Electroforming of Replica (continued):

No. 4 Collimator Submaster Plating Tools (continued):

Submaster MM-17 began to decay at the hex tips, and also had a cosmetic decay problem.

It was decided to remove the structural backing from these three submasters and rebond the backing in an attempt to save the submaster skin. All backing structures are retained with epoxy and, since it appeared this epoxy bond was cracking during plating, it was decided to plate an additional nickel rim around the O. D. to mechanically lock the structure together. This rework appeared to work very well in retaining the submaster assembly; however, the life of Submaster MM-14 was short lived. Also, Submaster MM-16, within a short period of time, decayed and acceptable mirrors could not be produced from this submaster.

With only Submaster MM-17 in service, EOS fabricated Submaster MM-19. This unit also had the retainer ring electroformed on the O. D. Platings from this submaster are acceptable; however, there is an orange peel appearance on the replicas which, though optically good, still presents cosmetic problems. This orange peel appearance is from the master plating tool, and this tool has since been reworked on Contract NAS-9-12960.

3.0 MIRROR REFURBISHMENT PROCESSING (continued):

3.4 Mirror Replica Bonding:

Upon completion of the replica and epoxy removal, each casting was inspected by Quality Control. Hydrostatic testing to 150 psig and water flow testing were checked to the applicable drawing. If water flow or leakage tests did not meet the specification requirements, repairs were made in accordance with referenced drawings and specifications.

After each casting was accepted, it was processed through cleaning per EOS Directive 12-2. Upon completion of the cleaning process, the unit was inspected and approval was given for mirror replica bond.

The replica was set up on a locating and holding fixture and the casting was carefully centered on the replica back side. After all locating fixtures were in place, the inside and outside diameters of the casting were marked. The casting was then removed and plastic platers tape applied to the back side of the replica area which would not be bonded.

After all masking was completed, the surfaces to be bonded on the casting and replica were scrubbed with 200° ethyl alcohol. After the alcohol had dried, the mirror replica surface to be bonded was coated with Primer K-1 and allowed to dry for a minimum of 45 minutes.

3.4 Mirror Replica Bonding (continued):

Bonding epoxy was then weighed and mixed (per EOS Directive 15-2) and applied to both the replica and casting surfaces; then, the two surfaces were indexed jointly for bond. After assurance of centering and indexing, epoxy was applied to the previously cleaned area of the casting. A torque test button was positioned and protected by means of a mechanical cover.

The bonded assembly was allowed to cure for a minimum of four hours, then all excess epoxy was trimmed and removed. After 24 hours, the breakaway torque of the test button was checked by Quality Control and DCAS personnel. If successful torque results were achieved (10 ft/lbs or more) the unit was accepted and released for preliminary optical testing.

Torque values of less than 10 ft/lbs were cause for rejection; however, very few units were below this level of torque value.

The No. 1 Mirror is bonded, using a contoured bonding fixture; the No. 2 Mirror uses a vacuum retention fixture; the No. 3 Mirror is centered on the optical axis and bonded to the casting; and the No. 4 Mirror is bonded to the replica while the replica is still retained on the No. 4 submaster plating tool.

After each electroformed nickel mirror replica was plated, it was cleaned and prepared with the mirror casting to be bonded. During this contract, there were no problems with available processing supplies as in the past, and mirror bonding proceeded smoothly.

3.0 MIRROR REFURBISHMENT PROCESSING (continued):

3.4 Mirror Replica Bonding (continued):

During the previous contract, EOS had epoxy and epoxy primer problems. This was just cause for the requirement of three test buttons to be used on the No. 4 castings. During the program, there were few torque problems other than those resulting from castings with contamination from silicone heaters bonded to the back side or other foreign contaminants. It was found that if the affected area of these castings was cleaned with a small amount of chloroform the torque test requirement of 10 ft/lbs or better could be achieved.

The casting/spinning sub-assembly cannot be cleaned in acid etch solutions due to spinning bond decay. Also, it was found that raw epoxy in the copper coil bonding area, on the back side of the casting, caused problems during vacuum coating. As a result, castings being processed for replica replacement had these coils removed. If a unit was to be cleaned and sandblasted, the coil was removed, and any residual epoxy remaining in the coil area was also sandblasted.

Overall, there were few bonding problems during this program, which points out significant progress has been made to reduce bonding rejects. Torque test results were over the required 10 ft/lbs limit, and are recorded in all Manufacturing Orders. Any further data required in tabulated form is available upon request.

3.0 MIRROR REFURBISHMENT PROCESSING (continued):

3.5 Preliminary Optical Test:

After completion of the bonding operation, the mirror assembly is tested to see if the optical figure is correct. The test serves two purposes: first, it verifies that the unit is acceptable for elox cutting; second, if it is out of optical tolerance, a plating stress correction may be made. This test is the "vernier adjustment" of stress control since very small stress changes cause significant optical geometry changes. Any large deviations are investigated, and this information is then transmitted back to the cognizant processing stations for corrective action.

Each unit is set up on an optical test bench and adjustments are made with the mechanical portions of the test equipment as referenced in Appendix B of Contract NAS-9-11461. The Nos. 1, 2, and 4 Mirrors are tested according to the test procedure in a test tower at points on the vertical (X axis) and horizontal (Y axis) of the mirror. Typical setups are shown in Fig. 1 through 3. Any areas which exhibit dark or light spots or deviations in image display patterns are also checked. The surface area is closely examined for digs, scratches, dimples, and general appearance. Any noted deformities are checked optically; and, if the required criteria are met, the unit is accepted for further processing. If the unit is not acceptable optically, it is rejected and reprocessed.

The optical testing on the No. 3 Mirror is performed using a 2.0 inch diameter glass checkplate on the mirror surface, and a fringe count is made. Many optical deviations can be noted by the experi-

3.5 Preliminary Optical Test (continued):

enced and trained eye and are closely checked with the glass checkplate. Fringe counts in excess of 16.7 fringes/inch, using the 2.0 inch diameter checkplate, are cause for rejection. If the unit is optically out of tolerance, inspections and examinations are made and all information is forwarded to the various process stations as noted above.

All acceptable units are released to production for further processing.

All units were checked optically after the mirror replica bond was completed. These tests served to check the electroforming, mirror bonding, and the replica optics in general. If the preliminary optical test was within tolerance, then the oversized mirror could be cut to dimensional blueprint requirements. If the mirror optics was not acceptable, then the mirror was rejected and cycled through the system.

Due to the size and flatness of the required curve for the No. 4 Mirror, preliminary optical tests gave much data for platings in process, and adjustments could be made with each particular submaster when required.

3.6 Electrical Discharge Machining (EDM):

EDM - Mirror Replica Cut to Blueprint
Dimension and Mechanical Inspection:

After preliminary testing, all acceptable mirror assemblies were processed through the Elox area. Using NASA tooling/fixtures,

3.6 Electrical Discharge Machining (Elox) (continued):

each mirror assembly has the inside and outside dimensions cut to drawing requirements. All assemblies were processed, using tooling designated for each mirror.

The average life for each tool blade is approximately thirty mirror cuts, with a resharpening occurring at 10 to 12 cuts. This tooling is all in usable condition, and is being used to cut mirrors being processed on NAS-9-12960 Contract.

There were no significant problems with the elox cutting operations other than arcing periodically on inner blade cuts. This arcing occurs periodically on a new or newly sharpened blade, or when a blade needs resharpening.

After each mirror assembly is cut to dimensional requirements, it is mechanically inspected. The inside and outside diameters, deburring of the cut edges of the nickel, and the optical surface of the replicas are checked. All of this data is recorded on a mirror surface examination sheet. If the resulting elox cuts are undersize, or the cosmetics of the mirror bad due to sleeks and scratches, it is rejected if it cannot be reworked. Some scratches and sleeks can be buffed out of the nickel; however, if they are too severe, the mirror is rejected.

3.7 Final Optical Test:

The final optical test is basically the same test as the preliminary optical test as referenced in Appendix B, but is witnessed by both DCAS and EOS inspectors. The No. 3 Mirror is tested using a 2.0 inch diameter glass checkplate which has the correct radius of curvature. A monochromatic light is used for a conventional fringe count and the entire surface of the 12.0 inch diameter convex mirror is checked. Acceptance criteria are in the specification in Appendix B.

The Nos. 1, 2 and 4 Mirrors were optically tested using a ray trace method for these specific mirrors. Typical setup shown in Figs. 1 through 3. A point light source is placed at or near the focal point of the mirror to produce a return beam which does not diverge or converge to an extreme. A slotted mask is placed across the surface of the mirror which then projects on a target bar which shows the theoretical position of the image and the optical tolerance. This test only tests the finite area exposed, and a judgment factor must be used to determine how many test points are made. Initially, tests are made across the mirror horizontal and vertical axes to align the unit in the X-Y plane and locate the central axis. Once this is done, the relationship between the mirror and light source is not changed, only the slot mask is moved for additional test points. All test data taken are recorded and included in the Manufacturing Order mirror data package.

After early problems on No. 4 Mirrors on previous contracts, EOS changed the test procedure to include looking at the projected image at 360 in. for zonal check locations, and checking with the 2-in. square grid. The actual measurements of angular error are still

3.7 Final Optical Test (continued):

made using the 150-in. range; but, in addition, the 2-in. square grid is projected on the target screen. The grid is made from 1/4-in. strips of steel spaced on 2-in. centers and mounted in a frame. Photos were made of the pattern produced by this grid at 150 and 360 in. using the stainless steel master. The photo was used to compare the projection of the mirror under test and the grid produced by the master at both ranges (Fig. 4). Although it is not required by the test procedure, all No. 4 Mirrors are now checked with the test mask projection every 2 in. around the diameter, as shown in Fig. 5.

Changes can occur to the mirror figure after elox cutting, since this tends to relieve any stresses of the outside edge and center section. If significant changes are observed, the data is relayed to process control for electroform stress control changes. Usually, the situation has been corrected prior to this operation; but in some cases, it does require additional correction.

Any mirror assembly out of specification requirements is rejected and is returned to production for rework.

All rejected replicas were removed from the castings, and the castings were cleaned and reprocessed.

During this program, the original optical test plate used to test the No. 3 Secondary Collimator Mirrors was scratched and replaced by a new test plate. This original test plate, though scratched, was returned at the request of NASA for use at MSC. Production testing

3.7 Final Optical Test (continued):

of the No. 3 Mirror requires a test plate to be free of all surface blemishes in order to test mirror replicas properly.

During final inspection of No. 3 replicas, the second test plate was scratched by a burr on the center hole of a No. 3 Mirror Assembly. This in turn scratched other areas of the replica, and it was decided not to use the plate on any other mirrors. Due to the size of the test plate (2.0 inch diameter), it cannot be reworked once it is scratched. Further grinding and polishing would roll the edge, and also reduce the diameter after the rolled edge area was cut away. Another test plate was fabricated and is in usable condition for any additional requirements.

3.8 Vacuum Coating:

Each mirror assembly, after being inspected and tested, was cleaned thoroughly. After being installed in the vacuum chamber (along with 2 inch square glass sample slides) and pumped down to the required pressure, it was vacuum coated to improve the spectral reflectance of the nickel mirror as follows: The coating consisted of an aluminum reflecting layer, overcoated with silicon dioxide, applied slowly so as to form a highly oxidized deposit. Prior to the aluminum deposit, it was necessary to apply a thin layer of chromium for enhanced adhesion, followed by a rapid layer of silicon dioxide to provide a diffusion barrier between the aluminum film and the substrate.

The overcoat of silicon dioxide was controlled to an effective optical thickness of one-half wave length of visible light. This thickness was

3.8 Vacuum Coating (continued):

established as the minimum for acceptable mechanical protection of the aluminum layer but the thickest practical from an optical standpoint, i.e., solar reflectance and thermal emittances.

Upon completion of the vacuum coating, the mirror assembly and sample slides were removed from the vacuum coating chamber. The mirror assembly was tape tested, and reflectivity curves run on the sample slides. These curves are evaluated and later copies become part of the data package.

After five days, the mirror assembly is tape tested and water tested. If there is no degradation or coating failure, the mirror is cleaned and packaged for shipment.

During the refurbishment program of all of the mirrors processed, twenty-four (24) No. 2 and five (5) No. 4's were returned from MSC due to coating failure. Extensive investigations were made to determine the cause of the coating failure. Due to the coating washing off of the mirror assemblies at MSC with distilled water, it was felt the initial substrate nickel was not clean enough. Further investigation verified this in that each mirror that failed had been buffed in one area or another prior to cleaning and vacuum coating.

Further investigation revealed that the carrier base of the buffing compound was not fully removed. After a series of tests, it was found that 111-trichloroethane dissolved the buffing compound carrier, and cleaned the nickel substrate successfully. Center sections cut from No. 4 replicas were cleaned and coated in various ways using reagents to clean and prepare the nickel substrate. After coating, these sections were subjected to temperature and humidity tests for 200 hours. At the end of each 24-hour period, these sections were removed from the test chamber, water rinsed and tape tested. All of the areas not cleaned with 111-trichloroethane failed within five days. The areas cleaned with 111-trichloroethane did not fail either tape or water tests during this period of testing.

It was jointly decided between NASA and EOS that each mirror assembly would be tape and water tested after vacuum coating for five days prior to shipment to MSC. This method was utilized on all hardware processed after the vacuum coating rework of these No. 2 and No. 4 Simulator Mirrors.

One other problem arose in the vacuum coating area that created coating problems on No. 1 Mirrors in process. The large gate valve on the base of the chamber developed a leak due to degradation of the gate valve "O" ring and the bore around this "O" ring. Oil vapors entered the chamber causing contamination of the nickel substrate and after five days the coating failed during tape tests.

This problem has been corrected by valve replacement; however, three parts were coated prior to showing evidence of failure. The oil vapor entering the chamber was not visible until the chamber and support equipment was disassembled and physically checked. The entire system was cleaned and assembled along with a new

3.8 Vacuum Coating (continued):

valve replacement. Mirror coatings are satisfactory and acceptable to tape and water testing, with no failures witnessed on coated substrates.

3.9 Final Inspection:

Upon completion of the mirror assembly processing, the Manufacturing Order was reviewed by the Project Engineer, Quality Control Inspector, and the DCAS representative. All paper work was reviewed and each operation verified for conformance and completion. When all paper work was in order, final inspection was completed and stamped off. All paper work was then duplicated and prepared for packaging with the shipment data package.

Cap plugs were installed in the water cooling passage ports. Each mirror was packaged in a wooden container and secured. After packaging inspection, the No. 1 and No. 4 mirror boxes were covered with poly sheeting prior to attaching the lid. Prior to sealing the mirror container, a green acceptance tag was secured inside, then the container was sealed and palleted for shipment.

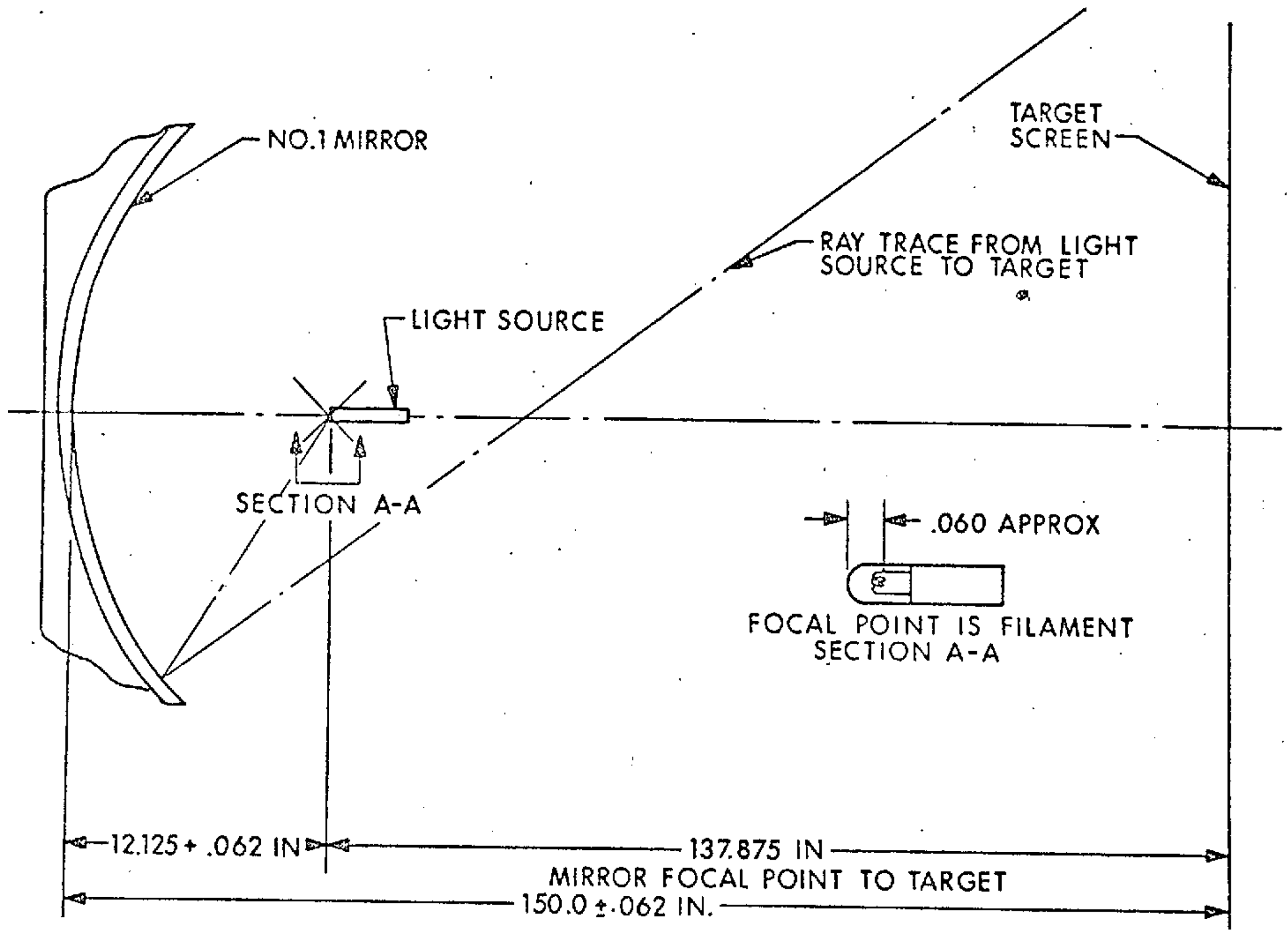

Figure 1   Schematic - No. 1 Mirror Test

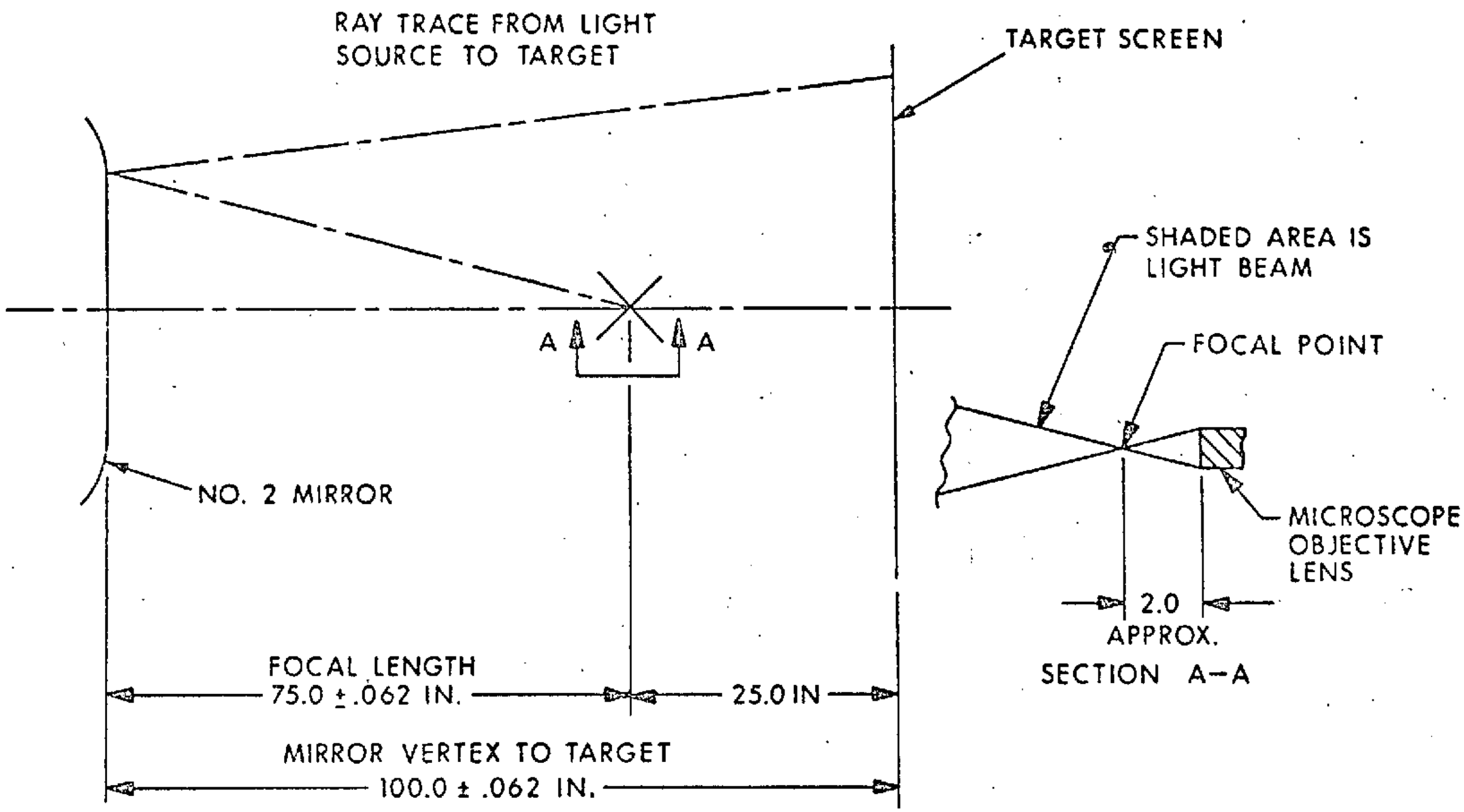

Figure 2 Schematic - No. 2 Mirror Test

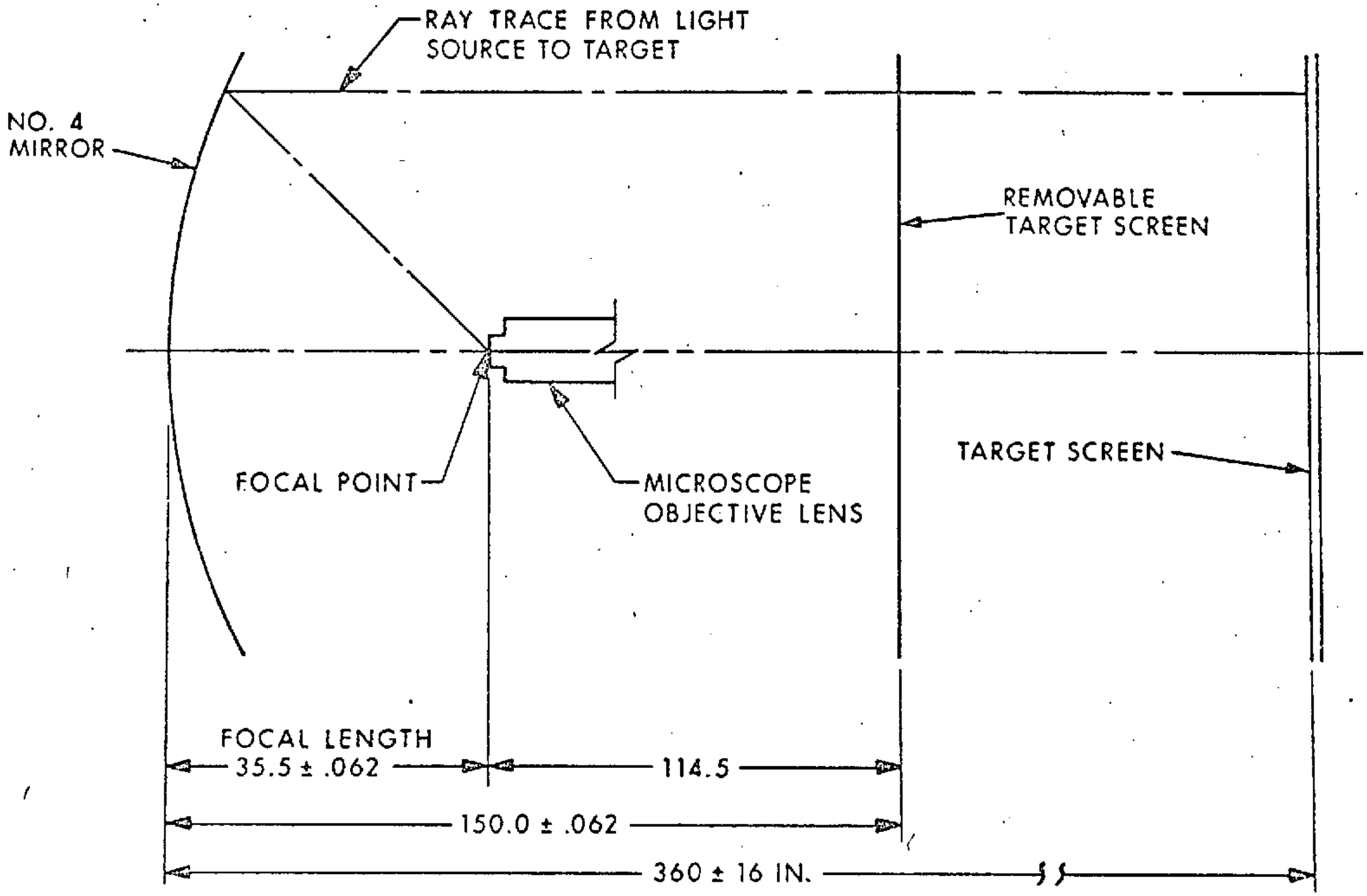

Figure 3 Schematic of No. 4 Mirror Test

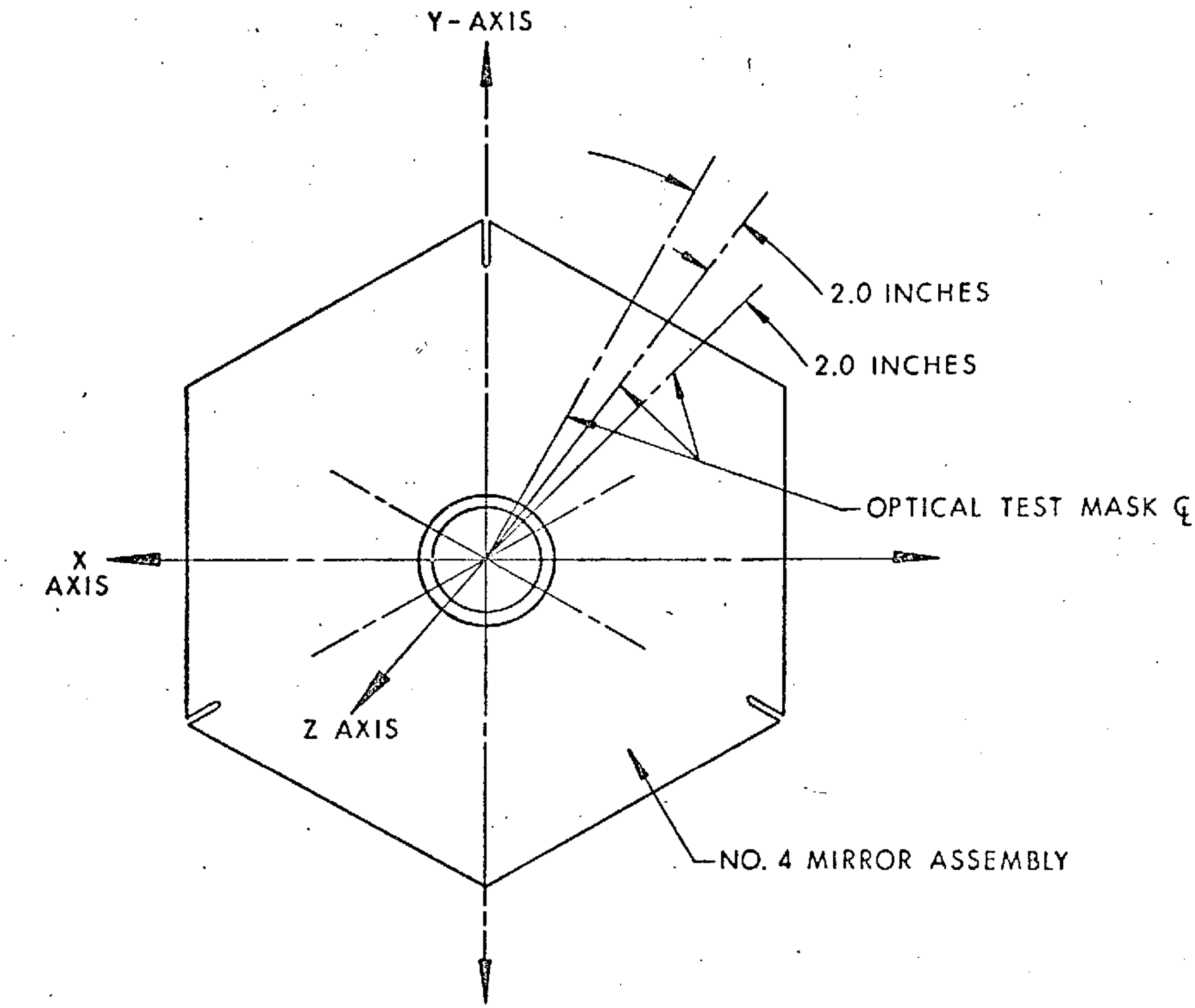

Figure 4 No. 4 Mirror Test Points

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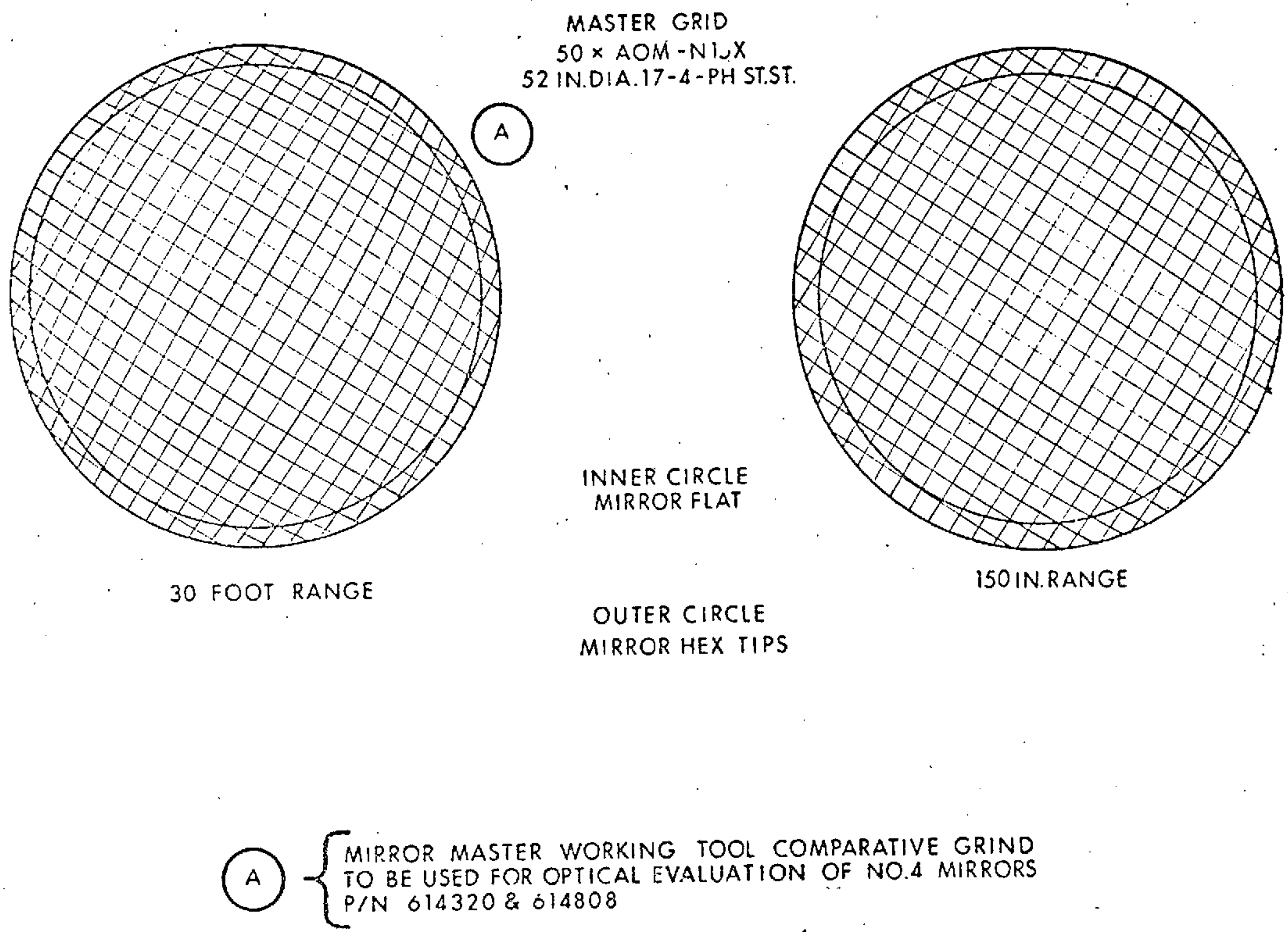

Figure 5 No. 4 Grid Photo